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Original Research

An ecological assessment for interactions between the physico-chemical characteristics of Gharaf river characteristics, Southern Iraq

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ABSTRACT:

This study was based on samples taken from one of the main branches of the Tigris River; Gharraf river, at Kut barrage in Wasit Province, Iraq. Which was aimed to study the physical and chemical properties of water. Monthly samples were collected randomly from the water, for 12 months, from January till December 2016. During the collection process; 5 stations on the river were chosen for sampling with ±10 km distance between each of the stations, including Wasit Province. The results showed that water temperature was affected by the air temperature, the temperature was from 13.3 to 30.6°C. However, the pH values were weak alkaline, the readings were 7.1-9.8. In addition, both of the dissolved oxygen and percentage oxygen saturation values were under the critical point in some of the reading at river Gharaf marking as low as 4.0-13.0 mg/L and 44.49-127.52% for the DO and POS, respectively. As for BOD5 values the results were from 0.4-6.8 mg/L, that made this rivers cleanness doubtful. As for the turbidity, it was observed that the water was turbid when the values were from 4.2-101.0 NTU. Turning now to total alkalinity, the results were from 183.0-384.0 mg/L. The results showed that river water is oligohaline, Gharaf results were 480-1070 μ/cm for conductivity and 0.30-0.68 for salinity. TDS and TSS results were 1.0-171.0 mg/L, 10.0-121.0 mg/L, respectively. Gharaf are considered to have hard water, as having hardness values from 312- 580 mg/L. As for anion and cation the results as follows: Bicarbonates 62-185 mg/L, Ca^{+2} 76.15-160.32 mg/L, Mg^{+2} 2.29-68.15 mg/L, sulphate 50-240 mg/L, nitrates 0.001-2.85 mg/L and phosphates 0.019-0.39 mg/L.

Keywords:

Physical properties, Chemical properties, Garraf river, Al-Kut barrage.

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INTRODUCTION

In the view of the importance of freshwater biology and its direct applications in human life, many international studies took place to focus on the physical and chemical characteristics of these water bodies (Sullivan *et al*., 2004; Lampert and Ulrich, 2007; Dallas, 2008; Walakira and Okot-Okumu, 2011). As for the local study, both Tigris and Euphrates rivers are considered the main source of water in Iraq, and that made them in the position of interest for researchers, therefore a considerable number of them have dealt with the physical and chemical characteristics of the water of both rivers, their tributaries and branches in their studies of water environment (Al-Azzawe *et al*., 2012; Nashaat *et al*., 2015; Salman *et al*., 2017; Abed and Muhanned, 2018).

Whereas the studies regarding Al-Gharraf river are considered by few, that it did not receive the appropriate attention from researchers in comparison with its importance, is derived from it being the main source of water in this area, as well as the dependence of a large percentage of people on it as a source of water that is used for drinking, agriculture and other uses. Therefore, this study is focusing on defining the important physical and chemical characteristics of this river, especially it is considered one of the main branches of the Tigris river before Al-Kut Barrage in Wasit province.

MATERIALS AND METHODS

Study area

Gharaf river branches from Tigris river at Al-Kut Barrage, therefore, it obtains its characteristics from Tigris river. The length of Gharaf river is 230 Km from the point of its branching in Al-Kut city to its estuary in Nasiriyah marshes, while the water depth in the river varies from 13 m at its branching point from Tigris river to 7 m at the point of its meeting with Euphrates river in the marshes area near Thi- Qar province (Jawad *et al*., 2009). The river is located in southeaster part of Iraq from 31° 2- 32° 27 N and from 45° 45- 46° 43 E. The river cuts the distance 90 km in Al-Kut city then enters Thi-Qar province from its north side. The discharge values ranged between the lowest value which was 124.4 m^3/sec obtained in November 2016, and the highest value which was 193.5 m^3/sec obtained in February 2016 (Figure 1). While the water current ranged between 0.385 m/sec in November 2016 and 0.454 m/sec in February 2016 (MOA, 2016).

Study station description

Five stations were chosen from which samples were collected, as shown in Figure 2.

Station 1: It is located 500 m after Al-Kut Barrage near the first Barrage regulator, under lies between the 48 and 45° E; 28 and 32° N.

Station 2: It is located 10 Km away from the first station in Bisroghiah area, at the under lies between 54 and 45° E; 23 and 32° N.

Station 3: It is located in Al-Muwaffaq area - Al-Badriya region, 10 Km away from the second station, at under lies between 57 and 45° E; 14 and 32° N.

Station 4: Located about 10 Km away from the third station, at under lies between 00 and 46° E; 11 and 32° N.

Station 5: This station is located at the under lies between 1 and 46° E; 6 and 32° N, in about 10 Km away from the fourth station.

Water samples were collected monthly from the

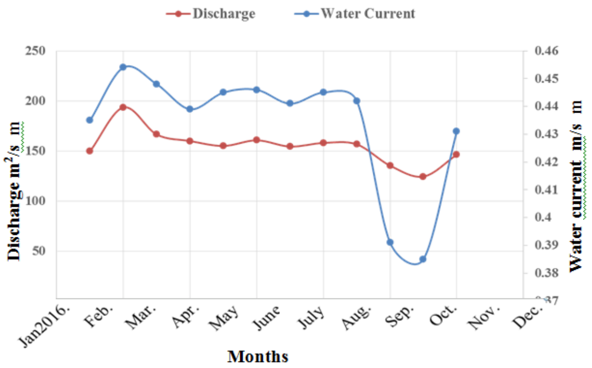

Figure 1. Seasonal variation of the current and discharge water values of Gharaf river during the period study

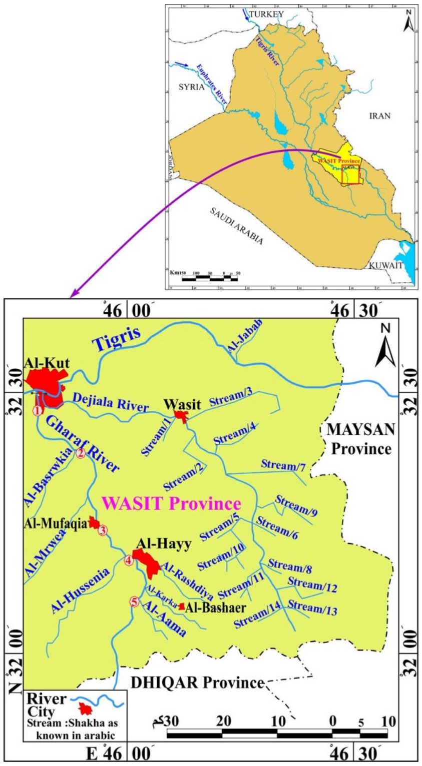

Figure 2. A map showing the studied stations on Gharaf river

studied stations, in the period from January to December 2016. The water samples were taken from the surface layer at about 20 cm under water depth, by using sealed polyethylene containers with 2.250 L capacity, after washing them with the river water at each station.

A mercury thermometer scaled from 0 to 100°C was used to measure both water and atmospheric temperatures at field. The pH was measured by pH-meter (HANNA brand) at the field after being calibrated by Buffer solution with the pH 4, 7, and 9. The turbidity meter (HANNA/H1 brand) was used and the results were measured by the Nephelometric Turbidity Unit (NTU). The acid modification of Winkler method was used as indicated by APHA (2005), and the results were measured by mg/L units. The percentage oxygen saturation was calculated using the equation described by Mackereth *et al*. (1978). The BOD5, total alkalinity, TSS, nitrates and phosphates were all measured using the protocol described in APHA (2005).While total hardness, and calcium and magnesium hardness were measured as described by Lind (1979). Bicarbonates were measured according to the protocol described in Degremont (1979). Whereas the sulphate were measured by the way described by Brands and Tripke (1982) using mg/L units.

