MATEC Web of Conferences **162**, 05005 (2018) https://doi.org/10.1051/matecconf/201816205005
BCEE3-2017

Assessment study of water quality index (WQI) for Shatt Al-arab River and its branches, Iraq

Ahmed Hamdan[1, *], *Ammar* Dawood[1], and *Douaa* Naeem[1]

[1]College of Engineering, University of Basrah, Basrah, Iraq

Abstract. Shatt Al-Arab River (in Basrah province South of Iraq) is approximately 192 km long. It plays a key role in providing water for domestic purposes, irrigation, manufacturing, in addition to shipment. Recently the river suffers from increasing pollution, due to wastes from industries, domestic sewage and agricultural activities that find their way into water sources and result in large scale deterioration of water quality. Investigating the river size and significance, becomes necessary to perform a study to understand the water quality of this river that is considered by some experts as one of the most contaminated in Iraq. This work uses the Water Quality Index (WQI) to describe the pollution level of the river and by using Geographic Information System (GIS) to create WQI map. This study also determines the critical pollutants affecting the river water quality throughout its course. WQI has been formulated making use of several water quality parameters such as pH, temperature, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Nitrate (NO3-2), Phosphate (PO4-3), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Turbidity (Tur), and Electrical Conductivity (E.C) which were measured at 37 sites along the river. Bad water quality was observed at the sites of the river branches, near the center of Basrah governorate. Furthermore, it was discovered that the main reason for river pollution was due to the high sewage water discharged into the river, especially river branches and illegal discharges of industrial effluent and sewage.

1 Introduction

Rivers are regarded as one of the main resources for supplying water for different purposes, such as for drinking, agricultural and industrial uses. Additionally, these resources are employed at some place for discharge of industrial wastewater, sewage, and additionally agricultural drainage[1].

Conventional reports on water quality are usually too detailed and technical, confronting monitoring data on single water quality variables, without supplying a comprehensive assessment of the water quality. To meet this gap, different water quality indices (WQIs) have been formulated to integrate water quality variables [2]. The WQI is regarded to be considered as one criterion for the classifications of surface water, on the basis of the usage of standard parameters for water evaluation and characterization[3]. The results associated with the WQI enable the classification of water for the objective of numerous uses and supply a benchmark for assessing administration strategies [4]. The WQI is a number that is certainly unitless ranging between 0 and 100 with the higher value, suggesting higher quality of water [5].
WQI regarded to be considered as one criterion for the classifications of surface water, on the basis of the usage of standard parameters for water evaluation and characterization.

In Iraq, social and industrial advancements replaced the qualitative attributes of the river water and contributed to increased pollution that is excessive.

The main objectives of this study are to assess the physicochemical properties of the river water, to determine the water quality of the Shatt Al -Arab River and the main branches depending on WQI, to create WQI map based on Geographic Information System (GIS) and to gatherknowledge of the resources of pollutants discharged into the river so that it can suggest the concern of actions that should be supposed by the local authority.

2 Study area

The Shatt Al-Arab river is formed by the confluence of the Tigris and the Euphrates Rivers at Qurna town located in the southern part of Iraq (Fig.1), then it discharges its water to the Arabian Gulf, with a total length of about 192 km. There are many branches affected by Shatt Al-Arab River during tide and ebb cases due to wedge intrusion from Arabian gulf, the

* Corresponding author: ahmed_n_ahmed2005@yahoo.com

main branches of which are Al Saraji, Al Khora, Al Ashar, Al khandaq, Al Ribat, Al Mufteah and Al Jubailah (see Fig. 2). The study area in this research includes the region between the confluence of Tigris and Euphrates Rivers and to a distance of about 5 km downstream of Basrah center.

