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Limnological Features of the Southern Part of Gharaf River and the Impacts of Floodplain Period on its Characteristics

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Abstract

The current study was conducted on the southern part of Gharaf River in order to define the physical-chemical properties and the impact of the Tigris River's floodplain water on its ecological characteristics during 2019. Four sites were selected along the southern part of the river. The findings showed a strong connection between the temperature of air and water at all sites. A value ranging from 4.85 - 84.65 NTU was reported for turbidity. The water was found to be oligohaline, low alkaline, and well ventilated due to high dissolved oxygen concentrations. Gharaf River is considered to be of questionable clean water, according to the results of BOD5. The total alkalinity values were recorded to be in the range of 92-292.8 mg /L, which are higher than the acceptable limits of 20-200 mg /L CaCO3 for the Iraqi and international water standards. It was also found that Gharaf River water was very hard, but still within the allowable natural water limits (200 mg /L Ca and 150 mg /L Mg). Concentrations of sulphate ranged 50-200 mg / L, while levels of bicarbonate ranged 140-230 mg /L. On the other hand, ranges of 3354-855 mg / L and 3-85 mg / L, respectively, were recorded for TDS and TSS. In addition, nitrates values were found to be in the range of 0.04-5.14 mg / L, being below the permissible limits for Iraqi water (15 mg / L). Other values observed for phosphates were 0.004-0.085 mg / L. Overall, the results demonstrated different effects on the properties of Gharaf River water during and after the floodplain period.

Keywords: Physical-chemical properties ; Floodplain; Gharaf River.

الملامح اللمنولوجية للجزء الجنوبي من نهر الغراف وتأثير فترة السيول الفيضية عليها

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الخلاصة

أجريت الدراسة الحالية على الجزء الجنوبي من نهر الغراف للتعرف على المعايير الفيزيائية والكيميائية وتأثير فترة فيضان مياه نهر دجلة خلال عام 2019 على الخصائص البيئية لنهر الغراف. تم اختيار أربعة مواقع مقسمة على طول الجزء الجنوبي من النهر. أظهرت نتائج الدراسة وجود علاقة قوية بين درجة حرارة الهواء والماء في جميع المواقع. وسجلت الكدرة قيما تراوحت مابين4.85 – 84.65 NTU وجد من خلال نتائج الدراسة الحالية أن مياه نهر الغراف هي مياه مويلحة Oligohaline وذات قاعدية قليلة، وجيدة التهوية

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بسبب تراكيز الأوكسجين المذاب العالية. كما وتعد مياه النهر مشكوك في نظافتها حسب المعدلات المسجلة لقيم المتطلب الحيوي للاوكسجين. فيما سجلت القاعدية الكلية قيما تراوحت ما بين92-292.8 ملغم/لتر وهي اعلى من الحدود الطبيعية المسموح بها حسب المواصفات القياسية للمياه العراقية والعالمية (20-200 ملغم/لتر كاربونات الكالسيوم) . كما تبين ان مياه نهر الغراف عسرة جداً وان مياهه ضمن حدود المياه الطبيعية المسموح بها (200 ملغم / لتر من الكالسيوم و 150 ملغم/ لتر من المغنيسيوم). فيما تراوحت تراكيز الكبريتات من 50-200 ملغم/ لتر، بينما تراوحت مستويات البيكربونات بين 140-230 ملغم/ لتر. ومن ناحية أخرى، تراوحت القيم TDS و TSS ما بين 3354-855 ملغم/ لتر و3-85 ملغم/ لتر على التوالي. بينما بلغت قيم النترات ما بين 0.04-5.14 ملغم/ لتر والتي توافقت مع معايير المياه العراقية اذ كانت أقل من الحدود المسموح بها المعتادة (15 ملغم/ لتر). فيما تراوحت قيم الفوسفات ما بين 0.004-0.085 ملغم/ لتر. كما أظهرت الدراسة إلى أنه خلال فترة السيول الفيضية وبعدها كان لها تأثيرات مختلفة على المعايير المختلفة.

Introduction

Water plays a major role in life of aquatic organisms. Quality of water is affected by changes in atmospheric and geological circumstances [1], eventually affecting quality, quantity, and distribution of aquatic organisms, including zooplankton [2].

Many of local ecological studies focused on the physical and chemical characteristics of Tigris and Euphrates Rivers and their tributaries [3- 14]. The current study dealt with the southern part of Gharaf River, one of the major branches of the Tigris River in Wasit Governorate. The main aims were to investigate the ecological characteristics of the river, along with the impacts of the Tigris River floodplain during the 2019 on these characteristics. Therefore, this study can be considered as the first of its kind to deal with this aspect.

Materials and Methods

Description of the Study Area

Gharaf River is one of the major branches of the Tigris River, located at Kut Barrage in the south east of Iraq [15]. Therefore, its physical and chemical characteristics are mainly influenced by the Tigris River. Gharaf River enters the northern part of Dhi-Qar Governorate after a distance of 90 Km far from its sources in Al-Kut City [16], and continues in the southern direction where it passes through the cities of Kalaat Sucar, Al-Rifay, Al-Naser, Al-Shatrah and Gharaf. The length of Gharaf River extends from its branching point in the Kut Barrage to its outlet in Nasiriya marshes after about 230 Km [17]. Gharaf River is surrounded by large agriculture areas which mainly contain palm and other kinds of trees.

Description of the Study Sites

We selected four stations for the collection of study samples in the southern part of Gharaf River (Figure-1). The first site is located in Al-Hay District in the southern part of Al- Kut City. On this site, located at longitude 598753.7945 and latitude 355497.927, the width of the river is about 120 m and its depth is 5 m . The second site is located on Al-Fajer District which is about 35 Km from the first station, at 59288.4016 longitude and 352983.94 latitude. The width of Al-Gharaf River at this station is 100 m, while its depth is 3.5 m. The third site is located in Al-Naser District, at 606,454.83 longitudes and 3,494,626.283 latitude, about 52 Km from the second site. The width of the river at this station is 80 m, whereas its depth is 3 m. The fourth site is located in Al-Gharaf District, at 618,619.5618 longitude and 3,462,700.877 latitude, about 32.3 Km from the third site. The width of the river at this station is 70 m and its depth is 2.5 m. .

The range of discharge was 129 -218 m3/sec during the periods of samples collection (October 2018 and August 2019, respectively), while the range of water current was 0.401-0.476 m / sec during the period from May to August 2019, respectively (Table-1).