RESULTS AND DISCUSSION

The water temperature results were changing according to the changes of the air temperature (Table 1 and Figure 3), the lowest degree recorded was 13.3°C in January in stations 3 and 4, while the highest degree was 30.6°C in July in stations 1 and 3, with seasonal averages ranging from 14.2°C- 29.1°C (Table 2 and Figure 4). It was noticed from the statistical analysis results that there are no significant difference between the stations at P>0.05. Additionally, it has been found that there is a positive correlation at P≤0.01 with both the atmospheric temperature and total alkalinity r=0.920, r=0.582, respectively. Also a positive correla-

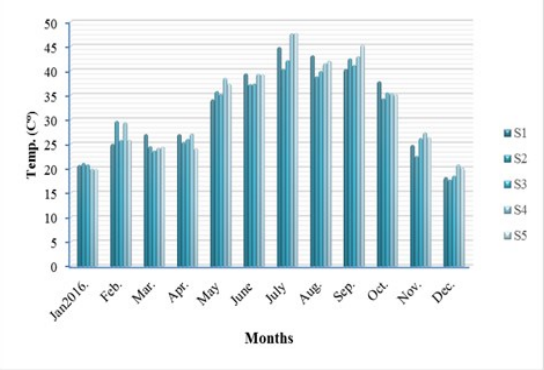

Figure 3. Variation of the air temperature values of Gharaf river water

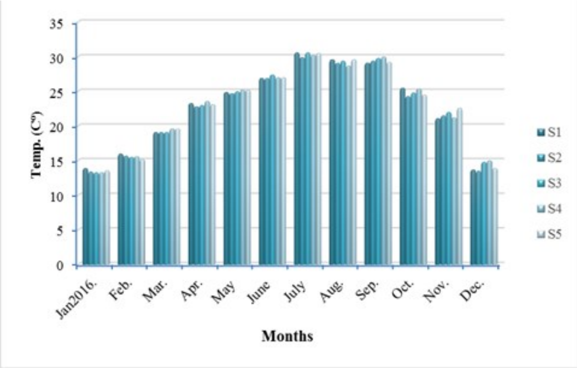

Figure 4. Variation of the water temperature values of Gharaf river water

Table 1. Seasonal changes (average ±SE) of the air temperature values in Gharaf river stations

Season Station	Winter	Spring	Summer	Autumn
1	21.3± 1.985^{a}	29.6± 2.366^{a}	42.4± 1.594^{a}	34.3± 4.804^{a}
2	22.8± 3.570^{a}	28.5± 3.640^{a}	38.7± 0.895^{b}	33.1± 5.804^{a}
3	21.7± 2.154^{a}	28.2± 3.535^{a}	39.7± 1.387^{b}	34.2± 4.345^{a}
4	23.6± 3.027^{a}	29.9± 4.364^{a}	42.8± 2.482^{a}	35.1± 4.503^{a}
5	21.9± 1.934^{a}	28.6± 4.350^{a}	42.9± 2.500^{a}	35.5± 5.48^{a}
Total	22.2± 1.009	28.9± 1.417	41.3± 0.848	34.4± 1.911
Sig.	N.S	N.S	P<0.05	N.S

Table 2. Seasonal changes (average ±SE) of the water temperature in the Gharaf river stations

Season Station	Winter	Spring	Summer	Autumn
1	14.5± 0.735^{a}	22.4± 1.729^{a}	29± 1.105^{a}	25.2± 2.313^{a}
2	14.2± 0.750^{a}	22.2± 1.644^{a}	28.6± 0.896^{a}	25± 2.312^{a}
3	14.5± 0.648^{a}	22.3± 1.732^{a}	29.1± 0.933^{a}	25.5± 2.281^{a}
4	14.6± 0.688^{a}	22.8± 1.665^{a}	28.6± 0.924^{a}	25.5± 2.541^{a}
5	14.2± 0.491^{a}	22.6± 1.633^{a}	29± 1.049^{a}	25.4± 1.961^{a}
Total	14.4± 0.257	22.4± 0.637	28.8± 0.376	25.3± 0.866
	N.S	N.S	N.S	N.S

The similar small letters indicate the lack of significant differences between the stations and seasons at P≤0.05

tion at P≤0.05 with total suspended solids r=0.295 (Table 20).

The turbidity values of Gharaf river water samples ranged from 4.2-101 NTU, the lowest value was recorded in station 5 in March and the highest value was recorded in station 3 in June, with an average of 36.9 NTU, while the seasonal averages were from 10.1-60.47 NTU during both spring and summer (Figure 5 and Table 3). The statistical analysis results showed that there are positional and seasonal significant differences at P≤0.05 during the study period. Also, the correlation coefficient analysis showed that there is a positive standard correlation at P≤0.01 between turbidity and total suspended solids r=0.586, and a negative standard correlation at P≤0.01 between turbidity and total suspended solids r=-0.586. While there was a negative standard correlation at P≤0.05 with each of the percentage oxygen saturation r=-0.338, total hardness r=-0.505, magnesium r=-394 and bicarbonates r=-0.428.

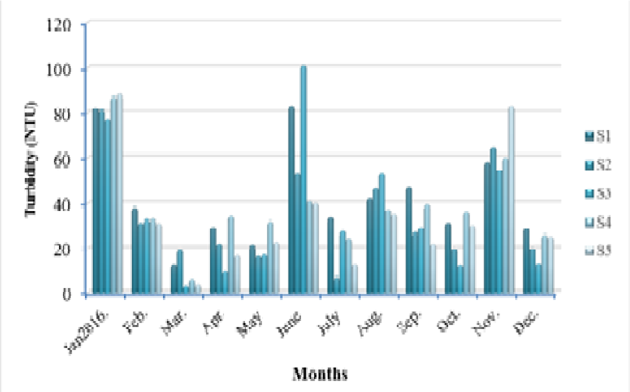

Figure 5. Variation of the turbidity values of Gharaf River water during the period study

The study results indicated a marked elevation in the turbidity values during January, June and November, and to a lower extent in February and August. This irregular pattern may be due to the relation between the turbidity values with the rain season and according to the flow velocity and drainage (Figure 5). And also according to the amount of additions of suspended particles such as clay, slit, algae and organic materials that drift into the river with the rain or when the flow velocity and drainage increase, which lead to the disruption of the precipitation of these suspended materials (Gangwara *et al.*, 2012).

Whereas the low turbidity values may be caused by the plentiful of vegetation which hold the pollutants and dirt and prevent them from drifting with the waters column (Nomman, 2012). The results showed that the conductivity and salinity values ranged from the lowest value which was 480 µs/cm (0.30%) in station 4 during January, and the highest value was 1070 µs/cm (0.68%) in stations 3, 4, and 5 during April, with seasonal aver-

Table 3. Seasonal averages and standard error of the turbidity values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	49.7± 16.370^{a}	21.4± 4.674^{b}	52.9± 15.221^{b}	45.6± 7.689^{a}
2	44.2± 18.656^{b}	19.3± 1.524^{b}	35.7± 14.394^{c}	37.3± 13.984^{b}
3	41.1± 18.740^{c}	10.1± 3.977^{d}	60.47± 21.566^{a}	32.47± 12.218^{c}
4	48.5± 19.321^{a}	24.2± 8.895^{a}	34.2± 5.093^{c}	45.1± 7.480^{a}
5	48.1± 20.020^{a}	14.5± 5.460^{c}	29.4± 8.205^{d}	45± 19.119^{a}
Total	46.3± 7.104	17.9± 2.460	42.5± 6.222	41.1± 5.061
	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$

The similar small letters indicate the lack of significant differences between the stations and seasons at $P \leq 0.05$

ages ranging from 772-980 µs/cm (0.49-0.64%) (Table 4 and 5 and Figure 6 and 7). The statistical analysis results of the conductivity showed significant differences between the stations during winter and in-between the seasons. While there were no significant difference between the stations during spring, summer, and autumn at $P \leq 0.05$.

The correlation coefficient analysis results showed that there is a positive standard correlation at $P \leq 0.01$ between conductivity and each of salinity, Hardness, Bicarbonates and calcium r=0.881, r=0.363, r=0.532 and r=0.374 respectively and negative standard correlation at $P \leq 0.05$ with temperature r=-0.291 and nitrate r=-0.259 (Table 20).

The statistical analysis of the salinity showed significant differences during winter and autumn at $P \leq 0.05$, there were no recorded significant differences during spring, summer, and in-between the seasons during the study period. Whereas the statistical analysis showed that there is a positive standard correlation at $P \leq 0.01$ between salinity and conductivity r=0.881 and bicarbonates r=0.456 and positive standard correlation $P \leq 0.05$ with hardness r=0.302 and calcium r=0.308, while the correlation was standard negative at $P \leq 0.05$ with the air temperature r=-0.271 (Table 20).

