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Received on: 19/05/2019
Accepted on: 19/06/2019
Published online on: 25/07/2019

Assessing Water Quality for Al-Diwaniyah River, Iraq Using GIS Technique

Abstract- *In this study, Al-Diwaniyah River within Al- Diwaniyah Governorate was monitored for a set of chemical, physical, and bacteriological parameters for the assessment of water quality during January to July 2018. Water quality maps for this river were plotted to represent the change in each parameter during the study period using GIS program. Three sampling stations along the river and eighteen parameters were selected: air temperature, water temperature, turbidity, pH value, electrical conductivity (EC), biochemical oxygen demand (BOD), dissolved oxygen (DO), alkalinity, chloride, Sulfate, total suspended solids (TSS), total dissolved solids (TDS), calcium, magnesium, total hardness, lead, total coliform, and Escherichia coli bacteria. The results explained that the water temperature varied between (15-31) °C. pH values ranged between (7.4-8.2) and river water was considered as slightly alkaline with alkalinity concentrations between (124-176) mg/L. Most water of the river was very hard according to the values of hardness that varied between (384-531) mg/L. The turbidity values of the river ranged between (1.5-35.2) NTU. Electrical conductivity was between (998-1380) µs/cm. Total dissolved solids and total suspended solids were their values varied between (620-932) mg/L and (2-28) mg/L respectively. It was found that among measured positive ions, calcium concentrations were higher than the magnesium concentrations, ranging between (71-175) mg/L and (21-67) mg/L respectively. On the other hand, when studying Anions, sulfate concentrations were higher than chloride concentrations with values ranging from (152-339) mg/L and (101-167) mg/L respectively. River water contained dissolved oxygen concentrations ranging (6.3-10.1) mg/L while concentrations of biochemical oxygen demand varied between (0.6-7.6) mg/L. Lead ranged in values between (0.001-0.017) mg/L. The study found that bacteriological parameters, including total coliform and E. coli, ranged between (500-1600) MPN/100ml and (30-1600) MPN/100ml respectively. In general, the parameters of Turbidity, SO4, BOD5, TC and E. coli have exceeded Iraqi standards for drinking water IQS: 417 while the rest of the parameters were within these limits. It revealed that station 2 which was located only at a short distance from the site of the wastewater treatment plant was more polluted than the other two stations. The results showed that the water of the river is neither suitable for drinking, nor suitable for swimming according to the high bacterial pollution in addition to the danger and threat to aquatic life but can be used for irrigation purposes.*

Keywords- *Water quality assessment, GIS technique, Al-Diwaniyah Rive.*

How to cite this article: K.M. Hussein, S.A.F. Al-Bayati and S.A.A. Al-Bakri, "Assessing Water Quality for Al-Diwaniyah River, Iraq Using GIS Technique," *Engineering and Technology Journal*, Vol. 37, Part A, No. 7, pp. 256-264, 2019.

1. Introduction

Of all the natural resources of our planet, water is essential and indispensable as life begins with water and nurtures water life. Some living organisms, such as anaerobic organisms, can survive without atmospheric or dissolved oxygen, but no organism can survive without water [1]. Water represents an invaluable natural source that requested to human life and community health. It is making up roughly 60% of body weight, and is considered as an essential daily requirement. Without water, life is impossible through a few days. It is still the main environmental health issue in all countries, and the most important industry is supplying water for human consumption. Contaminated water stays responsible for waterborne diseases. Health implications of water pollution are concern growing [2]. However, because of human activities in the last two decades, water quality degradation has been spotted in a large number of rivers throughout the world [3]. Many factors have been found to have an impact on the rivers in Iraq. Iraq administration has not controlled external factors such as water policies in neighboring riparian states and natural (climate) factors. Internal factors are under Iraqi control such as irrigation methods and losses. Some of these factors affect the water quantity, quality, or both [4]. To determine the state of the contamination and its degree of gravity in any