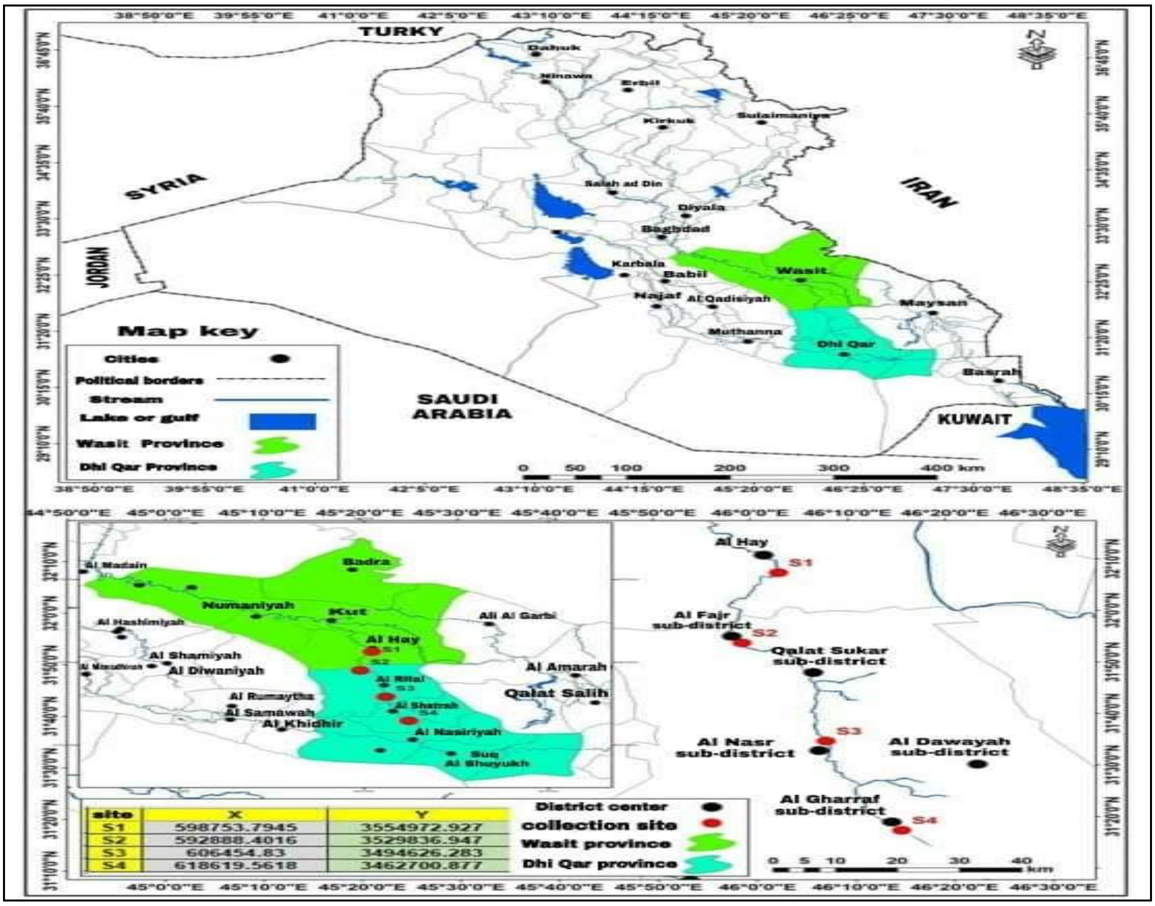

Figure 1-A map showing Gharaf River with locations of the studied sites.

Table 1-The average of discharge (m^3/ s) and water current (m/s) of the southern part of Gharaf River during the period of the study (Al- Kut Barrage Management Office, Personal Communication).

Months	Water discharge (m^3/sec)	Water current (m / s)
October 2018	129	0.433
November	135	0.457
December	140	0.418
January 2019	139	0.430
February	199	0.445
March	217	0.42
April	213	0.405
May	188	0.401
June	184	0.437
July	210	0.474
August	218	0.476
September	191	0.461

Samples were collected on a monthly basis from October 2018 to September 2019, by using polyethylene containers with capacity of 2.25 L which were washed well with river water before using.

Physical and chemical parameters included air and water temperature, measured by using a precise mercury thermometer. Dissolved oxygen and biological oxygen demand were measured by a modified Winkler method [18]. The percentage of oxygen saturation was calculated as reported in Mackereth *et al* . [19]. Electrical conductivity, salinity, pH, and TDS were determined using HANA (HI9811) device. TDS was measured according to the method mentioned in APHA [18]. Turbidity was measured by turbidity-meter (Jenwaw Company Model-6035). Total hardness, calcium , and magnesium were measured according to Lind [20]. Sulphate level was estimated using the method described by Brands and Tripke [21]. Nutrients (Nitrate)levels were measured as in

APHA [22], while the level of phosphate was measured according to APHA [23]. Finally, the Degremont method [24] was used to measure the bicarbonate level in the water of the studied sites.

Results and Discussion

Air temperatures clearly varied during the period of the study. The lowest and the highest values were recorded during the winter and summer, respectively, due to the nature of Iraqi climate which is generally hot-dry in the summer and cold-rainy in the winter [25]. As water temperature is affected by the surrounded environmental temperature, latitude and longitude line, season, air stream, presence of clouds, turbidity, vegetation, water current, and depth [26] , all of these factors might explain the strong and clear correlation between high and low temperatures of both water and air (Tables-2 and Figure-2).

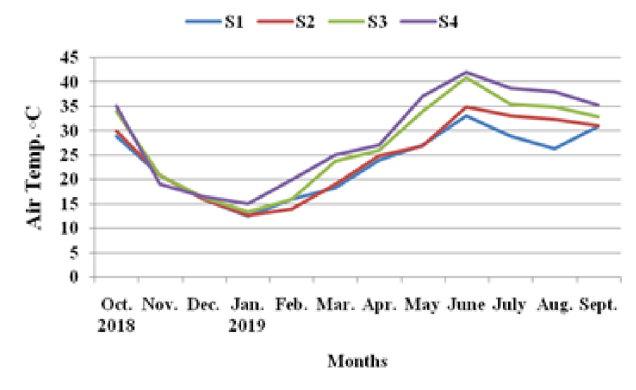

Figure 2 - Variation of air temperature during the study period.

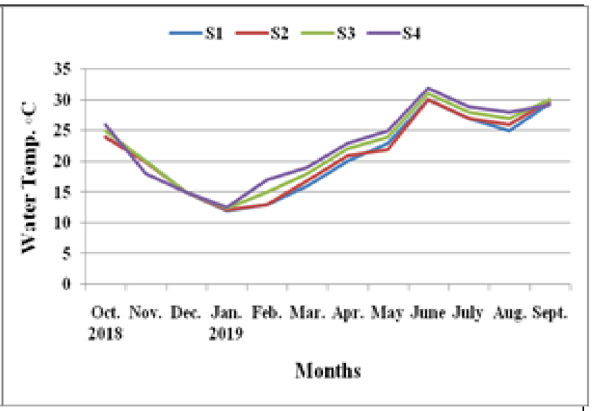

Figure 3- Variation of water temperature during the study period.