The highest conductivity value was recorded during winter and in April with significant differences between the studied stations, which might be caused by the decrease in the water level (Figure 1) and the variation in the drainage averages and the water coming from Tigris river through Al-Kut Barrage, which took place in Gharaf river during the study period because of Al-Mosul dam issues, in addition to the presence of drains, domestic and wastewater, which cause an increase in the salts and dissolved solids concentrations as well as in the sedimentary processes (Hutchinson, 1957; Al-Lami and Al-Jaberi, 2002). These factors led to the emergence of an irregular pattern in the seasonal and positional changes, and that what the results of the statistical analysis have confirmed as there was no correlation between conductivity and water temperature, and the correlation was negative with the air temperature r=-0.291.Therefore and according to the results, Gharaf

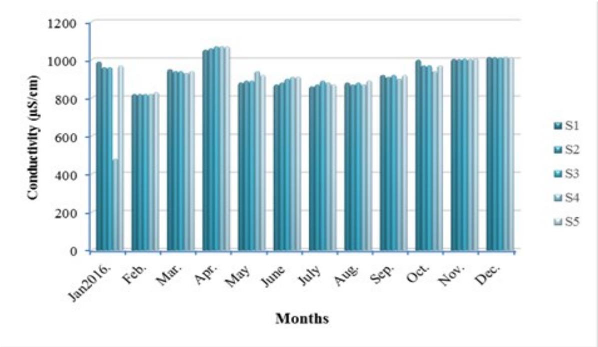

Figure 6. Variation of the conductivity values in Gharaf river stations during the period of study

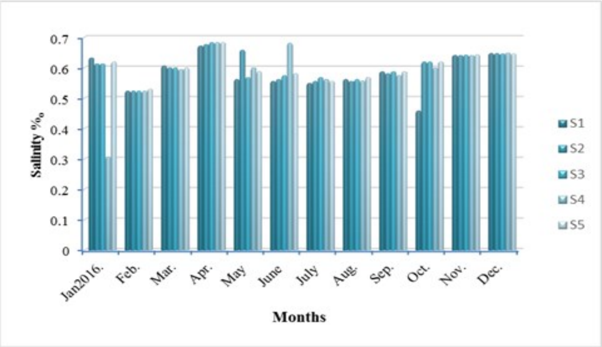

Figure 7. Variation of the salinity values in Gharaf river stations during the period of study

Table 4. Seasonal changes (averages ± SE) of the conductivity values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	941.3± 61.060^{a}	960.6± 46.937^{a}	870.0± 5.773a	974.6± 27.357^{a}
2	931.3± 57.808^{a}	963.3± 50.442^{a}	873.3± 3.333 a	961.0± 27.22^{a}
3	930.6± 57.333^{a}	966.6± 53.644^{a}	890.0± 5.773a	965± 24.664^{a}
4	772± 165.580^{b}	980± 45.092^{a}	886.6± 12.018a	947.6± 29.979^{a}
5	937.3± 55.019^{a}	976.6± 47.022^{a}	890± 11.547^{a}	965.6± 25.208^{a}
Total	902.5± 37.259	969.4± 18.748	882± 3.927	962.8± 10.454
	P≤0.05	N.S	N.S	N.S

Table 5. Seasonal changes (averages ± SE) of salinity values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	0.602± 0.039^{a}	0.614± 0.031^{a}	0.556± 0.003^{a}	0.563± 0.054^{b}
2	0.596± 0.036^{a}	0.646± 0.023^{a}	0.558± 0.002^{a}	0.615± 0.017^{a}
3	0.595± 0.036^{a}	0.618± 0.034^{a}	0.569± 0.003^{a}	0.617± 0.015^{a}
4	0.494± 0.100^{b}	0.627± 0.028^{a}	0.601± 0.040^{a}	0.606± 0.019^{a}
5	0.599± 0.035^{a}	0.625± 0.030^{a}	0.569± 0.007^{a}	0.618± 0.016^{a}
Total	0.577± 0.023	0.626± 0.011	0.571± 0.008	0.604± 0.012
	P≤0.05	N.S	N.S	P≤0.05

The similar small letters indicate the lack of significant differences between the stations and seasons at P≤0.05

river water is considered to be brakish water, oligohalin according to Venice classification system (Reid, 1961; Al-Saadi and Al-Mayah, 1983).

The Iraqi water bodies characterized by being slightly alkaline, and that is originally caused by bicarbonates ions (Sabri *et al.*, 1989). And that what was confirmed by the current study results of the pH of all the studied stations with a lowest value of 7.1 in stations 1 and 5 during November and September, respectively. While the highest value was 9.8 in station 4 during June, with seasonal averages ranging from 7.2-8.3 and a general average of 7.7 in all the five studied stations during the study period (Table 6 and Figure 8). The statistical analysis results showed no significant differences between the stations, while the showed differences between the values during the seasons at P≤0.05. Also there was a positive correlation at P≤0.01 between the pH and both the dissolved oxygen and nitrogen r=0.443, r=0.462, respectively. It was also found that the correlation is negative at P≤0.01 with each of the water temperature, calcium, and total suspended solids r=-0.420, r=-0.352, r=-0.326 (Mohan *et al.*, 2013). (Table 20).

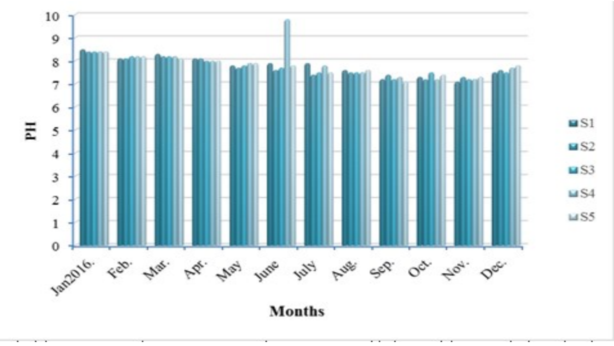

Figure 8. Variation of the pH values in Gharaf river stations during the period of study

The results of this study regarding the Iraqi water being slightly alkaline, are consistent with most of the previous local studies, (Al-Rubayi, 2007); Al-Azzawe *et al*. (2012); Salman *et al*. (2015); Al-Shamy *et al*. (2015) and Khalaf (2016). The total alkalinity values recorded in this study ranged between the lowest value 183 mg/L in station 5 at January and the highest value384 mg/L in station 3 at August 2016, with seasonal averages ranging from 225-309 mg/L at winter and summer respectively (Figure 9 and Table 7).

It was observed that there are both positional and seasonal statistical changes in the total alkalinity

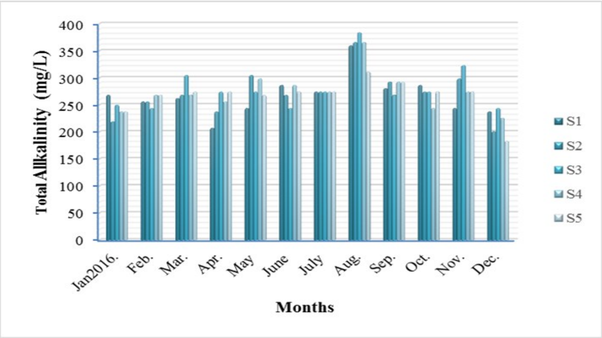

Figure 9. Variation of the total alkalinity values in Gharaf river stations during the period of study

Table 6. Seasonal changes (average ±SE) of pH values in Gharaf river stations

Season Station	Winter	Spring	Summer	Autumn
1	8.03± 0.290^{a}	8.06 ± 0.145^{a}	7.8 ± 0.100^{a}	7.2 ± 0.057^{a}
2	8.03 ± 0.233^{a}	8.0 ± 0.152^{a}	7.5 ± 0.057^{a}	7.3 ± 0.057^{a}
3	8.03 ± 0.272^{a}	8.0 ± 0.115^{a}	7.5 ± 0.066^{a}	7.3 ± 0.100^{a}
4	8.1 ± 0.208^{a}	8.03 ± 0.088^{a}	8.3 ± 0.721^{a}	7.2 ± 0.033^{a}
5	8.1 ± 0.176^{a}	8.0 ± 0.057^{a}	7.6 ± 0.088^{a}	7.2 ± 0.088$_{a}$
Total	8.06 ± 0.091	8.02 ± 0.044	7.7 ± 0.150	7.2 ± 0.028
	N.S	N.S	N.S	N.S

Table 7. Seasonal changes (average ±SE) of total alkalinity values in Gharaf River stations

Season Station	Winter	Spring	Summer	Autumn
1	254.1 ±8.863^{a}	237.9 ±16.139^{c}	307 ±26.699^{a}	270.4 ±13.333^{c}
2	225.7 ±16.139^{c}	270.4 ±19.396^{b}	302.9 ±31.565^{a}	288.7 ±7.331^{a}
3	246 ±2.033^{b}	284.6 ±10.166^{a}	300.8 ±42.505^{a}	288.8 ±17.314^{a}
4	244 ±12.698^{b}	274.6 ±12.674^{b}	309 ±28.683^{a}	270.4 ±14.233^{c}
5	229.7 ±24.986^{c}	272.4 ±2.033^{b}	286.6 ±12.166^{b}	280.6 ±6.100^{b}
Total	239.9 ±6.346	268 ±6.614	301.3 ±11.516	279.8 ±5.182
	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$

The similar small letters indicate the lack of significant differences between the stations and seasons at $P \leq 0.05$

values at $P \leq 0.05$ (as seen in Table 7), and there were no carbonates in the river to be recorded during the study period, as the alkalinity is a common characteristic in the Iraqi water that provide the bicarbonates salts in the water (Hassan, 2004). The statistical analysis results showed a positive correlation at $P \leq 0.01$ between total alkalinity and both air temperature and water temperature r=0.550, r=0.582, respectively. The results also showed that the highest total alkalinity value was recorded in August. While the correlation was negative at $P \leq 0.01$ with the total dissolved solids r=-0.359 and the organic materials r=-0.373, and also a negative correlation at $P \leq 0.05$ with magnesium r=-0.306 (Table 20).