http://dx.doi.org/10.30684/etj.37.7A.6
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river, it is essential to begin by continuously monitoring the water quality of this river [5]. Thus, Assessment of physical, chemical and biological (bacteriological) water pollution is necessary to reduce freshwater pollution. The Euphrates and Tigris rivers are the main sources of water in Iraq. They are used for many important glasses of water uses including industry, drinking, livestock, irrigation, and fishing [6]. Water quality is deteriorating towards middle and south of Iraq due to the diminution of water resources, increasing farmland, an increasing number of drainage, and high temperatures. Thus, there is an increase in the number of salts and contaminants in this water, which is reflected in the drinking water quality of those areas. For these reasons, it is most important to assess the quality of the river's water continuously to determine their suitability for different uses and identify pollution as soon as possible to take the necessary measures by the competent authorities. Water quality could be evaluated through analysis of physical, chemical, and biological parameters. These parameters may be having a harmful effect on the consumer when their concentrations are exceeding the allowable limits and influence on water through odor, taste, color, and diseases. GIS and remote sensing are modern techniques adopted in the assessment of the water quality. Many latest studies used principles of these systems in the management and improving water quality, such as satellite images, scanned documents, and contour maps.

The major objective of the present study is to research and develop susceptibilities in Iraq using modern technology to predict and detect adverse changes in water quality in Al-Diwaniyah River in real time allowing for reaction to any threat to the quality of water.

2. Materials and Methods

I. Study Sites

Al-Diwaniyah River represents the major source of water requirement for Al-Diwaniyah province for different uses (drinking, irrigation, and other uses). It is one of the branches of Shatt Al-Hilla that is coming from Babylon province, north of Al-Diwaniyah province. The flow of this river begins in the area of Sadr al-Daghara, north of Al-Diwaniyah province. The river length is about 120 km. It runs south-west, passes through the areas of Saniyah, Diwaniyah City, Sidair and Al-Hamza areas respectively to enter Al-Muthannah province which lies in the south of Al-Diwaniyah province. The average annual discharge of the Diwaniyah River is about 45 m^3 / s, but the design discharge of this project is about 60 m^3 / s. This river helps to irrigate about 410000 acres of agricultural areas on both sides of the river and is the main source of water needs for the city of Diwaniyah and other areas for various uses such as irrigation, and drinking, etc. The three stations cover the river length from north to south in site 1-Sadr Al-Daghara, 2-Diwaniya, and 3-Hamza. Locations with the Coordinates that are taken by Geographical Positioning System (GPS) are shown in figure (1).

II. Sampling

The samples of water were collected from the three stations from January to June 2018, by using clean polyethylene bottles for most tests and glass bottles for other tests. Samples were analyzed for chemical, physical and bacteriological properties immediately after collection according to standard methods [7]. These parameters are air temperature (T_a), water temperature (T_w), turbidity, pH value, electrical conductivity (EC), biochemical oxygen demand (BOD), dissolved oxygen (DO), alkalinity, chloride (Cl), Sulfate (SO_4), total dissolved solids (TDS), total suspended solids (TSS), total hardness (TH), calcium (Ca), magnesium (Mg), lead (Pb), total coliform and Escherichia coli bacteria. The results were compared with the standards of (WHO) [8], (WHO) [9], (WHO) [10], (CCME) [11], (CCME) [12], (Iraqi standard IQS: 417) [13], (Iraqi standard IQS: 417) [14], (System Maintenance of River) [15] and (Ayers & Westcot) [16]. Tests were conducted in the field and laboratory. The methods illustrated in Table (1).

III. Geographic Information System (GIS) Tools used for water pollution assessing

Geographic Information System (GIS) is defined as a software-based computer technology that deals with geographical data obtained in digital format. Its advantage is capturing, storing, analyzing and displaying spatial or geographic data [17]. The coordinates of three sampling stations were recorded by GPS mobile (Garmin eTrex Vista C). The results (mean value) of the physical, chemical and bacteriological tests were used as input data in ArcGIS Desktop 10.5. Water data were combined with sampling sites to create spatial distribution maps. The present study used a polygon option to modify the pre-processed aerial image of the study area.