Table 2- Average, range, and standard error values of physical and chemical parameters during the period of the study

Site / Parameters	1	2	3	4	LSD value
Air Temp. ◦ C	12.5-33.2 23.65 ± 1.94 A	12.8-35 24.733 ± 2.28 A	13.5-41 27.442 ± 2.64 A	15-42 29.05 ± 2.80 A	4.167 NS
Water Temp. ◦C	12-30 21.2 ± 1.79 A	12.2-30 21.417 ± 1.78 A	12.4-31 22.283 ± 1.80 A	12.5-32 22.808 ± 1.83 A	2.981 NS
Turbidity NTU	4.85-75 40.062 ± 7.28 A	7.56-84.56 41.828 ± 7.10 A	5.51-93 43. 962 ± 7.27 A	8.47-62 28.191 ± 4.94 A	10.59 NS
EC µS / cm	690-1755 966.58 ± 82.88 A	767-1319 998 ± 53.28 A	747-1315 1000.7 ± 49.06 A	780-1360 ± 1027.6. 53.32 A	132.75 NS
Salinity ‰	0.44-1.123 0.622 ± 0.05 A	0.49-0.841 0.6389 ± 0.03 A	0.48-0.842 0.6257 ± 0.031 A	0.49-0.87 0.6608 ± 0.03 A	0.169 NS
pH	6.9-7.8 7.44 ± 0.08 A	6.8-7.9 7.50 ± 0.10 A	6.9-8 7.49 ± 0.09 A	6.9-8 7.44 ± 0.09 A	0.338 NS
DO mg / L	6.5-11.4 8.45 ± 0.42 A	6-10.5 8.625 ± 0.39 A	4.5-10 8.2833 ± 0.49 A	5.2-9 7.7583 ± 0.35 A	1.028 NS
BOD_5 mg / L	1.2-7.9 4.90 ± 0.64 A	1-8.2 4.58 ± 0.70 A	0.5-8 4.42 ± 0.69 A	1-6.4 3.88 ± 0.54 A	1.035 NS
Oxygen	74.82-115.64	73.89-132.1	56.46-127.55	66.32-109.14	11.547 NS

Saturation POS%	95.75 ± 4.04 A	97.588 ± 4.83 A	94.912 ± 6.13 A	88.743 ± 3.11 A	
TH mg / L	300-500 401 ± 17.07 A	320-512 405.33 ± 16.53 A	320-540 408 ± 19.76 A	328-560 419.17 ± 21.86 A	33.711 NS
Ca^{+2} mg / L	60.12-212.4 105.54 ± 11.76 A	60.12-160.32 105.87 ± 7.74 A	60.12-180.36 103.57 ± 9.19 A	60.12-144.28 107.21 ± 8.168 A	16.526 NS
Mg^{+2} mg / L	29.18-48.68 37.508 ± 1.71 AB	14.48-75.9 38.367 ± 4.64 AB	11.56-70.5 41.33 ± 4.65 A	12.02-54.07 36.123 ± 3.99 B	5.093 *
SO_4^{-2} mg / L	50-200 118.33 ± 14.86 A	70-200 120.42 ± 15.50 A	60-200 120.17 ± 10.57 A	100-200 133.33 ± 10.82 A	21.757 NS
$HCO_3^{=}$ mg / L	140-200 175.17 ± 5.58 A	150-220 181.67 ± 7.05 A	154-230 183.33 ± 6.35 A	155-220 180.75 ± 5.789 A	8.631 NS
TDS mg /L	354-355 485.25 ± 38.96 A	384-650 497.33 ± 25.38 A	374-666 504.42 ± 24.35 A	378-693 498.83 ± 25.26 A	38.025 NS
NO_3^{-2} mg / L	0.5-3.98 1.8322 ± 0.271 B	0.04-4.76 1.8193 ± 0.35 B	0.5-5.14 2.0008 ± 0.36 AB	1.127-4.8 2.4163 ± 0.28 A	0.519 *
PO_4^{-2} mg / L	0.004-0.073 0.0418 ± 0.061 A	0.011-0.084 0.0475 ± 0.006 A	0.015-0.082 0.0484 ± 0.006 A	0.019-0.085 0.0452 ± 0.006 A	0.0168 NS
TSS mg /L	5-44 24.667 ± 4.46 A	3-60 32.667 ± 5.54 A	10-61 29.083 ± 4.67 A	5-85 30.333 ± 8.28 A	8.529 NS
Total Alkalinity mg /L	122-292.8 221.55 ± 13.08 A	122-268.7 220.64 ± 10.35 A	165-292.8 231.36 ± 10.06 A	92-292.8 227.82 ± 14.8 A	19.620 NS

*P≤0.05. NS :Not significant.
Averages values with different letters within a same row differ significantly.

The highest value of turbidity was 84.65 NTU which was recorded on site 2 in July, while the lowest values were 4.85 NTU, recorded on site 2 in May . Statistically, it was found that there were no significant differences (p> 0.05) between the studied sites (Table-2 and Figure-4).

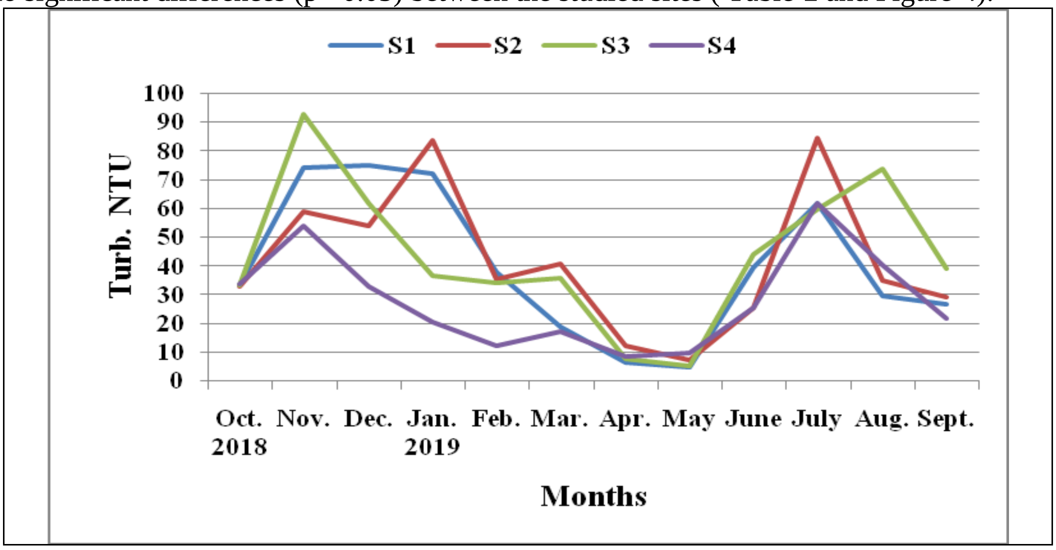

Figure 4 -Variation of the turbidity value (NTU) during the period of the study.