The high total alkalinity values which were recorded in August may be caused by elevated temperatures and the organic decomposition process rates, and also the increased rate of insoluble calcium carbonates conversion into bicarbonates. While the low and varied values recorded during winter, spring, summer and autumn months may be attributed to the fluctuating water levels, drainage rate (Figure 1), reduction processes, bicarbonates decomposition processes, and carbon dioxide consumption by the producers (Hussain *et al*., 2000; Hassan, 2004). The recorded alkalinity values in this study were consistent with other studies of the same water body, where they attributed the high values to the passage of the river in the Mesopotamian plain area, which considered, certainly, an sediment soils(Hassan, 2007), as well as Fahad (2006) which has attributed the elevated alkalinity to its relation with low drainage, turbidity and high productivity.

Both Table 8 and 9 and Figure 10 and 11 demonstrate the monthly, positional and seasonal changes of the dissolved oxygen and the percentage

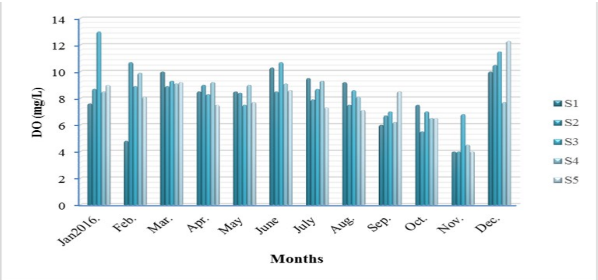

Figure 10. Variation of the dissolved oxygen values in Gharaf River stations during the period study

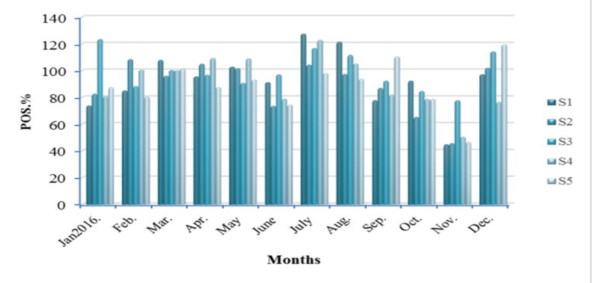

Figure 11. Variation of the percentage oxygen saturation values in Gharaf River stations

Table 8. Seasonal changes (average ±SE) of the dissolved oxygen values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	7.4±1.502^{c}	9±0.500^{a}	10.6±0.800^{a}	5.8±1.013^{b}
2	9.9±0.635^{b}	8.7±0.185^{ab}	7.9±0.290^{b}	5.4±0.781^{b}
3	11.1±1.197^{a}	8.3±0.520^{ab}	9.3±0.683^{a}	6.9±0.066^{a}
4	8.7±0.642^{c}	9.1±0.057^{a}	9.1±0.635^{a}	5.7±0.622^{b}
5	9.8±1.276^{b}	8.1±0.536^{b}	7.6±0.470^{b}	6.3±1.301^{a}
Total	9.4±0.534	8.6±0.184	8.9±0.366	6±0.356
	P≤0.05	P≤0.05	P≤0.05	P≤0.05

The similar small letters indicate the lack of significant differences between the stations and seasons at P≤0.05

oxygen saturation values.

The lowest value recorded was 4 mg/L in November in stations 1, 2 and 5. While the highest value was 13 mg/L recorded in station 3 in January. The general average was 8.1 mg/L for all the five stations during the study period, while the seasonal averages ranged from 5.4-11.1 mg/L during autumn and winter. Table 8 shows that there are positional and seasonal significant differences at P≤0.05, also the statistical analysis results showed a positive standard correlation at P≤0.01 between the dissolved oxygen and each of the pH r=0.443, percentage oxygen saturation r=0.797, nitrates r=0.424, and a negative standard correlation at P≤0.05 with the total suspended solids r=-0.303, while there was a non-standard negative correlation with the other factors (Table 20).

Table 9. Seasonal changes (average ±SE) of the percentage oxygen saturation values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	85.4± 6.724^{c}	102.1± 3.538^{ab}	113.5± 20.168^{a}	71.7± 14.049^{bc}
2	97.9 ± 7.779^{b}	100.9± 2.602^{b}	91.9± 9.315^{c}	66± 11.910^{c}
3	108.6± 10.496^{a}	95.9± 2.784^{c}	108.5± 5.900^{b}	85± 4.236^{a}
4	85.8± 7.373^{c}	106.14± 2.963^{a}	106.6± 6.552^{b}	70.3± 9.974^{b}
5	95.8± 12.054^{b}	94.0± 4.006^{c}	88.7± 7.248^{c}	78.5± 18.394^{b}
Total	94.6± 4.140	99.8± 1.685	104.4± 6.131	74.3± 5.089
	P≤0.05	P≤0.05	P≤0.05	P≤0.05

The similar small letters indicate the lack of significant differences between the stations and seasons at P≤0.05

Seasonal changes in the dissolved oxygen values were noticed during the study period, as the results show an elevation in the dissolved oxygen values during winter, spring, and summer months. And that may be caused by the decreased temperature during winter and spring which allow more oxygen dissolution in water.

In addition to the increase in the current and discharge water in summer which increases the water movements and disturbances which in turn lead to an increase in the atmospheric oxygen dissolution in water (Stevens, 2000). Gharaf river has witnessed during the study period, an irregular pattern of drainage of the water coming from Tigris river through Al-Kut barrage because of Al-Mosul dam issues and the reduction in the dam storage. While during autumn, the values were decreased, and that was attributed to the wide-spreading

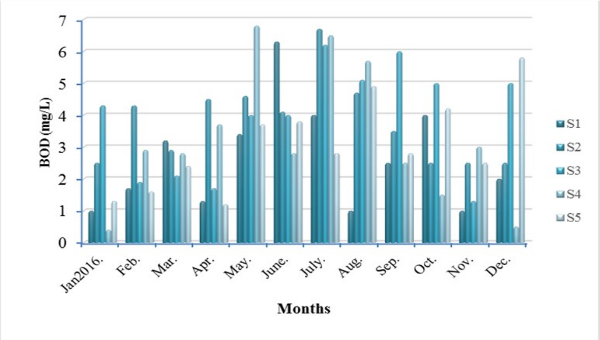

Figure 12. Variation of the BOD_5 values in Gharaf River stations during the study period

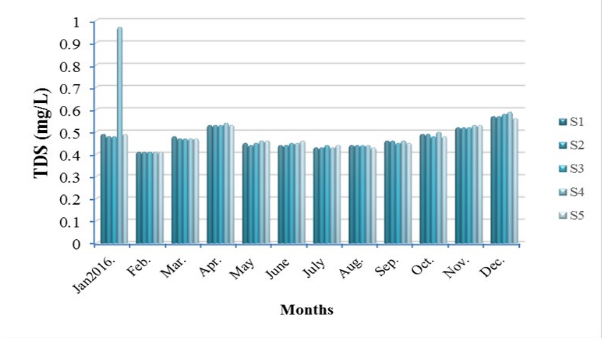

Figure 13. Variation of the percentage of total dissolved solids values in Gharaf River stations during the study period

Table 10. Seasonal changes (average ±SE) of the BOD_5 in Gharaf river stations

Season Station	Winter	Spring	Summer	Autumn
1	1.5 ± 0.296^{c}	2.6 ± 0.669^{b}	3.7 ± 1.534^{b}	2.5 ± 0.866^{c}
2	3.1 ± 0.600^{a}	4 ± 0.550^{a}	5.1 ± 0.785^{a}	2.8 ± 0.333^{c}
3	3.7 ± 0.938^{a}	2.6 ± 0.709^{b}	5.1 ± 0.635^{a}	4.1 ± 1.429^{a}
4	1.2 ± 0.817^{c}	4.4 ± 1.211^{a}	5 ± 1.123^{a}	2.3 ± 0.440^{c}
5	2.9 ± 1.452^{b}	2.4 ± 0.721^{b}	3.8 ± 0.606^{b}	3.1 ± 0.523^{b}
Total	2.5±0.425	3.2±0.376	4.5±0.414	2.9±0.352
	$P\leq0.05$	$P\leq0.05$	$P\leq0.05$	$P\leq0.05$

The similar small letters indicate the lack of significant differences between the stations and seasons at $P\leq0.05$

of *Eichhornia crassipes* plant starting from Al-Kut Barrage and along the river, according to the field observation during September, October and November.

The *Eichhornia crassipes* plant reproduces and spreads in the period between March and November, its spread and reproduction increase with the presence of both *Saccharum* and papyrus, which are widely spread plants on both sides of Gharaf river. This plant consumes about 1L of water daily, as well as the dissolved oxygen and works as an insulation layer on the surface of water which effects on the volume and amount of oxygen that is in contact with the water surface (Mohammed, 2013).