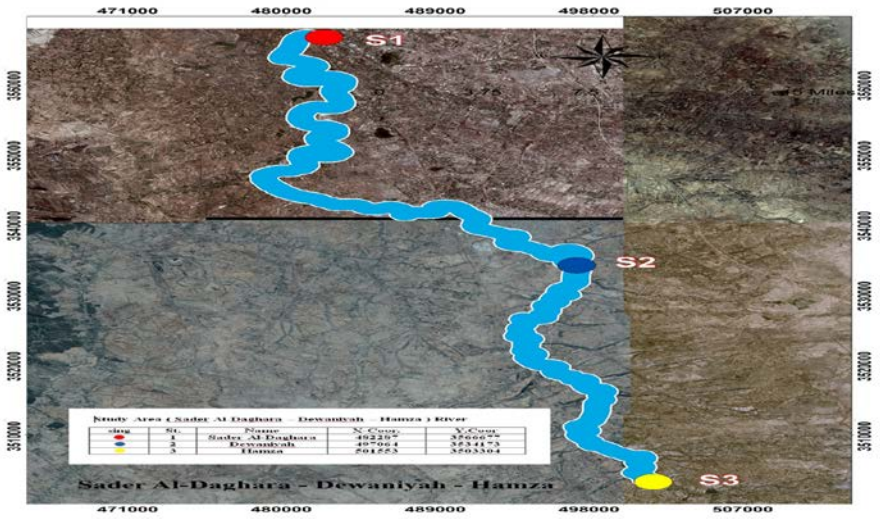

Figure 1: The examined stations at Al-Diwaniyah River, Al-Diwaniyah Province

Table 1: Physicochemical and bacteriological parameters with their methods

Parameter	Method name or device name
Temperature	Portable electronic thermometer HM Digital instruments (TDS-3)
pH	Portable pH meter HM Digital instruments (pH-80)
EC	Portable conductivity meter HM Digital instruments (EC-3)
TDS	Portable TDS meter HM Digital instruments (TDS-3)
TSS	Weighting a standard glass-fiber filter
Turbidity	Turbidity meter Hanna instruments (LP 2000)
Alkalinity	Titration by H2SO4
Hardness	Titration by EDTA
Calcium	Titration by EDTA
Magnesium	Calculation method : Mg = (TH-(Ca*2.497))*(4.118)^-1
DO	Azide modification
BOD	5-Day BOD test
Chloride	Mercuric Nitrate method
Sulfate	The turbidimetric method with LaMotte turbidimeter (2020 wi)
Lead	Flame Atomic Absorption Spectrophotometer Shimadzu instruments
Total Coliform	Standard Total Coliform Fermentation Technique
Escherichia coli	Escherichia coli Fermentation Technique method

3. Results and Discussions

Table (2) presents the (mean) value of the seventeen examined parameters and standards.

Table 2: Iraqi and general standards

Parameter	Mean	River Maintenance	Drinking	Irrigation	Living aquatic
Water temperature (°C)	23.48	-	- -		25 – 35#
pH	7.93	6.5 – 8.5	6.5 – 8.5*	6.5 – 8.4**	6.5 – 9.0#
EC (µs/cm)	1159.24	-	2500****	3000**	-
TDS (mg/L)	752.92	-	1000*	-	1500#
TSS(mg/L)	13.63	-	-	-	-
Turbidity (NTU)	13.71	-	5*	-	45#
Alkalinity (mg/L)	151.55	-	100***	-	-
Hardness (mg/L)	450.24	-	500**	-	500**
Ca (mg/L)	106.66	-	150**	-	-
Mg (mg/L)	44.6	-	100**	-	-
DO (mg/L)	7.9	> 5	-	-	5.5 – 39#
BOD5 (mg/L)	3.49	5	3**	-	5***
Cl (mg/L)	119.88	200	250**	100##	250#
SO_4 (mg/L)	258.3	200	200*	-	-
Pb (mg/L)	0.0079	0.05	0.01*	0.2##	0.007#
Total Coliform (MPN/100 ml)	1331	-	0****	-	-
E. coli (MPN/100 ml)	407.85	-	0****	-	-

*[13]; **[14]; ***[8]; ***[9]; ****[10]; ##[11]; #[12]; **[16].

I. Water Temperature

The temperature has an influence on so many aquatic variables and processes in rivers water. It was varied from 15°C to 31°C for all stations during the study period with an average of 23.48°C. Figure 2 shows the distribution of water temperatures at the studied stations.

II. pH Value

The value of pH is one of the most important indicators of water quality in rivers [5]. The pH for the three sites ranged from 7.3 to 8.3 with a mean value 7.93, which shows slightly alkaline water in the river. Figure 3 shows that all the three sites are usable for drinking, aquatic life, and irrigation. Also, they did not exceed the limits of [12], [13] and [16].