The values of turbidity changed throughout the year; they increased at the end of autumn, winter and summer , which may be due to the increased water discharge ,(129-218m^3 \sec in August 2019) and water current (0.476m / sec) (Table -1) [27], that leads to increased water circulation of river, in addition to the increased decomposition of organic material from suspended plants [28]. While the decline of turbidity values in spring may be attributed to the slow movement of water , which reached 0.42 m /sec (Table -1), leading to deposition and partial dissolution of suspended material in the river over time at low temperatures. Another reason may be related to the presence of aquatic plants which catch soil and impurities and prevent them from being drift into the river [29]. Regarding the effect of floodplain on turbidity, the values of turbidity in February, before the floodplain, had the range of 12.11-84 NTU , whereas the value during the floodplain period in March, April and May, decreased to a range of 4.85-40.87 NTU. As for the period after the floodplain, the values increased in June and reached 25.37-84.65 NTU. This may be related to water circulation processes, rapid flow of water, and high percentage of organic matter (Table-3).

Table 3- The effects of floodplain period on physical and chemical parameters of the southern part of the Gharaf River during the period of the study.

Floodplain / Parameter	Before	During	After
	Jan. and Feb.	Mar., Apr. and May	June and July
Turbidty NTU	12.11-84	4.85-40.87	25.37-84.65
EC µS/cm	916-1245	780-980	690-837
Salinity ‰	0.586-0.797	0.499-0.627	0.44-0.53
pH	7.3-7.9	7.3-8	6.8-7.6
BOD5 mg / L	0.5-5	5.2-8	4-8.2
DO mg / L	7-7.7	7.7-11.4	7-10
POS %	74.28-93.26	89.78-115.6	909-132.1
T. H mg / L	400-460	344-460	300-360
Ca^{+2} mg/L	88.17-108.2	72.14-140.28	60.12-96.192
Mg^{+2} mg/ L	31.6-53.78	12.02-53.56	41.39-21.34
SO_4^{-2} mg/ L	100-200	70-200	50-150
$HCO_3^{=}$ mg/ L	160-180	180-230	180-200
NO_3^{-2} mg/L	2.8-5.14	0.04-3.18	1.4-2.64
TDS mg / L	435-597	409-514	354-425
PO_4^{-2} mg/L	0.017-0.064	0.03-0.077	0.033-0.084
TSS mg / L	6-44	3-44	5-85
T.Alkalinity mg/ L	183-244	92-275	183-244

Values of electric conductivity of Gharaf River ranged from the highest value of 1755 µS/cm, withe a salinity value of 1.123 ‰ , recorded at site 1 during October 2018, and the lowest value of 690 µS/cm, withe salinity value of 0.44 ‰ , recorded at site 1during June 2019. The results of the statistical analysis of electrical conductivity show no significant differences ($P> 0.05$) between the studied stations (Table-2 and Figure-5).

Regarding salinity levels, the results of the statistical analysis showed no significant differences at $P> 0 .05$ between the studied sites (Table -2 and Figure-6).

As related to spatial changes, the study showed that the highest values of electrical conductivity and salinity were recorded at the first site , possibly due to agricultural activities [30]. Furthermore, the differences in soil properties in the areas at which the river passes might have an impact [31]. While the decrease of electrical conductivity and salinity values may be due to the lack of salts that arrive from the nearby irrigation water and the low disposal of human waste that contains salts [32]. Our study also found that the water of the Gharaf River is oligohaline according to the classification of EPA [33].

A clear decline in the values of both electrical conductivity and salinity was found after the floodplain period; the electrical conductivity ranged 945-1245 µS/ cm before the floodplain period, with salinity of 0.586-0.797 ‰. During the floodplain period, electrical conductivity ranged 780-980 µS/cm, with salinity of 0.499-0.727 ‰, whereas after floodplain period, electrical conductivity ranged 690-837 µ S/ cm, with salinity of 0.44-0.53‰. These results may be attributed to the dilution factors and the lack of chemical compounds, which reduces the percentage of dissolved salts and electrical conductivity.

The current study showed that the water of river water is weak alkaline to neutral and within a narrow range. This may be due to the presence of calcium bicarbonate , which is characterized by a high buffering capacity. The results of this study are consistent with those of most previous studies, indicating that Iraqi waters tend to weak alkaline with a narrow range of pH values [34, 35] (Table-2 and Figure -7).

The results of the statistical analysis showed no significant differences (P> 0.05) between the studied stations (Table -2 and Figure-7).

Also, no effects of floodplain period were found (Table-3). Generally, the Iraqi water bodies are considered as neutral to weak alkalinity due to the high buffering capacity of Iraqi waters which are rich with bicarbonate that resists the change in pH [36].

The higher alkalinity value of the southern part of Gharraf River was 292.8 mg/L during September at sites 1, 3, and 4, whereas the lowest value was 92 mg /L during April in site 4

The results of statistical analysis demonstrated no significant differences (P> 0.05) between the study sites (Table- 2 and Figure-8).

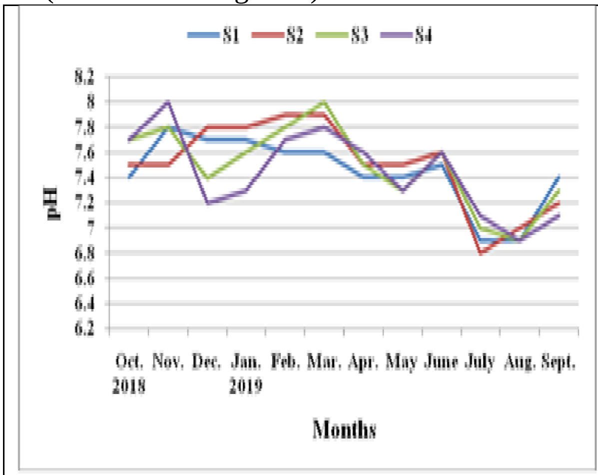

Figure 7- Variation of pH values during the period of study.

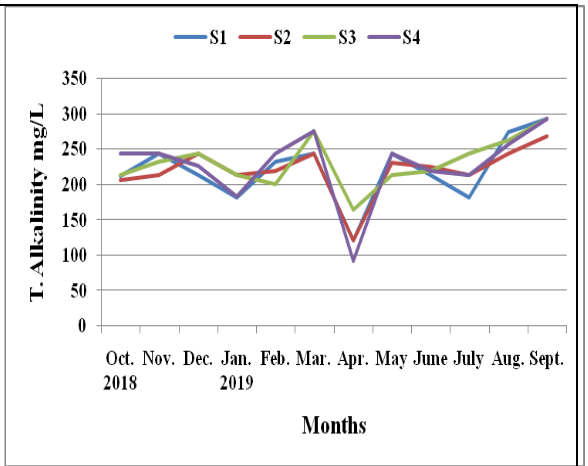

Figure 8 -Variation of total alkalinity values during the period of study.