On the other side, the wide-spreading of this plant decreases the water current and increases the decomposition of the organic materials in the basal layer, in addition to being one of the factors that affects on the values of the dissolved oxygen which resulted in its arrival to a critical value which was 4 mg/L (Lind, 1979; Al-Omar, 2000) and the appearance of extreme results of dissolved oxygen values during November. In addition to the changes in the drainage and the water coming to Gharaf river through Al-Kut Barrage which was closed during this month (Figure 1).

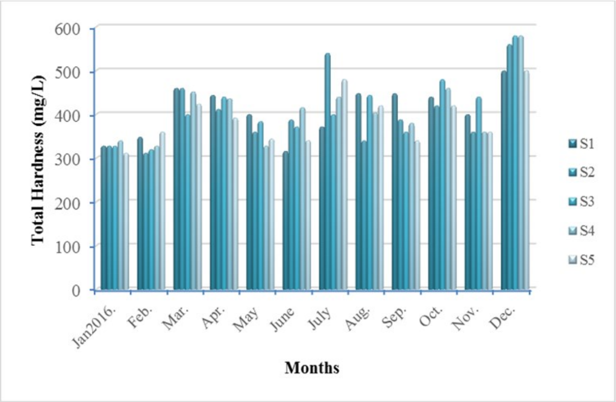

Figure 15. Variation of the total hardness values in Garraf River during the study period

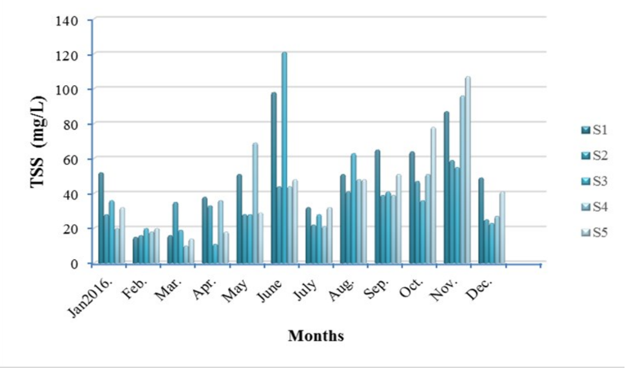

Figure 14. Variation of the percentage of total suspended solids values in Gharaf River stations during the study period

The lowest saturated oxygen value was recorded in station 1 during November, which was 44.89%, whereas the highest value was 127.52% in station 1 during July, with seasonal average ranged from 66-113.5% during autumn and summer, respectively (Table 9 and Figure 11).

Table 9 shows standard positional and seasonal differences at $P\leq0.05$, and the statistical analysis results showed a positive standard correlation at $P\leq0.01$ with each of BOD5 r=0.391, DO r=0.797, and nitrates r=0.372. And a positive standard correlation at $P\leq0.05$ with the air temperature r=0.257, while the standard correlation was negative at $P\leq0.01$ with the turbidity r=-0.338 and the total suspended solids r=-0.376. The current study had showed that Gharaf river water has good aeration and reaches to above the saturation level for several times during the year and at all stations, due to the high self-purification capability, current movements and photosynthesis (Al-Lami *et al.*, 1999). The elevation of the percentage oxygen saturation is noticed in the stations and months which witnessed elevation in

Table 11. Seasonal changes (average ±SE) of the total dissolved solids values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	0.490 ± 0.046^a	0.486 ± 0.023^a	0.436 ± 0.003^a	0.490 ± 0.017^a
2	0.486 ± 0.046^a	0.480 ± 0.026^a	0.436 ± 0.003^a	0.490 ± 0.017^a
3	0.490 ± 0.049^a	0.483 ± 0.024^a	0.443 ± 0.003^a	0.483 ± 0.020^a
4	0.656 ± 0.165^a	0.490 ± 0.025^a	0.440 ± 0.005^a	0.496 ± 0.020^a
5	0.486 ± 0.043^a	0.486 ± 0.021^a	0.443 ± 0.008^a	0.486 ± 0.023^a
Total	0.522 ± 0.036	0.485 ± 0.009	0.440 ± 0.002	0.489 ± 0.007
	N.S	N.S	N.S	N.S

Table 12. Seasonal changes (average ±SE) of the total suspended solids values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	38.6 ±11.864^a	35 ±10.214^{ab}	60.3 ±19.615^b	72 ±7.505^b
2	23 ± 3.605^c	32 ± 2.081^b	35 ± 6.887^d	48 ± 5.811^d
3	26.3 ± 4.910^c	19.3 ± 4.910^c	70.6 ± 27.119^a	44 ± 5.686^d
4	21.6 ± 2.728^d	38.3 ± 17.071^a	37.6 ± 8.412^d	62 ±17.349^c
5	31 ± 6.082^b	20.3 ± 4.484^c	42.6 ± 5.333^c	78.6 ± 6.169^a
Total	28.1 ± 3.012	29 ± 4.121	49.4 ± 7.048	61 ± 5.673
	P≤0.05	P≤0.05	P≤0.05	P≤0.05

The similar small letters indicate the lack of significant differences between the stations and seasons at P≤0.05

the dissolved oxygen values winter, spring, and summer, while it declined during autumn especially in November due to the exceptional circumstances and the non-standard patterns that the river underwent during the study period, which comprise changes in the water level, discharge, and the flow velocity (Figure 1). In addition to the wide-spreading of *Eichhornia crassipes* plant along the river, which reached to its maximum during this month, as well as the closure of Al-Kut Barrage.

The highest BOD5 value was 6.8 mg/L in station-4 during May, while the lowest value was 0.4 mg/L in station-4 during January. The seasonal averages ranged from 1.2- 5.1 mg/L during winter and summer, respectively. The general average was 3.3 mg/L for all the five stations during the study period (Table 10 and Figure 12). The statistical analysis results that are shown in Table 10 represent that there are standard differences at P≤0.05 during the study seasons and between the stations. According to Odum (1970) classification, Gharaf river water in the stations and in some of the times during the study period was considered as contaminated and its cleanliness is questionable especially in summer season due to the highest values were recorded in that season.

The statistical analysis results also showed a positive standard correlation at P≤0.01 with the air and water temperatures and the percentage oxygen saturation r=0.498, r=0.449, r=0.391, respectively. And a positive standard correlation at P≤0.05 with dissolved oxygen r=0.261, while the standard correlation was negative at P≤0.01 with TDS r=-0.362 and negative correla-

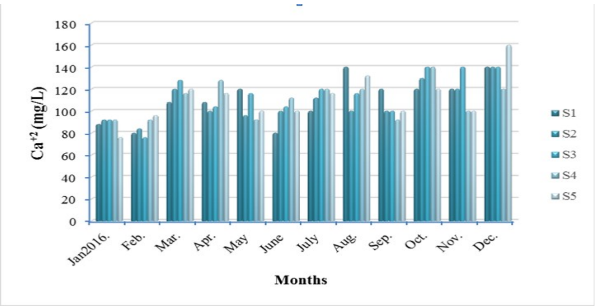

Figure 16. Variation of the calcium values in Gharaf River stations during the period study

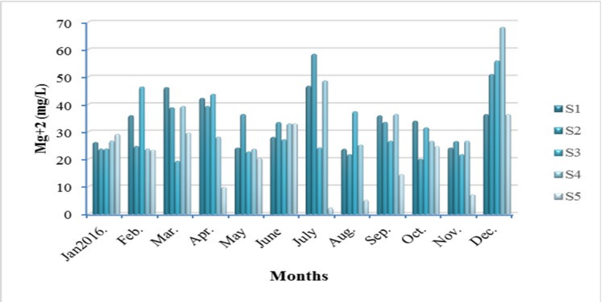

Figure 17. Variation of the magnesium values in Gharaf River stations during the period study

Table 13. Seasonal changes (average ±SE) of the total hardness values in Gharaf river stations

Station \ Season	Winter	Spring	Summer	Autumn
1	392 ± 54.307^{b}	434.6 ±17.938^{a}	378.6 ±38.250^{c}	429.3 ±14.847^{a}
2	400 ± 80.133^{b}	410.6 ±28.875^{b}	422.6 ±60.280^{a}	389.3 ±17.333^{c}
3	409.3 ± 85.364^{a}	408 ±16.653^{b}	405.3 ±20.945^{b}	426.6 ±35.276^{a}
4	416 ±82.073^{a}	405.3 ±38.941^{b}	420 ±10.583^{a}	400 ±30.550^{b}
5	390.9 ± 56.395^{b}	386.6 ±23.247^{c}	413.3 ±40.551^{a}	373.3 ±24.037^{c}
Total	401.6 ± 27.679 $P \leq 0.05$	409 ± 10.793 $P \leq 0.05$	408 ± 15.042 $P \leq 0.05$	403.7 ± 11.262 $P \leq 0.05$

The similar small letters indicate the lack of significant differences between the stations and seasons at $P \leq 0.05$

tion with organic materials r=-0.201 (Table 20). It is noticed from the study results that the lowest values were recorded during winter, while the highest were recorded during summer and continued until the beginning of autumn, as the elevation in the temperatures causes an increase in the vital activities of the microorganisms, the occurrence of decomposition and increase oxygen consumption, and that what the statistical analysis results have shown.