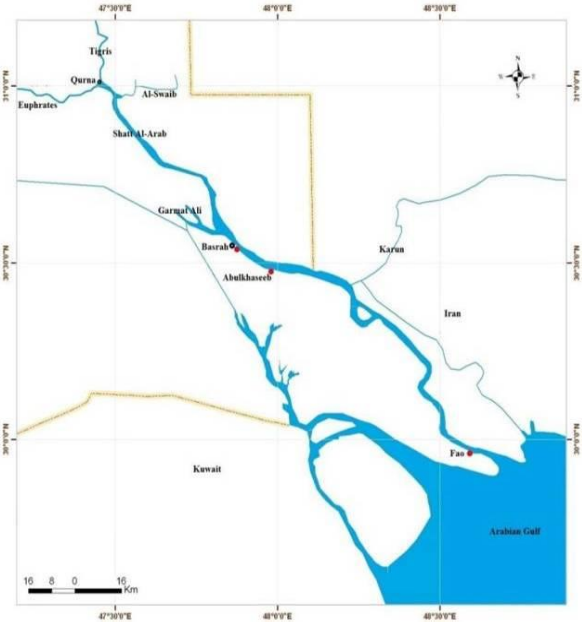

Fig. 1. Study area

Fig.2. Shatt Al-Arab River branches

3 Collection of samples and analysis procedures

The sampling of physical, chemical and biological parameters was performed for thirty-seven sites along Shatt Al-Arab River and its branches in December, 2016 (see Fig.3 and Fig.4).

The environment parameters surveyed included pH, water temperature (T), Total Dissolved Solids (TDS), turbidity (Tur), Electrical Conductivity (EC), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), phosphate (PO_4^{-3}), and nitrate (NO_3^{-2}).

Some of water parameters were measured directly at site such as temperature, pH, TDS, EC, DO and turbidity, for the rest, samples were collected in polyethylene bottles of 1.5 liter volume, and kept in the cool box until transportation to the laboratory for the tests by using the method illustrated by (APHA, 2005; Ell-Amin et al., 2012), [6].

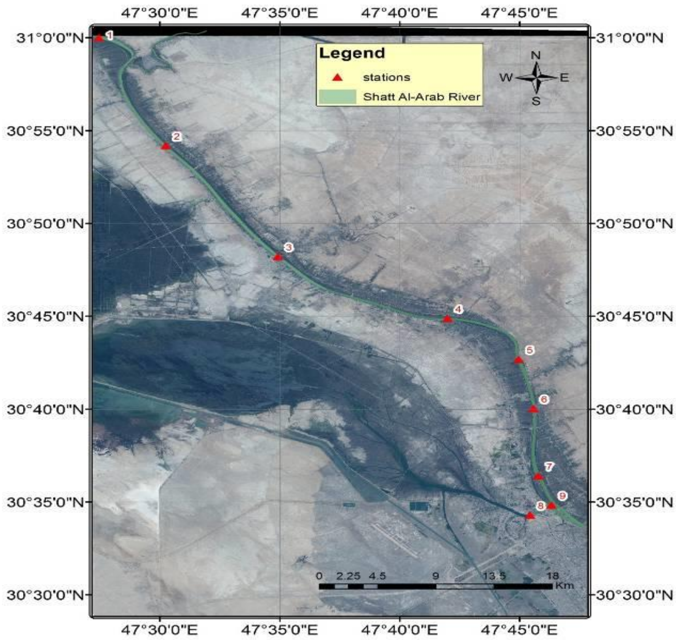

Fig. 3: Water sampling locations in the Shatt Al-Arab River in the upper direction

https://doi.org/10.1051/matecconf/201816205005

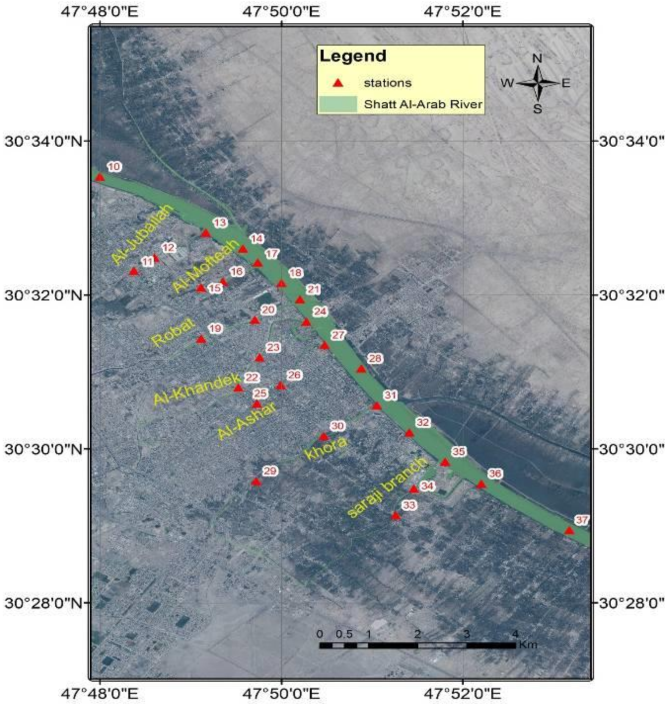

Fig. 4: Water sampling locations in the Shatt Al-Arab River and its branches in the lower direction