The high total alkalinity values in the sites 1, 3 and 4 may be caused by the high rates of decomposition of organic material and the conversion of undissolved calcium carbonate to dissolve bicarbonate [37]. While the decrease in total alkalinity may be due to the consumption of free carbon dioxide by the organisms belonging to Protista and the decomposition of the bicarbonate [38]. The current study showed that the alkalinity values were above the normal limits allowed by the Iraqi and international standards of water, which is 20-200 mg/L CaCO3 [23]. Also, it was reported that Iraqi waters have alkaline characteristics because of the presences of bicarbonate salts [39, 40] .

As for the impact of floodplain period on total alkalinity , the value of this parameter before floodplain period reached 183-244 mg / L, while it was 92-275 mg /L during this period. After floodplain period, this value ranged 183-244 mg / L . The clear increase in this parameter recorded during the floodplain period may be due to the increase of drifted organic matter (Table-3).

The results of dissolved oxygen and the percentage of oxygen saturation, of Gharaf River showed that the lowest values of 4.5 mg/L (56..46%) were recorded during August at site 3, while the highest values of 11.4mg/L (132.1%) were recorded in March at site1 (Figures- 9and 10) .

The results of the statistical analysis showed no significant differences (p>0.05) between the studied site (Table-2).

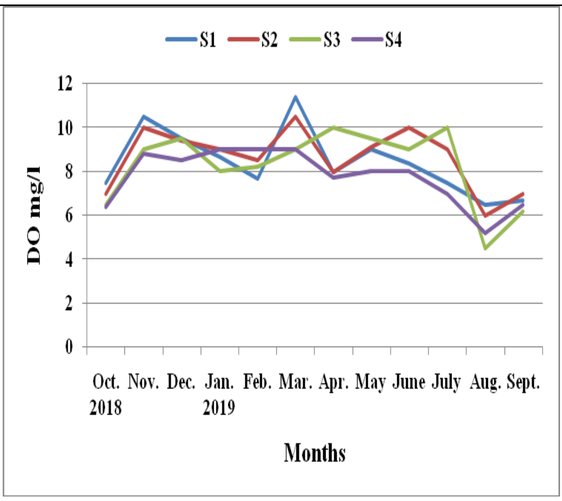

Figure 9- Variation of dissolved oxygen value during the period of study.

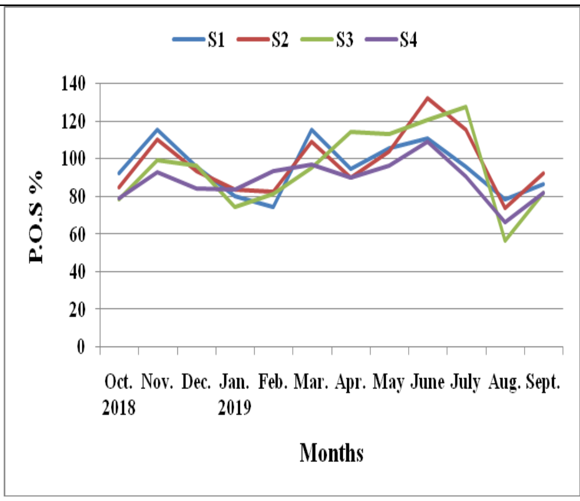

Figure 10 -Variation of the percentage of oxygen saturation value during the period of study.

Recording high values of dissolved oxygen concentrations may be due to the rapid water circulation, especially after the clear increase of river water level during February, March and April 2019, which resulted in the increased dissolved oxygen [41,42]. Whereas recording a decrease in the percentage of dissolved oxygen may be related to the disposal of household waste to the river water, which contains the organic materials that consume a large amount of oxygen when decomposed by microorganisms [43]. In addition to that, the increase in temperature leads to increased density and activity of microorganisms, while recording high percentage of oxygen saturation, despite disposal of household waste into the river, may be related to the high potential of self-purification [44].

As for the effect of the floodplain period on dissolved oxygen, the average value before the flood was 7.7-9 mg/L (74.28-93.26 %), whereas it was 7.7-11.4 mg /L (89.78-115.6 %) during the floodplain period, and 7-10 mg /L (90.9-132.1%) and after the floodplain period (Table-3). This may be due to the fact that the nutrients that are transferred with floodplain water can promote the growth of algae and water plants, which are responsible for producing oxygen in water [45].

The results of BOD5 in Gharaf River showed that the value ranged 5-8.2 mg / L , with the lowest value being recorded during January 2019 at site 3 , while the highest values was recorded during June 2019 at site 2 . Statistically, no significant differences (P>0.05) was found among the studied sites (Table-2 and Figure-11).

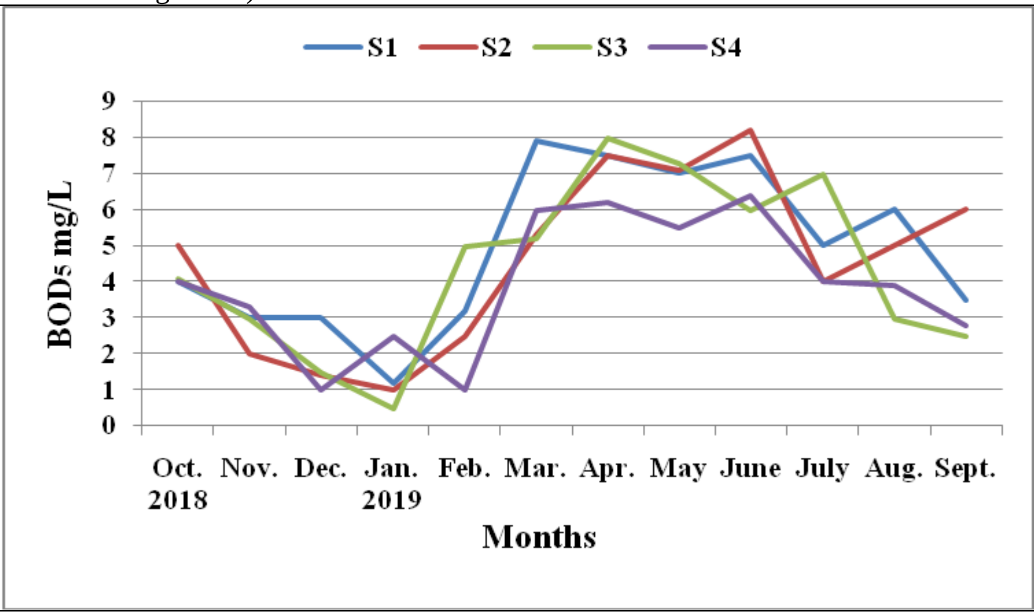

Figure 11- Variation of the biological oxygen demand values during the period of study.

The high biological oxygen demand value exceeded the allowable levels of 5 mg/L due to several reasons, which include sewage pollutants due to continuous human activities, in addition to the presence of agricultural lands and drainage of water containing manure to the river [46].