On another side and from November results, we can notice a decline in the DO, BOD5, POS% values, as unexpectedly the dissolved oxygen values showed no inverse correlation with the BOD5, and that maybe caused by the exceptional circumstances and the non standard patterns that Gharaf river underwent during this period, such as changes in the water levels, the volume of water coming from Tigris river, as well as the wide-spreading of *Eichhornia crassipes* plant along the river which reached its maximum during November, in addition to the closure of Al-Kut barrage.

The results also showed that the decline in the DO values during this month was not related to the increase of the organic decomposition processes which increase the BOD5 values, rather the causes of this decline are the decrease in water level, the wide-spreading of the *Eichhornia crassipes* plant which works as an insulation layer for the air in contact with water, in addition to its consumption of a large amounts of the dissolved oxygen (Mohammed, 2013). Therefore the values can fluctuate when comparing same areas in different periods and for a number of studies, due to the differences in the factors during the study period.

As shown in Table 11 and Figure 13, the lowest recorded value of the total dissolved solids was 0.41 g/L and for all the stations during February, while the highest value was 0.97 g/L in station 4 during January 2016. The seasonal averages ranged from 0.43-0.65 g/L during summer and winter, respectively. The statistical analysis results showed no seasonal and stationary locational differences at $P \leq 0.05$ during the study period, while the results of the correlation coefficient analysis showed a negative standard correlation at $P \leq 0.01$ with each of the water and air temperatures, BOD5, bicarbonates and total alkalinity r=-0.507, r=0.-412, r=0.-

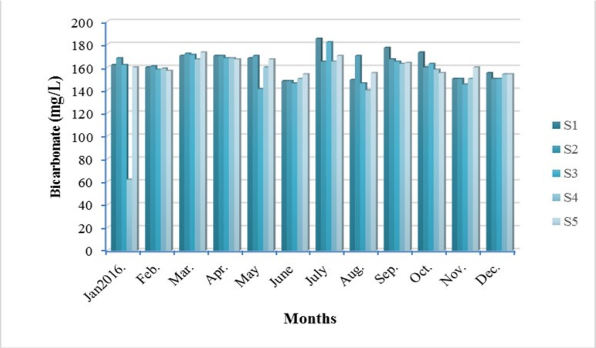

Figure 18. Variation of the bicarbonates values in Gharaf River stations during the period of study

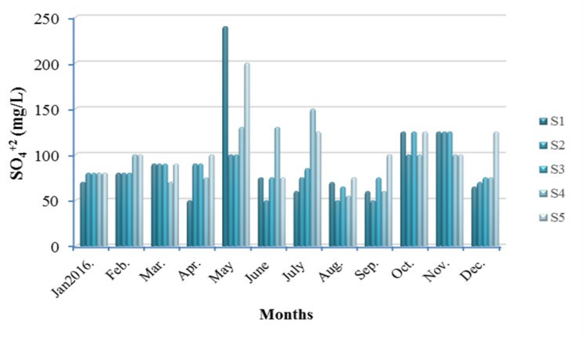

Figure 19. Variation of the sulphate values in Gharaf River stations during the period of study

Table 14. Seasonal changes (average ±SE) of the calcium values in Garaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	102.8 ± 18.846^{a}	112.2 ± 4.018^{a}	106.9 ± 17.635^{a}	120.2 ±0.010^{ab}
2	105.5 ± 17.523^{a}	105.5 ± 7.438^{a}	104.2 ± 3.988 ^{a}	116.8 ±8.774^{bc}
3	102.8 ± 19.268^{a}	116.2 ± 6.942^{a}	113.5 ± 4.816 ^{a}	126.9 ±13.346^{a}
4	101.5 ± 9.353^{a}	112.2 ± 10.597^{a}	117.5 ± 2.673 ^{a}	110.9 ±14.873^{c}
5	110.8 ± 25.384^{a}	112.2 ± 6.098^{a}	116.2 ± 9.246 ^{a}	106.8 ± 6.671^{c}
Total	104.7 ± 3.157	111.6 ± 2.922	111.7 ± 3.821	116.3 ± 4.289
	N.S	N.S	N.S	P≤0.05

Table 15. Seasonal changes (average ±SE) of the magnesium values in Garraf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	32.8 ± 3.327^{b}	37.5 ± 6.779^{a}	32.8 ± 7.054^{b}	31.3 ± 3.632^{a}
2	33.2 ± 8.922^{b}	38.2 ± 0.899^{a}	37.8 ± 10.796^{a}	26.7 ± 3.875^{b}
3	42 ± 9.532^{a}	28.6 ± 7.631^{b}	29.6 ± 4.00^{b}	26.6 ± 2.817^{b}
4	39.5 ± 14.324^{a}	30.4 ± 4.640^{b}	35.6 ± 6.893^{a}	29.9 ± 3.270^{a}
5	26.2 ± 2.940^{c}	32.09 ± 7.054^{b}	37.2 ± 6.779^{a}	22.9 ± 1.727^{b}
Total	35.3 ± 3.868	33.7 ± 2.718	34 ± 3.364	28.6 ± 1.584
	P≤0.05	P≤0.05	P≤0.05	P≤0.05

The similar small letters indicate the lack of significant differences between the stations and seasons at P≤0.05

362, r=0.-689, r=-0.359, respectively, while the standard correlation was positive at P≤0.05 with the organic matter r=0.217 (Table 20).

The high values of the total suspended solids, which are recorded in November, December and April, attributed to increase salts concentrations and precipitation due to decreased water level and the amount of water drained into the river (Figure 1) also to the exceptional circumstances which the river underwent during the study period, especially during November, in addition to the increased load of human activities returned to the river from sanitation, drains water, and industrial activities. Whereas the low total suspended solids values during summer and autumn are thought to be due to the temperature differences and increased water level (Figure 1) as well as the reduction and diffusion processes, and decreased rates and decomposition processes (Imnatoshi and Sharif, 2012).

The current study indicated that the lowest total suspended solids value was 10 mg/L recorded in station 4 during March, while the highest value was 121 mg/L recorded in station 3 during June 2016. The seasonal averages ranged between 19.3 mg/L during winter and 78.6 mg/L during autumn, with a general average of 41.85 mg/L for the five stations during the study period (Table 12 and Figure 14). The statistical analysis results showed standard differences at P≤0.05 between all the stations and seasons during the study period.

The results of the correlation analysis indicated the presence of a positive standard correlation at P≤0.01

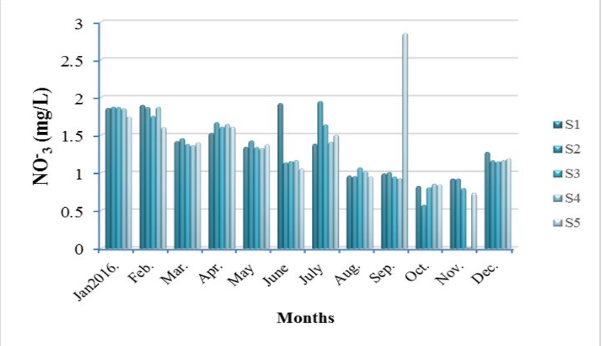

Figure 20. Variation of nitrates values in Gharaf river stations during the study period

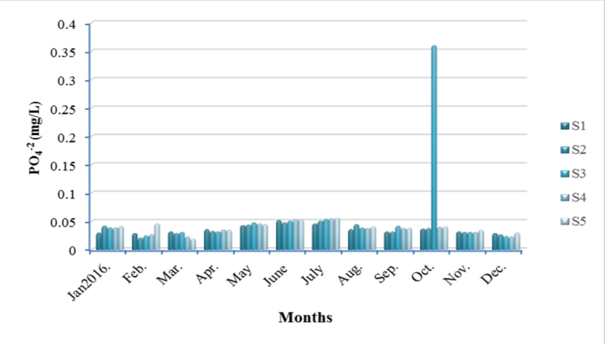

Figure 21. Variation of phosphates values in Gharaf river during the study period

Table 16. Seasonal changes (average ±SE) of bicarbonate values in Garraf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	159±2.08^{a}	169.3±0.66^{a}	160.6±4.03^{a}	166.6±4.2^{a}
2	159.6±5.23^{a}	170.6±0.66^{a}	161±6.65^{a}	159±4.9^{a}
3	156.6±3.53^{a}	160±3.17^{b}	158±4.03^{a}	157.6±3.26^{a}
4	125±5.13^{b}	165±2.51^{ab}	151.6±3.4 ^{b}	157±3.9^{a}
5	157±1.73^{a}	169±2.0^{a}	159.7±5.17^{a}	159.6±2.6^{a}
Total	151±6.50	166.8±2.0	158.2±3.6	160±2.31
	P≤0.05	P≤0.05	P≤0.05	N.S