Physicochemical analyses were performed at the University of Basrah and Basrah Environment Directorate following the standard and recommended methods (APHA 2005). pH, water temperature were measured on site using a pH meter type (SD 300), DO test was measured at site by using a membrane electrode (DO meter type Lovibond (Oxi 200)), turbidity test was carried out at the site by using device of type Lovibond (TB 300 IR), TDS and EC, were measured at site using UBANTE device. The BOD_5 test was measured in the laboratory, based on five days incubation at 20°C, COD test was carried out in the laboratory using device type Lovibond (RD 125). In addition, NO_3^{-2} and PO_4^{-3} were tested in laboratory according to the standards methods [6].

4 Water quality index (WQI)

There are different indices which tend to be appropriate for water quality indices. Among these indices is National Sanitation Foundation Water Quality Index (NSFWQI). NSFWQI had been chosen due to its high accuracy, simplicity and accessibility to the parameters that are required [7]. The index of water quality calculated by NSFWQI is one of the most extensively used indicators which includes primary parameters such as pH, water temperature, DO, NO_3^{-2}, PO_4^{-3}, BOD_5, TDS, and turbidity. NSFWQI is obtained by the sum of multiplication of W_i by I_i, [8].

$$\text{NSFWQI} = \sum \text{Wi Ii} \quad ....(1)$$

In this equation, Ii is the quality of the ith parameter (a number between 0 and 100 read from the appropriate subindex graph) and Wi is the weight factor of the ith parameter. After measuring the above characteristics, the sub-index of each of them is obtained from conversion curves (Wilcox Standard Graphs)[9], as shown in Figs.(5-12), these curves convert the parameters into measures that range from 0 to 100. To calculate the final index in this method, each sub-index obtained from the related curves is multiplied by the weight factor (as shown in Table 1), and the final index is obtained by summing them, according to Equation 1. Classification of river pollution intensity and water description according to NSFWQI are presented in Table 2[10].

Table (1): weighing factors of water quality parameters

Parameters	Weight factor
DO	0.17
BOD_5	0.11
pH	0.11
Nitrate	0.10
Phosphate	0.10
Temperature	0.10
Turbidity	0.08
Total Dissolved Solid	0.07

Table 2. Water quality index (WQI) legend

Range	Class	Quality
91-100	A	Excellent
71-90	B	Good
51-70	C	Medium
26-50	D	Bad
0-25	E	Very Bad