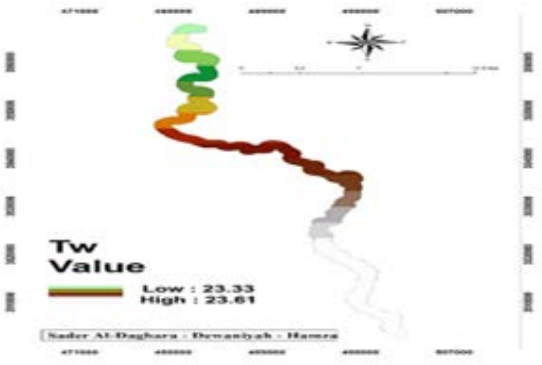

Figure 2: Average temperature water values

Figure 3: Average pH values

III. Electric Conductivity and Total Dissolved Solids

Both of electrical conductivity (EC) and total dissolved salts (TDS) refer to the salinity of the water. The amounts of electrical conductivity ranged between 998 µs/cm and 1380 µs/cm with a mean value of 1159.24 µs/cm. TDS values ranged from 620 to 932 mg/L with a mean value of 752.92 mg/L shown in Figures 4 and 5 respectively. There is no excess of permissible limits for EC and TDS according to [9] and [13] regarding the validity of drinking water. High values of EC and TDS indicate the discharge of sewage to the river from an inefficient wastewater treatment plant. The linear relationship between TDS and EC was linked using the SPSS statistical program as shown in the following equation:

TDS = 42.769 + 0.613 EC

IV. Turbidity and Total Suspended Solids

The turbidity parameter indicates water clarity. Increasing the suspended solids in water reduces the amount of light falling into the river until darkness appears. This is one of the reasons for increasing the turbidity of water. Turbidity amount ranged from 1.50 to 35.20 NTU with a mean value of 13.71 NTU. On the other hand, TSS values ranged from 2 mg/L to 28 mg/L with a mean amount of 13.63 mg/L as shown in Figures 6 and 7 respectively. Based on [13], turbidity in Al-Diwaniyah River was not acceptable. Nevertheless, according to [12], aquatic organisms are not affected within the limits of this turbidity. The main reason for the presence of turbidity and TSS in the river is to bring sewage to the river from the wastewater treatment plant.