The highest values of biological oxygen demand were recorded during the spring and summer 2019. This result might be due to the decomposition process of organic matter which consumes large quantities of oxygen with high temperatures of the summer, leading to the depletion of dissolved oxygen in the water [47].

As for the floodplain and its impacts on the biological oxygen demand, the value of BOD_5 before floodplain period ranged 0.5-5 mg/L, while the value during floodplain period was 5.2-8 mg/L. However, this value was increased after floodplain period to 4-8.2 mg/L (Table-3), which may be due to the microorganisms drifted by floodplain, which consume oxygen by biological decomposition processes.

Odum [48] divided water into two types depending on BOD_5, as follows: BOD_5 = 2 refers to clean water, and BOD_5 = 5 or higher refers to water that is doubtful in its cleanliness. Thus, it can be noted that Gharaf River was doubtful in its cleanliness.

The results of total hardness during the current study of the southern part of Gharaf River showed values ranging 300-560 mg/L, with the lowest value recorded during July 2019 at site 1, while the highest values were recorded during October 2018 at site 4 . The results of the statistical analysis recorded no significant differences (P> 0.05) between the studied sites (Table-2 and Figure-12).

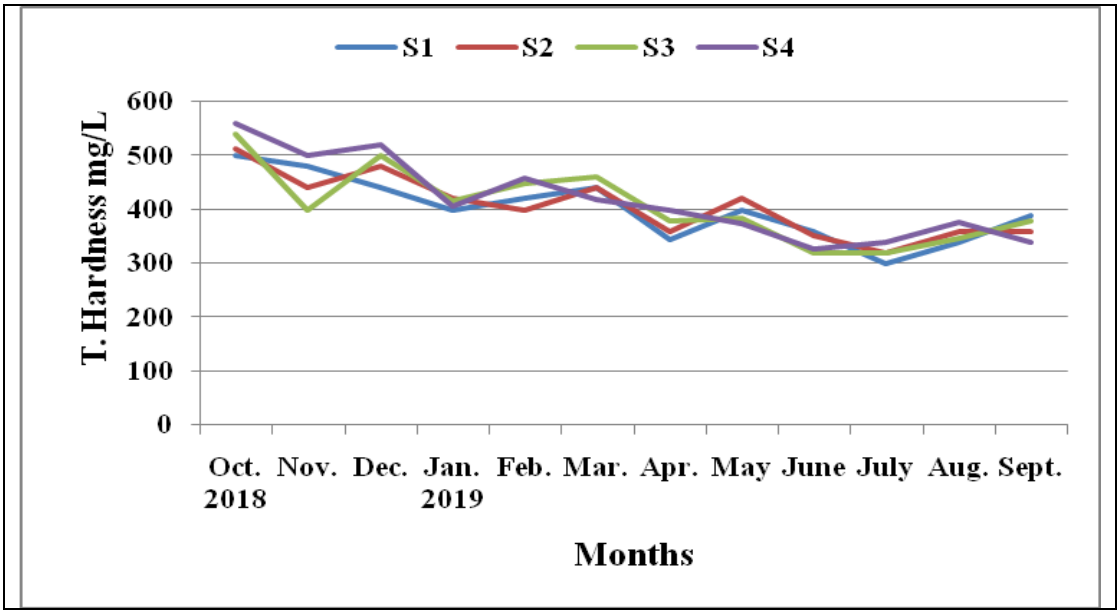

Figure 12 –Variation of the total hardness values during the period of study.

As for calcium , the values ranged 60.12-180.36 mg /L, with the lowest values recorded at sites 2 and 3 during July 2019 as well as during August 2019 at sites 1 and 4. Whereas the highest value was recorded at site 3 during October 2018. The results of the statistical analysis recorded no significant differences (P>0.05) among all studied sites (Table-2 and Figure-13).

On the other hand, the values of magnesium ranged 11.56-75.9 mg / L. The lowest values were recorded during August 2019 at site 3 while the highest values were recorded during October 2018 at site .2 The statistical analysis revealed significant differences between sites (P≤0.0 5), (Table-2 and Figure-14).

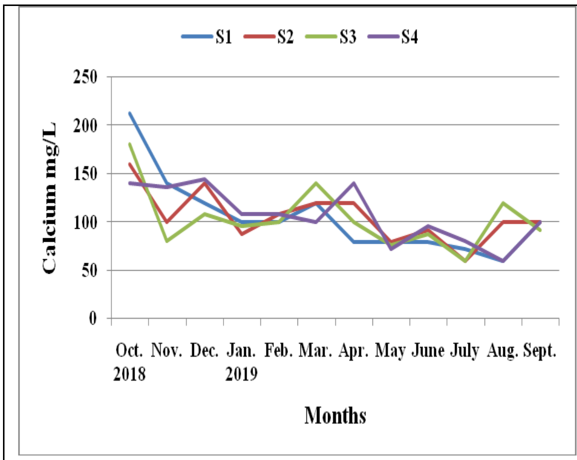

Figure 13 -Variation of calcium level during the period of study.

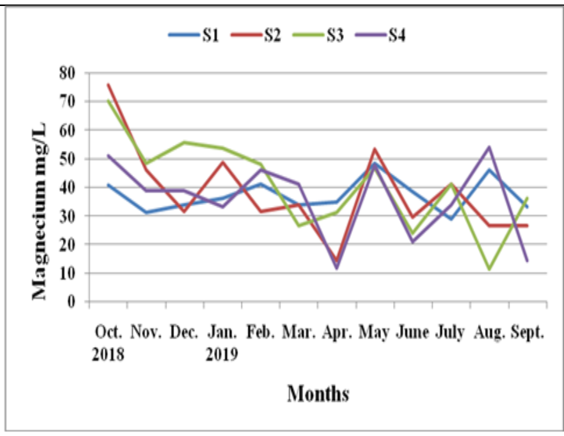

Figure 14 -Variation of magnesium level during the period of study.

Kevin [49] classified water into four forms based on total hardness; values less than 50 mg / L of calcium carbonate refer to non-hard water, values ranging from 50 to 100 mg / L refer to moderately hard water, values between 100 and 200 mg / L refer to hard water, and values higher than 200 mg/L refer to very hard water. It can be noted that Gharaf River had very hard water according to the total hardness values reported in the present study.

As for the effects of floodplain period on total hardness, the value of hardness before the floodplain period was high, ranging 400-460 mg / L, while the value was 344-460 mg / L during the floodplain and 300-360 mg / L after the floodplain, which is lower than the value before the floodplain period (Table 3). This could be due to the high water level, the dilution factor, and the high water current which reduces total hardness.

From the present study, it was found that calcium concentrations at all sites are higher than magnesium concentrations, which may be correlated with the higher interaction between carbon dioxide and calcium as compared to magnesium. Thus, larger quantities of calcium are converted to dissolved bicarbonate [50].