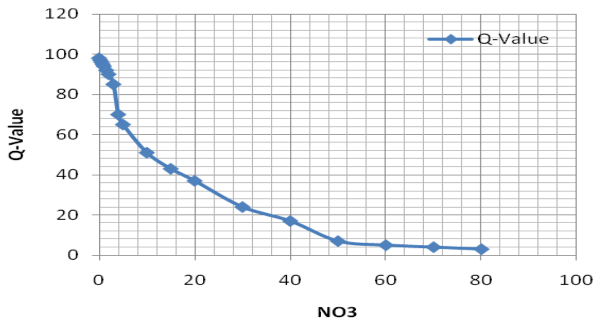

Fig 5: Relation between nitrate and Q-Value

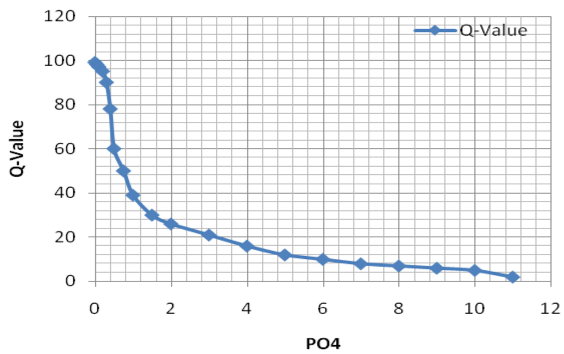

Fig 6: Relation between Phosphate and Q-Value

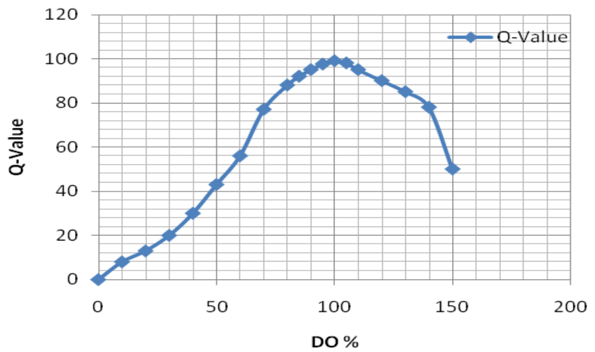

Fig 7: Relation between DO and Q-Value

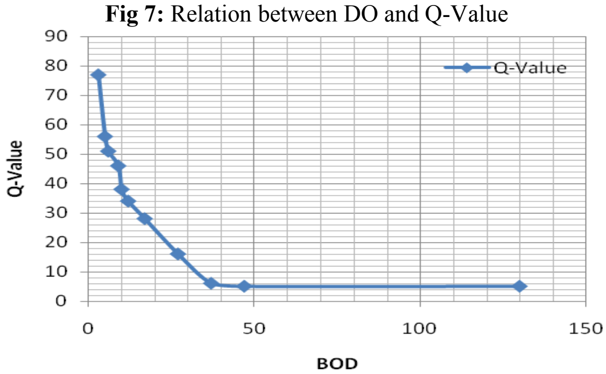

Fig 8: Relation between BOD5 and Q-Value

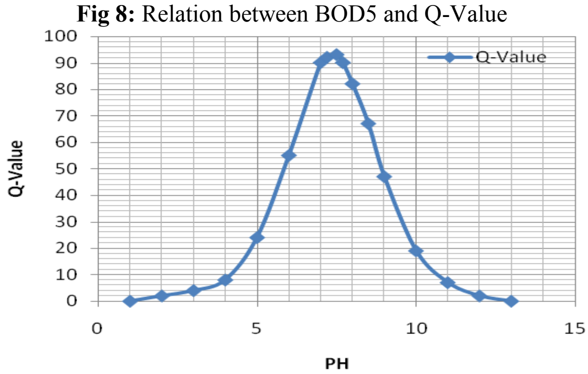

Fig 9: Relation between PH and Q-Value

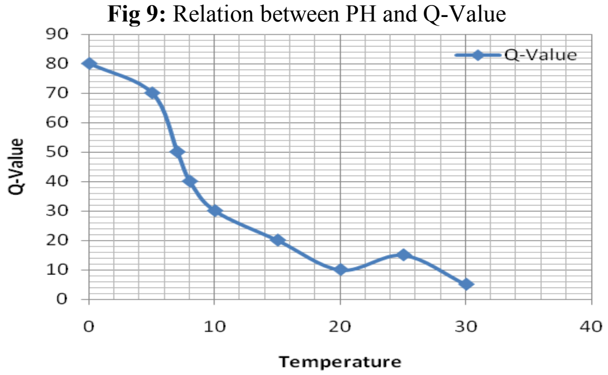

Fig 10: Relation between Temprature and Q-Value

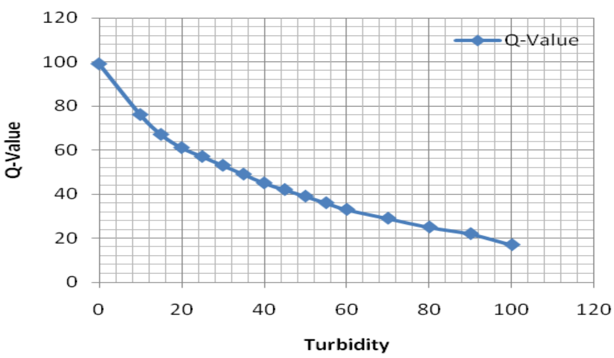

Fig 11: Relation between Turbidity and Q-Value

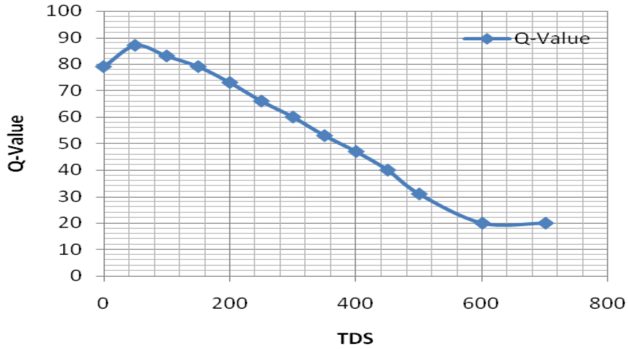

Fig 12: Relation between TDS and Q-Value

5 Results and discussion

The descriptive statistics of the parameters of the studied sites in the Shatt Al-Arab River and its branches are shown in Table 3.