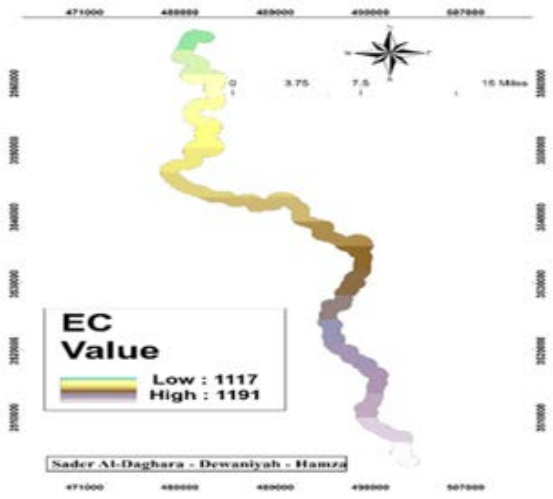

Figure 4: Average EC values

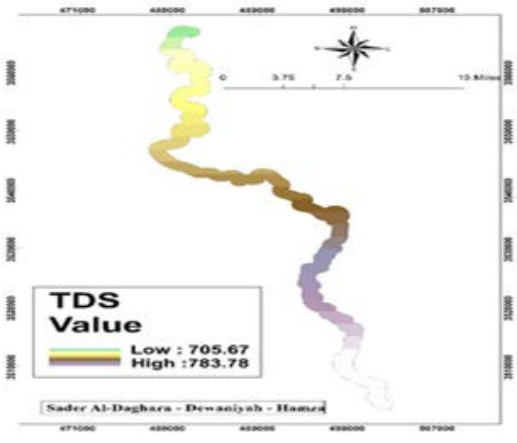

Figure 5: Average TDS values

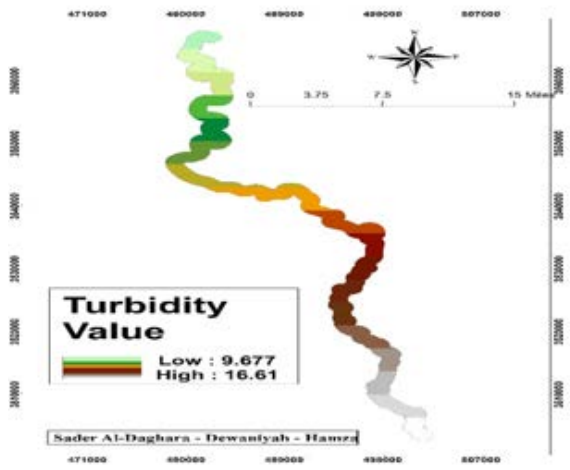

Figure 6: Average Turbidity values

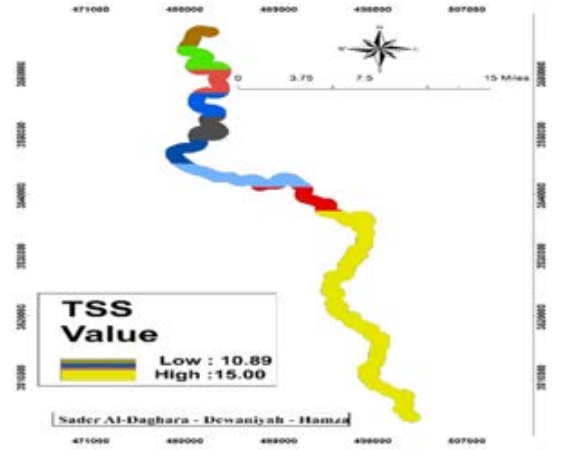

Figure 7: Average TSS values

V. Cations (Ca, Mg), Total Hardness

According to the guidelines for classification of hardness water; "(0 – 60) mg/L is classified as soft; (61 – 120) mg/L as moderately hard; (121 – 180) mg/L as hard and more than 180 mg/L as very hard" [6]. Thus, water in Al-Diwaniyah River is classified as a very hard water as shown in Figure 8. The results of total hardness for all stations varied from 384 to 531 mg/L with a mean value of 450.24 mg/L as shown in Table 2. Most of the calcium concentrations of the stations were within the limits of the criteria listed in Table 2 except for some of the June readings. The reason was due to high temperatures and low water level. The maximum value was 175 mg/L and the minimum value was 71 mg/L with a mean value of 106.66 mg/L as shown in Figure 9. In addition, Figure 10 presents that the concentrations of magnesium in all sites of this work are within the limits of Iraqis Standards. The values of Mg varied from 21 to 67 mg/L with an average value of 44.6 mg/l. More known metals that cause more water hardness are magnesium and calcium dissolved in water [18].

VI. Anions (Cl, SO_4)

All sites of Al-Diwaniyah River for Cl concentrations were within the Iraqi drinking water Standard (2009) for CCME for aquatic life (2007), which is represented in Figure 11. The concentrations varied from 101 to 167 mg/L with an average value of 119.88 mg/L. Most of the readings in Al-Diwaniyah River had SO_4 concentrations exceeding the limits of the Iraqi drinking water Standard (2001) as shown in Figure 12. However, they did not go beyond the limits set provided by [10]. The highest value of SO_4 was 339 mg/L, the lowest value was 152 mg/L, and the mean concentration is 258.3 mg/L. The difference between the values of sulphate concentrations of the three stations was close, as were the concentrations of chlorides. The main reason for the concentrations of sulphates and chlorides in this river is to discharge sewage to the river from the wastewater treatment plant.