The similar small letters indicate the lack of significant differences between the stations and seasons at P≤0.05

Table 17. Seasonal changes (average ±SE) of sulphate values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	71.6± 4.409^{d}	126.6± 57.831^{a}	68.3± 4.409^{b}	103.3± 21.666^{a}
2	76.6± 3.333^{c}	93.3± 3.333^{b}	58.3± 8.333^{c}	91.6± 22.047^{b}
3	78.3± 1.666^{c}	93.3± 3.333^{b}	75± 5.773^{b}	108.3± 16.666^{a}
4	85± 7.637^{b}	91.6± 19.220^{b}	111.6± 28.915^{a}	86.6± 13.333^{b}
5	101.6± 13.017^{a}	130± 35.118^{a}	91.6± 16.666^{b}	108.3± 8.333^{a}
Total	82.6± 3.899	107± 12.796	81± 7.779	99.6± 6.925
	P≤0.05	P≤0.05	P≤0.05	P≤0.05

The similar small letters indicate the lack of significant differences between the stations and seasons at P≤0.05

with turbidity r=0.586, while the correlation was standard positive at P≤0.05 with water temperature r=0.295. The correlation was standard negative at P≤0.01 with the pH r=-0.408, the percentage oxygen saturation r=-0.376, and nitrates r=-0.448, the correlation was also standard negative at P≤0.05 with the dissolved oxygen r=-0.303 and magnesium r=-0.336 (Table 20). It was noticed that the lowest values were recorded during winter and spring, whereas the highest values were recorded during summer and autumn (Table 12).

The results showed that the positional and monthly changes took an irregular pattern and that maybe due to the differences of the monthly additions from the contaminated nearby sources such as water purification plants, drains water returned from the surrounding agricultural lands or the plants growth and density and the organic materials (Al-Kinani, 2010), also it might be due to water level and drainage amount (Figure 1), as the low river discharge and high temperature during summer and autumn play an important role in increasing the total suspended solids concentration in the river, and because of Gharaf river witnessed exceptional circumstances, especially during summer and autumn, represented by the variation and irregularity of the water drained into it from Tigris river, as well as increased growth and density of the plants, especially *Eichhornia crassipes* plant.

As shown in Figure 15 and Table 13, the current study recorded values of total hardness ranged from 312 - 580 mg/L. The lowest value was recorded in stations 2 and 5 during February and January, and the highest value was recorded in stations 3 and 4 during December 2016. Whereas the seasonal averages ranged between 373.3 mg/L during autumn and 434.6 mg/L during spring. The statistical analysis results indicated, as shown in Table 13, standard differences at P≤0.05 between all the stations and seasons. Also showed a positive standard correlation at P≤0.01 with each of the conductivity r=0.363, calcium r=0.772, and magnesium r=0.656 and a positive standard correlation at P≤0.05 with the salinity r=0.302.

While the correlation was standard negative at P≤0.01 with the turbidity r=-0.505, and standard negative at P≤0.05 with nitrates r=-0.270 and the organic matter r=-0.207 (Table 20). Depending on Weiner (2000) classification, soft 0-75 mg/L, slightly hard 75-120 mg/L, hard 120-200 mg/L, very hard >200 mg/L, Gharaf river water is considered very hard, as it exceeded in some stations and months normal permissible limits for the Iraqi and international water standards, which is 500 mg/L. The high values of the hardness which are recorded in winter, and the low values recorded in summer, can be due to, and according to (Buringh, 1960), the limestone nature of the Iraqi soil over which the

Table 18. Seasonal changes (average ±SE) of nitrates values in Gharaf river stations

Season / Station	Winter	Spring	Summer	Autumn
1	1.6 $\pm 0.202^{a}$	1.4 $\pm 0.053^{a}$	1.4 $\pm 0.277^{a}$	0.9 $\pm 0.048^{b}$
2	1.6 $\pm 0.235^{a}$	1.5 $\pm 0.075^{a}$	1.3 $\pm 0.306^{b}$	0.8 $\pm 0.132^{b}$
3	1.5 $\pm 0.223^{b}$	1.4 $\pm 0.083^{a}$	1.2 $\pm 0.177^{bc}$	0.8 $\pm 0.049^{b}$
4	1.6 $\pm 0.232^{a}$	1.4 $\pm 0.101^{a}$	1.2 $\pm 0.112^{cd}$	0.5 $\pm 0.297^{c}$
5	1.5 $\pm 0.165^{b}$	1.4 $\pm 0.073^{a}$	1.1 $\pm 0.169^{d}$	1.4 ± 0. 687^{a}
Total	1.6 ± 0.081	1.4 ± 0.031	1.2 ± 0.087	0.9 ± 0.150
	$P\leq 0.05$	N.S	$P\leq 0.05$	$P\leq 0.05$

Table 19. Seasonal changes (average ±SE) of phosphates values in Gharaf river stations in the period from January till December 2016

Season / Station	Winter	Spring	Summer	Autumn
1	0.029 ± 0.0003^{a}	0.037 ± 0.003^{a}	0.044 ± 0.004^{a}	0.033 ± 0.001^{a}
2	0.030 ± 0.006^{a}	0.035 ± 0.004^{a}	0.048 ± 0.001^{a}	0.033 ± 0.002^{a}
3	0.029 ± 0.004^{a}	0.037 ± 0.005^{a}	0.048 ± 0.004^{a}	0.144 ± 0.107^{a}
4	0.029 ± 0.004^{a}	0.034 ± 0.006^{a}	0.048 ± 0.005^{a}	0.036 ± 0.002^{a}
5	0.039 ± 0.004^{a}	0.033 ± 0.007^{a}	0.050 ± 0.004^{a}	0.038 ± 0.001^{a}
Total	0.031 ± 0.002	0.035 ± 0.002	0.047 ± 0.001	0.057 ± 0.021
	N.S	N.S	N.S	N.S

The similar small letters indicate the lack of significant differences between the stations and seasons at $P\leq 0.05$

rivers pass, considering that (Maulood and Hinton, 1978; Saadullah, 1988) state that the concentration of hardness increases with heavy raining in Iraq. As it drifts into the water from the nearby soils during raining. Also the high total hardness values indicate the silt nature of the bottom layer of the water body (Ishaq and Khan, 2013).

The calcium values in the river water ranged between the lowest value 76.15 mg/L in stations 3 and 5 during February and January, respectively, and the highest value 160.32 mg/L in station 5 during December 2016. The general average was 111.06 mg/L for all the five stations during the study period. While the seasonal averages ranged from 101.5-126.9 mg/L during winter and autumn, respectively (Table 14 and Figure 16). The statistical analysis results showed standard differences at $P\leq 0.05$ between the stations during autumn, while there were no standard differences between the stations and the seasons in winter, spring and summer.

The correlation results showed a positive standard correlation at $P\leq 0.01$ with the conductivity r=0.374 and total hardness r=0.772, and a negative standard correlation at $P\leq 0.01$ with the turbidity r=-0.402, pH r=-0.352, nitrates r=-0.452, and with the organic matters r= -0.370. While the correlation was standard positive at $P\leq 0.05$ with the salinity r=0.308 (Table 20). Magnesium values in the river water ranged from 2.29- 68.15 mg/L, as the lowest value was recorded in station 5 during July, and the highest value in station 4 during December, with a general average of 30.5 mg/L in all the five studied stations during the study period. The seasonal averages ranged from 22.9-42 mg/L during autumn and winter, respectively (Figure 17 and Table 15).

The statistical analysis results stated that there are standard differences at $P\leq 0.05$ between all the stations and seasons. Also stated that there is a positive standard correlation at $P\leq 0.01$ with the total hardness r=0.656 and a negative standard correlation at $P\leq 0.01$ with the turbidity r=-0.394, and also a negative standard correlation at $P\leq 0.05$ with both the total suspended solids r=-0.336 and total alkalinity r=-0.306 (Table 20). The highest calcium value recorded was during autumn months and in December and that can be due to the process of washing the soil by rain water in December. As the limestone rocks constitute a large proportion (Crance and Masser, 2005).