Table 3. Descriptive statistics for study area's parameters

Parameter	Min.	Max.	Mean	Std. Deviation
T (C°)	13.40	22.70	16.78	2.12
DO (mg/l)	4.71	9.85	7.64	1.43
EC (µs/cm)	1375.00	7718.00	3721.22	1325.63
pH	6.90	8.15	7.60	0.28
TDS (mg/l)	805.00	3859.00	1956.27	630.50
TSS (mg/l)	48.00	974.00	365.95	266.10
NO_3 (mg/l)	1.56	10.24	3.97	1.98
PO_4 (mg/l)	0.25	2.47	0.712	0.55
BOD (mg/l)	3.00	123.00	30.06	32.84
COD (mg/l)	12.90	546.00	112.71	126.57
Tur (NTU)	8.83	206.00	34.75	44.15
WQI	41.00	71.00	58.7838	9.88

The water temperature values in this study varied from the lowest value equal to 13.4 °C at site 1 and the highest value which was 22.7 °C at site 19. It also showed a high temperature beside the industry locations such as Paper mill factory (beside site 4 where the temperature was 20.2°C) and Al Hartha Power Station (located in Hartha region 10 km upstream of Basrah governorate, in the middle distance between sites 5 and 6, where the temperature exceeds 21 °C), where this station withdraws water from Shatt Al-Arab River and uses it for refrigerating the power station plant, after some RO treatments, the wastewater, at high temperature, is discharged back into Shatt Al Arab River that leads to an increase in the river water temperature near this site.

Generally, optimal pH range for sustainable aquatic life is pH 6.5-8.5. pH of an aquatic system is an important indicator of the water quality and the extent of pollution in the watershed areas. The maximum pH value for the water samples was 8.15 which was recorded at site 5 while the minimum was 6.9 which was recorded at site

11, this range indicates that water is slightly alkaline. All water samples were within the permissible limits prescribed by (WHO standards for drinking water in 2004) [12], EEC 464/76 standards for surface water quality [13] and Iraqi standards for water quality in 1998 (as shown in Table. 4).

Table 4: Comparison between water quality parameters for Iraqi and international standards

Parameter	WHO standards for drinking water in 2004	EEC 464/76 standard for surface water Quality Tebbutt,1997	Iraqi standards for water quality in 1998
TDS, mg/l	500-1500	500-1500	1000
Turbidity,NTU	0-50	0-25	25
pH	6.5- 8.5	6.5- 8.5	6.5- 8.5
DO, mg/l	> 5	> 5	> 5
BOD_5, mg/L	<3	< 5	<3
COD, mg/l	10		
NO_3^{-2}, mg/l	0 – 45	0 – 40	25-50
PO_4^{-3}, mg/l	0.1	0.4	0.4

DO, BOD_5, and COD had been tested in this research which tend to be an indicator of organic pollutants.

In this study it was shown the lowest value of DO recorded was at site 31 which was 4.71 mg/l that may be assigned to raw sewage discharge and highest value was 9.85 mg/l at site 2. The concentration of dissolved oxygen increases when the temperature decreases because the fact that the levels of oxygen saturation are temperature dependent, the average DO concentration in the river is 7.64 mg/l. Furthermore, the key factor that is main in contributing to changes in the level of DO may be the accumulation of organic wastes. Apart from the other parameters, the lower the DO concentration the poorer the water quality. When the DO concentration is less than 2 mg/L, it indicates that the river water is not safe.

The obtained BOD_5 data showed that the maximum value was recorded at site 29 which was 123 mg/L and minimum value which was 3 mg/l at site 8, from whole area of study it can be shown that all the sites the water quality parameter is beyond the range of WHO standards, and Iraqi standards, as well as most of the water samples were beyond the range of EEC 464/76 standards, the areas of high dangerwere in all branches, the high BOD_5 value was probably linked to the level of organic matter load from sewage, industrial or urban discharges.

The obtained COD data showed that the maximum value was recorded at site 29 which was 546 mg/L and minimum value which was 12.9 mg/l at site 24, From the whole area of study it can be shown that all the sites were beyond the range of WHO, EEC 464/76 standards and Iraqi standards, and the areas of high danger were in all branches.