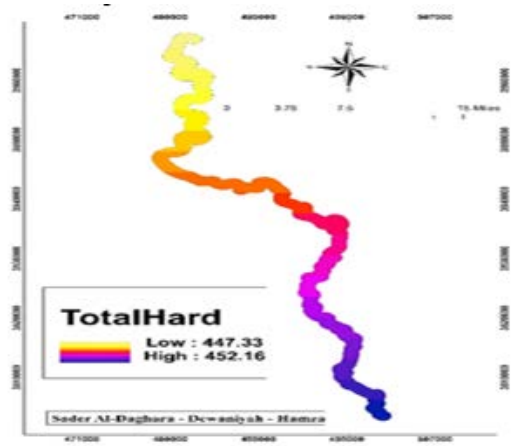

Figure 8: Average TH values

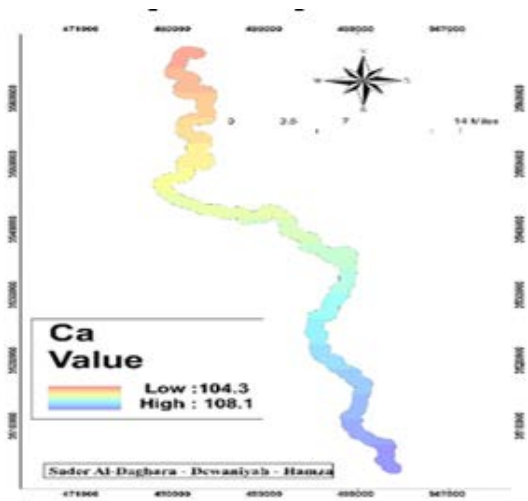

Figure 9: Average Ca values

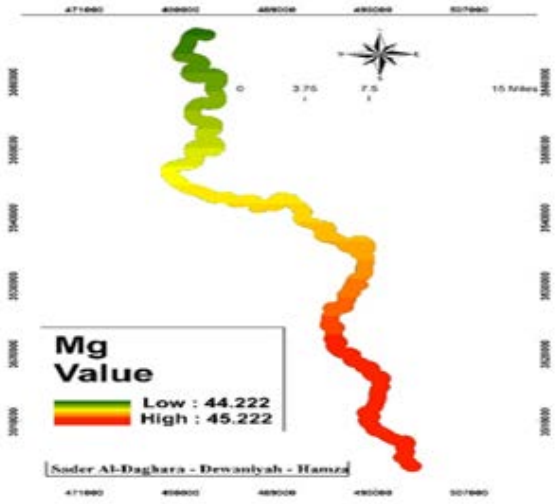

Figure 10: Average Mg values

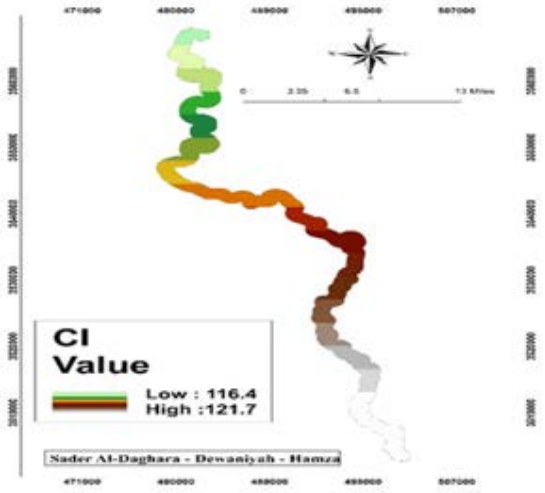

Figure 11: Average Cl values

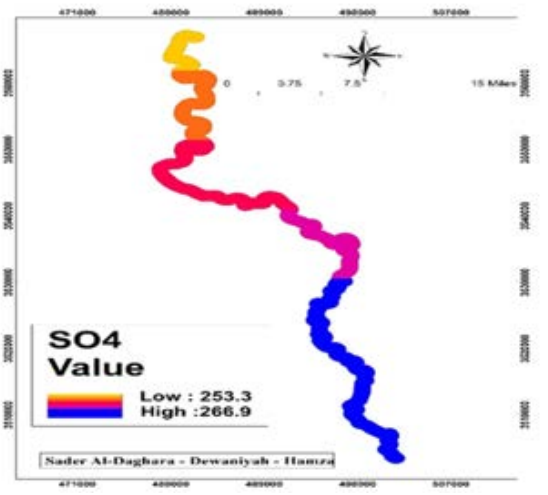

Figure 12: Average SO_4 values

VII. Alkalinity

The alkalinity of river water reflects the content in that water of bicarbonates, carbonates, and hydroxide. The values in the three sites vary from 124 to 176 mg/L and the mean value was 151.55 mg/L as shown in Table 2. These values are considered unacceptable for drinking water based on [9]. These values are represented in Figure 13. Sewage discharged to the river from the wastewater treatment plant contains high salts, which are in the form of bicarbonates and carbonates. This is the main cause of the high alkalinity values in this river.