Or it can be due to the released barrage water that contains large amounts of precipitated salts, as a result of the water storage process which leads to precipitating the calcium salts because of their tendency to

Table 20. Correlation (r) between physical and chemical characteristics of Gharraf river

S. No		Air. Temp.	Water Tem.	Turbidity	Cond.	Salinity	pH	BOD	DO	POS%	T.H.	Ca^{+2}	Mg^{+2}	SO_4^-	PO_4^-	NO_3^-	Bicarb.	TDS	TSS	Alkal.
1	Air. Temp.	1																		
2	Water Tem.	.920**	1																	
3	Turbidity	-.137	-.158	1																
4	Cond.	-.291*	-.071	-.181	1															
5	Salinity	-.271*	-.061	-.175	.881**	1														
6	pH	-.326*	-.420**	.081	-.174	.001	1													
7	BOD	.498**	.449**	-.166	-.060	-.006	-.177	1												
8	DO	-.102	-.234	-.092	-.091	-.052	.443**	.261*	1											
9	POS%	.267*	.153	-.338**	-.132	-.130	.170	.391**	.797**	1										
10	T.H.	-.116	-.002	-.505**	.363**	.302*	-.237	.011	.138	.194	1									
11	Ca^{+2}	-.045	.093	-.402**	.374**	.308*	-.352**	.037	.080	.165	.772**	1								
12	Mg^{+2}	-.096	-.060	-.394**	.177	.169	.006	.041	.165	.183	.656**	.101	1							
13	SO_4^-	.063	.034	-.177	.061	.045	.016	.068	-.126	-.069	-.030	.177	-.204	1						
14	PO_4^-	.197	.175	-.092	.60	.013	-.078	.224	-.081	-.031	.096	.166	-.061	.164	1					
15	NO_3^-	-.126	-268*	-.024	-.259*	-.192	.462**	-.026	.424**	.372**	-.270*	-.452**	.117	-.075	-.139	1				
16	Bicarb.	.207	.247	-.428**	.532**	.456**	-.066	.195	-.006	.207	.070	.012	.145	.060	.029	.052	1			
17	TDS	-507**	-.412**	.220	-.128	-.150	.048	-.362**	-.011	-.204	.203	.197	.103	-.042	-.059	-.033	-.689**	1		
18	TSS	.215	.295*	.586**	.172	.104	-.408**	.116	-.303*	-.376**	-.168	.023	-.336*	.083	.017	-.448**	-.142	-.031	1	
19	Alkal.	.550**	.582**	-.010	-.188	-.161	-.233	.220	-.176	.136	-.178	.002	-.306*	-.114	.052	-.240	.016	-.359**	.168	1

**= Significant correlation at $p \leq 0.01$. * = Significant correlation at $p \leq 0.05$. NS = Non significant correlation interact with the carbon dioxide, and then they convert to the dissolved calcium bicarbonates (Kamal *et al.,* 2004). While the increase during autumn months may be attributed to low water levels and drainage (Figure 16). The decreased in the calcium ions averages during spring and summer months may be attributed to its consumption by the organisms, as they are a part in the egg's growth process, fish reproduction, and the growth and construction of the structures of some organisms (Al-Maliki, 2005). While the highest magnesium values and averages were recorded in December and winter, and that is thought to be attributed to the decomposition of the chlorophyll in the green plants, which leads to magnesium release as it is one of the basic components in the construction of the chlorophyll (Al-Zubaidi, 2012).

The magnesium values showed a decrease in the hot months and in autumn, as the lowest value was recorded in July, and the lowest averages were recorded during autumn months and that maybe due to its consumption by the phytoplankton (Al-Zubaidi,2012). It was noticed in this current study that the calcium ions concentration overcome the magnesium ions concentration in all the stations and during all the months, and that may be attributed to the fact that the carbon dioxide react more with the calcium than its reaction with the magnesium and therefore amounts of calcium are converted to soluble bicarbonates (Hassan *et al.,* 2008). The recorded bicarbonates values in this study for Gharaf river, ranged between the lowest value 62 mg/L in January at station 4, and the highest value 185 mg/L in July 2016 and at station 1. The seasonal averages ranged from 125 mg/L during winter and 170.6 mg/L during spring (Figure 18 and Table 16).

By the statistical analysis results, it was indicated that there are standard differences at $P \leq 0.05$ between stations and seasons in winter, spring and summer, while there were no standard differences during autumn. There was found a positive standard correlation at $P \leq 0.01$ between the bicarbonates and both conductivity $r=0.532$ and salinity $r=0.456$, while the correlation was found to be standard negative at $P \leq 0.01$ with turbidity $r=-0.428$ and the total dissolved solids $r=-0.689$ (Table 20). The results showed that the highest bicarbonates averages were recorded during spring, as the highest value was recorded in July, and that maybe attributed to the changes in the temperature and its increment during summer which leads to increase in the organic decomposition processes and elevated carbon dioxide concentration, which in turn convert the insoluble calcium carbonates into soluble bicarbonates. However, the relatively low averages in the other seasons and months can be attributed to bicarbonates decomposition and carbon dioxide consumption by the producers (Hassan*,* 2004). The sulphate averages which are recorded in this study ranged from 50-240 mg/L, as the lowest values were recorded in 1 and 2 during April and June, while the highest values were recorded in station 1 during May 2016, with an annual average of 92.5 mg/L. The seasonal averages ranged from 58.3-130 mg/L during summer and spring, respectively (Figure 19 and Table 17).

By the statistical analysis results, it is indicated that there are standard differences at $P \leq 0.05$ between all the stations and seasons throughout the study period. It was also found that there is a negative standard correlation at $P \leq 0.05$ with the organic matter $r=-0.220$, while there was no other recorded correlation between sulphate and other chemical and physical factors (Table 20). The high sulphate value and its high average which is recorded during May, spring, and autumn, maybe attributed to the gypsum nature of the Mesopotamian plain through which the river pass, which is considered to be the main source of sulphate in natural water (Hassan*,* 2007). While the low sulphate levels, which are recorded in April and June, and its low average during summer, can be attributed to the water levels and the amount of discharge (Figure 1).

The recorded nitrates values, as shown in Table

18 and Figure 20, ranged between 0.001 mg/L as its lowest recorded value in station 4 and during November, and 2.85 mg/L as its highest value recorded in station 5 during September 2016. While the seasonal averages ranged from 0.5-1.6 mf/L during autumn and winter, respectively.

The statistical analysis results indicated the presence of standard differences at $P \leq 0.05$ during winter, summer, and autumn, while there are no differences in spring. The correlation coefficient analysis results showed a positive standard correlation at $P \leq 0.01$ with the pH r=0.462, the dissolved oxygen r=0.424, the percentage oxygen saturation r=0.372 and the organic matter r=0.519. While the correlation was negative standard at $P \leq 0.01$ with calcium r=-0.452 and total suspended solids r=-0.448. The nitrates correlated also a negative standard correlation at $P \leq 0.05$ with water temperature r=-0.258, conductivity r=-0.259, and total hardness r=-0.270 (Table 20).

The increased nitrates values during winter maybe attributed to the human and agricultural additions into the different stations along the river, as the nitrates which is used as fertilizers for agricultural breeding, 40% of which can enter into the river by surface run-off and washing from the agricultural lands. In addition to that, the increased values can be caused by the increased activity and availability of the microorganisms due to the availability of high percentage of the organic matter, and this increase leads in turn to increase activity of these organisms, which also leads to increase in the organic matter decomposition process and its conversion into nutrients dissolved in the water, and that has been proven by the statistical analysis results, as the nitrates concentration was directly correlated with the organic matters r=0.519 (Salman and Hussain, 2012). While the decreased values recorded during autumn maybe attributed to the changes in the temperature and its relative increase, as the nitrates concentration was inversely correlated with water temperature r=-0.258, as well as the reduction of nitrates to nitrite because of decreased concentration of the dissolved oxygen, especially as it coincides with the low water level and decreased drainage during this season (Figure 1), in addition to the growing number of phytoplankton which is considered a cause of nitrates consumption and its decreased values (Atobatele and Olutona, 2013).

The recorded phosphates values, which are obtained in this current study, ranged from 0.019-0.39 mg/L. As the lowest value was recorded in station 5 during March, and the highest value was recorded in station 3 during October 2016, with a general annual average of 0.042 mg/L. The seasonal averages ranged between 0.029 mg/L as the lowest average during winter and 0.144 mg/L as the highest average during autumn (Figure 21 and Table 19).

As it was shown by the statistical analysis results, there are no standard differences at $P > 0.05$ between the stations and the seasons during the study period. Also, the correlation coefficient analysis results showed that there is no standard correlation between phosphates concentration and any of the other physical and chemical characteristics of the river water (Table 20).

The increased phosphates concentrations during the hot months may be attributed to increased water level (Figure 1) and mixing processes which increase phosphates release from the sediments (Hassan *et al.*, 2001). While the decreased concentrations during winter, spring and autumn can be attributed to decreased temperatures and the lack of light which works on keeping the phosphates stable in the riverbed, or it might be caused by increased hardness values, especially during December, as well as calcium concentrations which reached 580 mg/L and 160.32 mg/L, which leads to increase phosphates values as calcium phosphates in the riverbed and the sediments, and decreases its values in the water column (Kathy, 2008).

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