The results showed that calcium value before the floodplain period ranging 88.17-108.2 mg/L, while during the floodplain period it was 72.14-140.28 mg/L. However, after the floodplain period, the value decreased to 60.12-96.192 mg/ L (Table-3). The floodplain also affected magnesium in the same manner it affected total hardness and calcium, as the values before the floodplain period ranged 31.6-53.78 mg/L , while declined during the floodplain period to 12.02-53.56 mg / L. However, after the floodplain period, the value ranged 21.34-41.39 mg/L . We assume that the decreased magnesium level during the floodplain period may be due to the decrease in turbidity during this time, which leads to sunlight leakage to water, leading to the blooming of magnesium-consuming algae [51].

The results of this study show that Gharaf River falls within the permissible limit of 200 mg / L for calcium and 150 mg / L for magnesium in natural water [52].

The current study recorded values for sulphates that ranged 50-200 mg / L, with the highest values observed during October 2018 at sites , 2, 1 and 4, as well as during January 2019 at site 1. The lowest value was recorded during July at site 1. The results of the statistical analysis recorded no significant differences ($P > 0.05$) among the studied stations (Table-2 and Figure-15).

During the summer, the low level of sulphate may be due to its absorption by aquatic plants and algae, or due to high water levels and the increase in the rate of water discharge, which ranges between 210 and 218 m3/s [53]. As for the high concentration of sulphates, the reason might be the increase in the concentration of sulphates to the south of the Tigris River, which is proportional to the nature of the groundwater, whose level is rising in the central and southern areas [54]. Another reason can be the high level of sulphur dioxide in the atmosphere, resulting from the combustion of fuel and thus reaching the water or falling as dry minutes, in addition to the erosion of rocks and soil [55] .

With regard to the effect of floodplain period on sulphate levels, the values ranged 100-200 mg / L before the floodplain period and 70-200 mg / L during the floodplain period. Nevertheless, after the floodplain period, the value was reduced to 50-150 mg / L, which may be due to consumption by algae (Table-3).

Bicarbonate values on the southern part of Gharaf River ranged 140-230 mg /L, with the highest value recorded at site 3 in May 2019, while the lowest was at site 1 in December 2019. Based on the findings of statistical analysis, no significant differences were found among the examined sites (P > 0.05) (Table-2 and Figure-16).

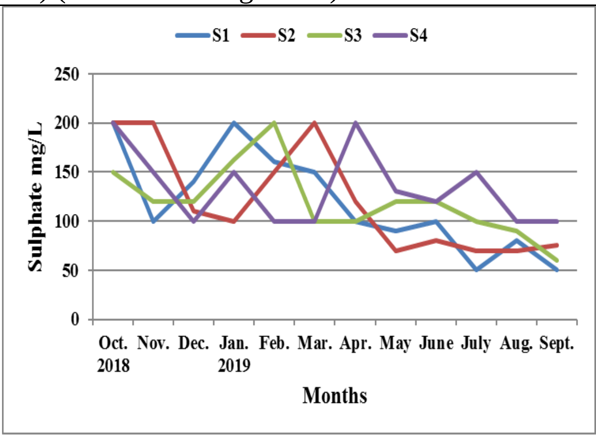

Figure 15-Variation of sulphate levels during the period of study

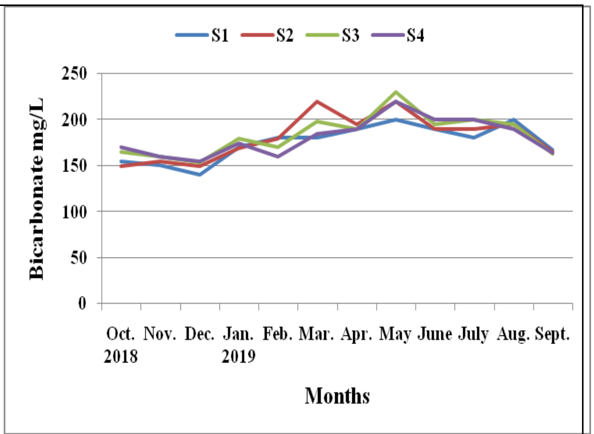

Figure 16 -Variation of bicarbonate levels during the period of study .

The increase of bicarbonate in site 3 may be due to the effect of untreated wastewater [56]. Also, it may be linked with the recorded decrease in water discharge (188 m 3/s) and turbidity (44.13 NTU). Another reason could be the organic decomposition processes and their relationship with the variation of carbon dioxide. The decrease in site 1 is possibly due to the large quantities of pollutants and the high level of bicarbonate degradation as a result of organic decomposition.

The value ranged 160-180 mg /L before the floodplain period and 180-230 mg /L during the floodplain period , but it increased and reached 180-200 mg /L after floodplain period. This may be due to the abundance of aquatic plants and algae, which release dissolved carbon dioxide in the water, or due to the location of the river in a region influenced by torrents and floods coming from Iran and Turkey (Table-3).

Total dissolved solids recorded the highest values (3354 mg/L) at site 1 during November 2018, while the lowest values (855 mg/L) were recorded on site 1 in June 2019. The statistical results of the study showed no significant differences between the sites analyzed (P>0.05) (Table-2 and Figure-17). The high level of total dissolved solids at site 1 is probably because the area is surrounded by agricultural lands, which increases salt-containing water drainage to the river [57] . As for the decline at site 1, it might be attributed to the reduction of salt-containing human and industrial waste.

The value of total dissolved solids before the floodplain period ranged 435-597mg/L. This parameter ranged 409-514 mg /L during floodplain period , but decreased to 345-425 mg /L after floodplain period. This reduction in TDS levels may be due to high water levels, which cause higher dissolution rates , or to the lack of organic materials (Table-3) . From our results, it was observed that the TDS values were within the acceptable limit of 1.5 g / L [58].

Our results agrees with those of Nashaat et al. [6] on the Kuffa River, who recorded values of TDS that ranged 440.4-977 mg / L.

The results of the present study showed that the highest value of TSS was recorded at station 4 in July 2019, while the lowest value was recorded during May 2019 at site 2. Statistically, no significant differences (P> 0.05) were found among the studied sites (Table-2 and Figure-18)

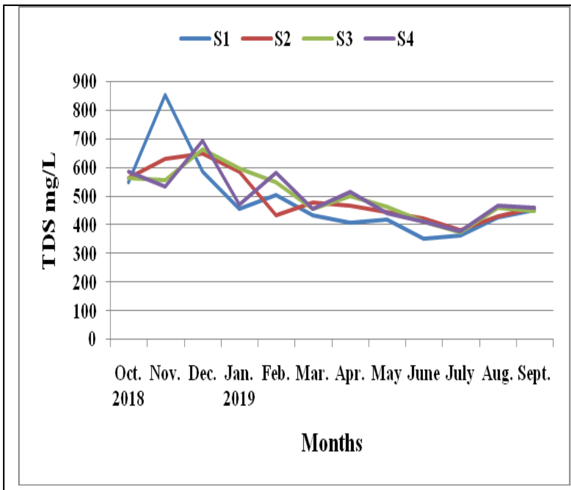

Figure 17-Variation of total dissolved solids value during the period of study.