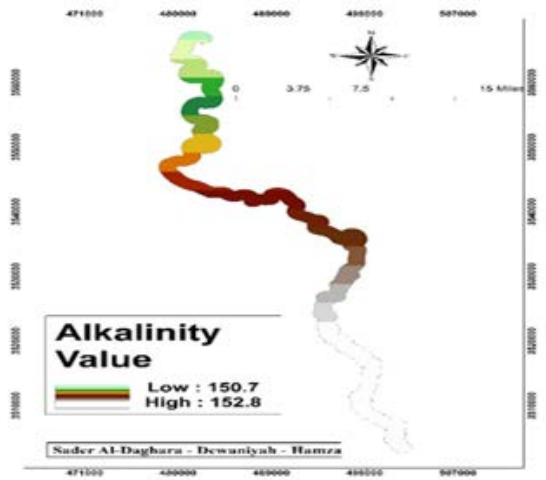

Figure 13: Average Alkalinity values

VIII. Dissolved Oxygen & Biochemical Oxygen Demand

Lack of water content of dissolved oxygen indicates contamination of water as it is the main element of aquatic survival. On the other hand, BOD_5 measurement is an indicator of the extent of water contamination with organic waste. The increase in BOD_5 values is followed by a reduction in DO values in water. DO values ranged from 6.3 to 10.1 mg/L in all tested stations with a 7.9 mg/L (average value) as shown in Table 2. It is observed that the highest values of dissolved oxygen were recorded in winter months due to the mixing processes that followed the rainfall. As shown in Figure 14, the DO values are among the criteria for System Maintenance of River and public water pollution in Iraq (2001) and are also within the permissible of aquatic life according to CCME (2007). While BOD_5 values ranged from 0.6 to 6.7 mg/L with an average value of 6.7 mg/L. The highest values of BOD_5 were recorded in Station 2 due to the pollution caused by the wastewater discharged from the wastewater treatment plant to the river directly without complete treatment. Some high values were also recorded at station 3 due to the discharge of sewage to the river by the

inhabitants of those areas. Figure 15 shows the distribution of BOD ranges of AL-Diwaniyah River.

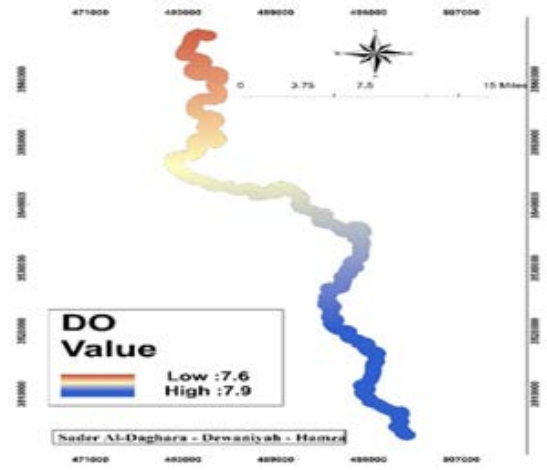

Figure 14: Average DO values

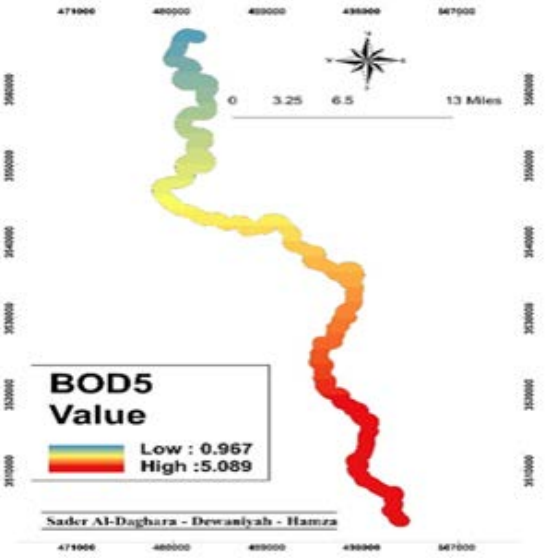

Figure 15: Average BOD_5 values

IX. Lead (Pb)

Lead is considered as a heavy toxic element that has a negative impact on living organisms. The average concentration of Pb in AL-Diwaniyah River was 0.0079 mg/L. The lowest and highest values were 0.001 and 0.017 mg/L respectively. The highest values that exceeding the Permissible of the [13] were recorded in station 2. This is due to the offerings that are placed directly to the river containing many lead compounds. Figure 16 shows the distribution of lead ranges along the Diwaniyah River.