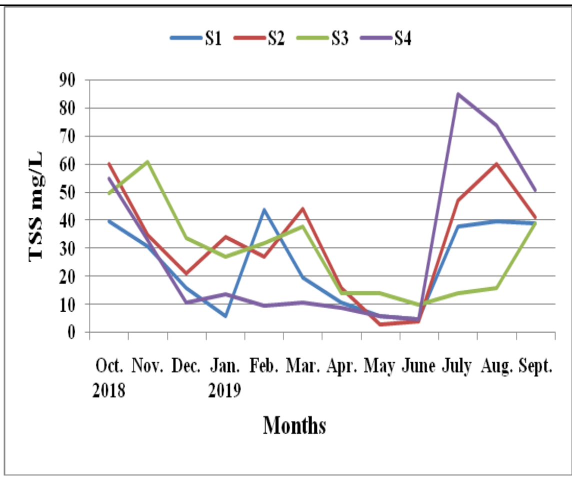

Figure 18- Variation of the total suspended solids values during the period of study.

The recording of the highest values at site 4 may be due to the agricultural activities (irrigation), where wastewater is drained directly into the river [59]. Also this site is located on the end part of Gharaf River near Al-Gharaf District.

The value of the total suspended solids ranged from 6-44 mg/L before the floodplain period before the floodplain period and 3-44 mg /L , during the floodplain period. However, after the floodplain period, the value increased to 5-85 mg /L, which may be due to the large amounts of pollutants, drifted salts, organic and inorganic materials, or because the floodplain drifted away the aquatic plants that perform the filtering process, as the suspended matter sticks on their surfaces (Table- 3) .

USEPA [60] divided the water into three forms based on the TSS; a concentration below 20 mg / L reflects clean water, 20-80 mg / L reflects low turbidity water, and above 150 mg / L reflects turbid water. This implies that Gharaf River water is turbid according to the presently reported TSS values.

The result of nitrate showed that the values ranged 0.04-5.14 mg/L with the peak value recorded at station 3 in February 2019, while the lowest value was at station 2 in March 2019. Statistically, significant differences ($P \leq 0.0\ 5$) were observed between sites (Table-2 and Figure-19.

The reduction in the value recorded in site 2 may be attributed to the low excretion of nitrogen fertilizers or to the oxidation of nitrite to nitrates in water, which requires the dissolved oxygen [61].

As for the spatial variation, site 3 showed a significant increase in nitrate values due to the agricultural waste that is dumped directly into the river, where fertilizers contain nitrates, as well as industrial and sewage waste and decomposing plant residues which add organic nitrogen compounds [62].

By reviewing the nitrate results, we find that it was below the usual permissible limits (15 mg /L) for Iraqi water standards [63] .

As for the floodplain period, the nitrate values before this period ranged 2.8-5.14 mg / L, while it was 0.04-3.18 mg / L during this period. However, after this period, the nitrate value was 1.4-2.64 mg / L. This may be due to the blooming of algae and their consumption of nitrates as their nutrients during the spring (Table-3).

The phosphate level results in Gharaf River showed that the lowest value (0.004 mg / L) was recorded at site 1 in April, while the highest value (0.085 mg / L) was recorded at site 4 in October. The statistical analysis results showed no significant differences between locations ($P > 0.05$) (Table-2 and Figure-20).

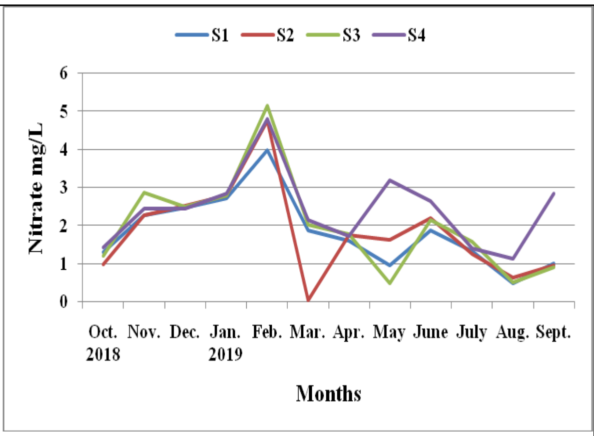

Figure 19-Variation of nitrate values during the period of study.

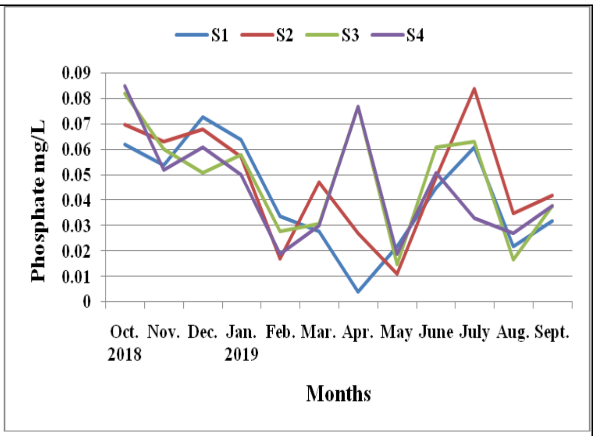

Figure 20-Variation of phosphate values during the period of study.

High concentrations of phosphate may be due to agricultural residues that contain phosphate fertilizers released into the river [64]. As for the low phosphate concentrations, it can be due to the high water hardness, as the amount of soluble phosphate decreases because of its consumption by phytoplankton [65].

The pre-floodplain values of phosphate ranged 0.064-0.017 mg / L. While, during this period, the values rose to 0.03-0.077 mg / L Likewise, the post- floodplain phosphate value ranged 0.0 33 -0.0 84 mg / L, which may be due to a decrease in total hardness after the floodplain or to erosion of agricultural fertilizers containing phosphates and phytonutrients from the agricultural lands adjacent to the river [66] (Table-3).

Our results agree with those of Al-Nimrawi [67] who reported that the phosphate values in the Tigris River ranged from not-detectable (ND) to 0.023 mg / L, whereas the values in the Euphrates River ranged from ND to 0.0412 mg / L. In his assessment, Flaeh [68] reported levels of 0.016-0.19 mg / L on the Tigris River, whereas Stanhope [69] showed that phosphorus is rapidly absorbed from soil particles, and it is absorbed by bacteria and plants.. Rasheed *et al.* [7] recorded phosphate values in the Shamiya River that ranged 0.13-1.75 mg / l. Al-Azawii *et al.* [8] recorded phosphate values in the Tigris River that ranged 3.03-176.5 mg / L. However, the level reported by Sarraj [70] was higher than that found by our study, which ranged 0.09-1.6 mg / L, possibly because of human, agricultural, and industrial stresses.

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