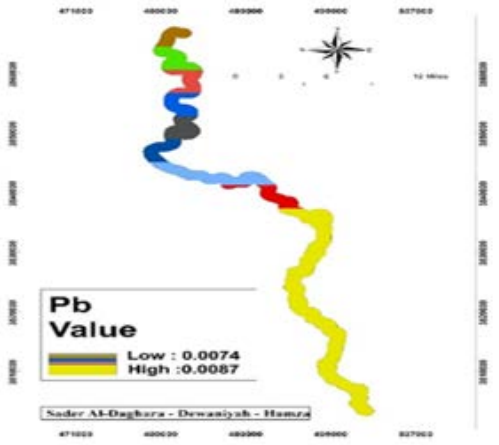

Figure 16: Average Pb values

X. Total Coliform and Escherichia coli bacteria

Coliform and Escherichia coli bacteria presence in the river waters is an indication of sewage (fecal) pollution. Total coliform values ranged from 500 to >1600 MPN/100 ml with an average value of 1331 MPN/100 ml. Figure 17 shows the distribution of total coliform bacteria along the river. Similarly, the highest value of Escherichia coli bacteria was in station 2. This is due to the untreated water being discharged from the wastewater treatment plant to the river. The values at station 3 were also high but less than station 2. This is due to the direct disposal of sewage by some areas to the river and the existence of some animals, such as cows, in the river which directly defecates in it. E coli values ranged from 30 to 1600 MPN/100 ml. In general, the values of Total Coliform and Escherichia coli bacteria were higher in the summer months due to high temperature. This is one of the reasons for increasing the activities of these types of bacteria. Figure 18 illustrates the distribution of E. coli bacteria along the river.

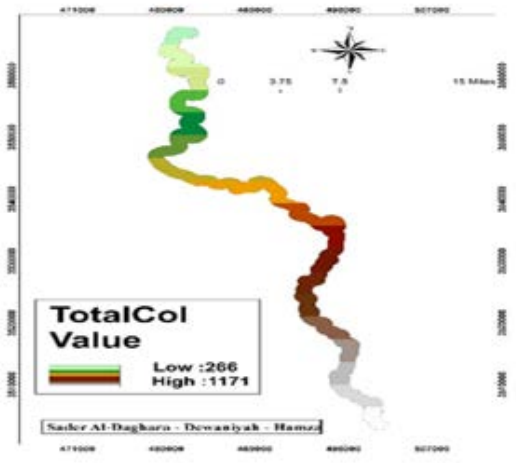

Figure 17: Average Total Coliform values

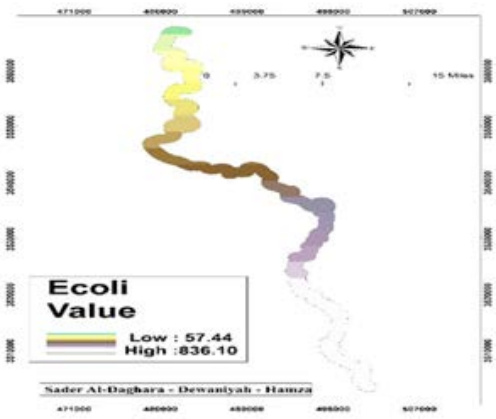

Figure 18: Average E. coli values

4. Conclusion

1. All stations in Al-Diwaniyah River are among the specific drinking water standards of WHO (2004) except alkalinity. While, according to [10], total coliform and Escherichia coli bacteria were out permissible limits.
2. The sites meet the Iraqi Drinking-Water Standard (QS: 417) [13], except the turbidity, TC, E. coli, sulfate and BOD.
3. According to [12], all samples were within the limits except lead. On the other hand, only the chloride was exceeding the limit of [11].
4. Referred to Ayers & Westcot standard (1985) for irrigation use, there is no parameter exceeds the limits.
5. Most of the water in Al-Diwaniyah River is very hard.
6. The water of the river is slightly alkaline according to the results obtained for pH values.
7. The results revealed that station 2, which was located only a short distance from the site of the wastewater treatment plant, was more polluted than the other two stations according to the total coliform and E. coli bacteria values.
8. According to the results, the water of the river is neither suitable for drinking, nor suitable for swimming according to the high bacterial pollution in addition to the danger and threat to aquatic life, but can be used for irrigation purposes.

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