The lowest value of TDS which was 805 mg/l was shown at site 1, and the highest value was 3859 mg/l which was shown at site 29. Generally the highest values of TDS were in branches.The high value of TDS recorded could be related to the increase in the load of soluble salts, increase in the urban and fertilizer runoff, wastewater, septic effluent, decaying plants, and erosion of river banks. Hence, it was shown that a decrease of TDS in upstream is due to a decrease in the effect of saline wedge intrusion from Arabian gulf and the sources of pollution.

Being an important factor that limits growth, phosphorus has been focused on studies that deal with water quality assessement. The obtained $PO4^{-3}$ data showed that the maximum value was recorded at site 29 which was 2.47 mg/L and minimum value which was 0.25 mg/l in site 6. From the whole area of study it can be shown that all sites exceed the maximum limits for $PO4^{-3}$ as per the WHO standards, but as per the EEC 464/76 standards and Iraqi standards most of the samples which were downstream of site 10 exceeded the limit. Increasing levels of $PO4^{-3}$ in Shatt Al-Arab River may be due to high concentration of detergents in sewage, in addition to the high density of agricultural areas, where phosphate fertilizers were used. That might be the cause of high concentrations of phosphate. High levels of phosphorus in nature can create algal blooms causing eutrophication or the premature "aging" of a water body. This process decreases sunlight and oxygen levels (hypoxia) thus, affecting fish and other aquatic life.

The obtained NO_3^{-2} data showed that the maximum value was recorded at site 29 which was 10.24 mg/l and minimum value which was 1.56 mg/l at site 7. From whole area of study, it can be shown that all sites had acceptable values for NO_3^{-2} as per WHO standards for drinking water in 2004, EEC 464/76 standards for surface water quality (Tebbutt, 1998) and Iraqi standards for water quality in 1998.

The highest value of turbidity recorded was 206 NTU, which was recorded in site 23. While the lowest value of turbidity was 8.83 NTU which was recorded at site 16. In the main channel of the river, turbidity was shown to be within the acceptable limits of standards and the highest values of turbidity was shown in branches of the river, especially in Al Khora, Al Ashar, and Al Khandek. This is due to the effect of banks erosions, domestic wastewater discharge , and appearance of phytoplankton. These branches showed the excess limits of standards.

Final WQI map of the river was prepared using Geographic Information System (GIS) and by using Inverse Distance Weighted (IDW) interpolation technique and presented in Fig.13 and 14, the observed range of WQI was 41–71 for Shatt Al-Arab River and

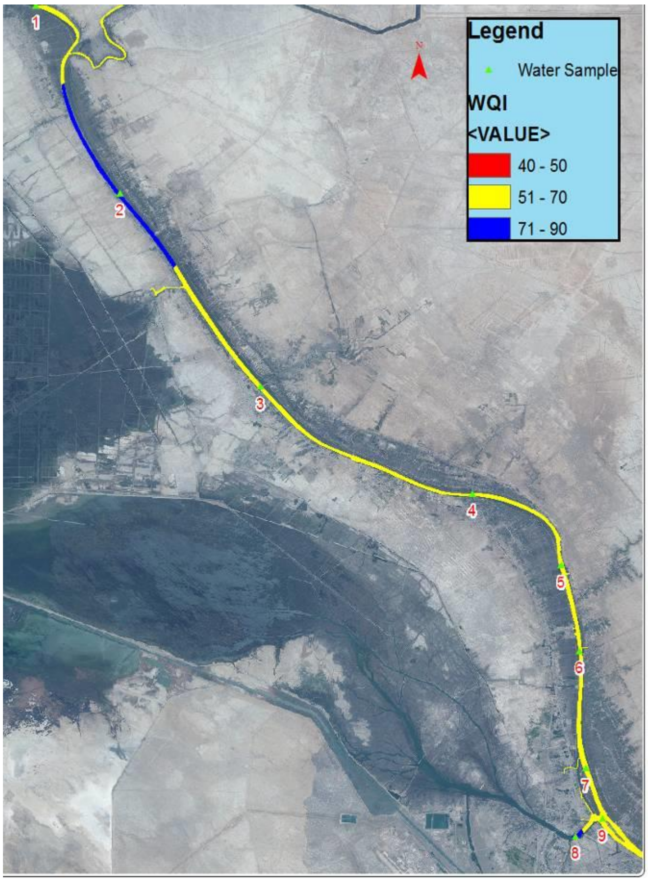

Fig. 13. WQI in the upper side of Shatt Al-Arab River

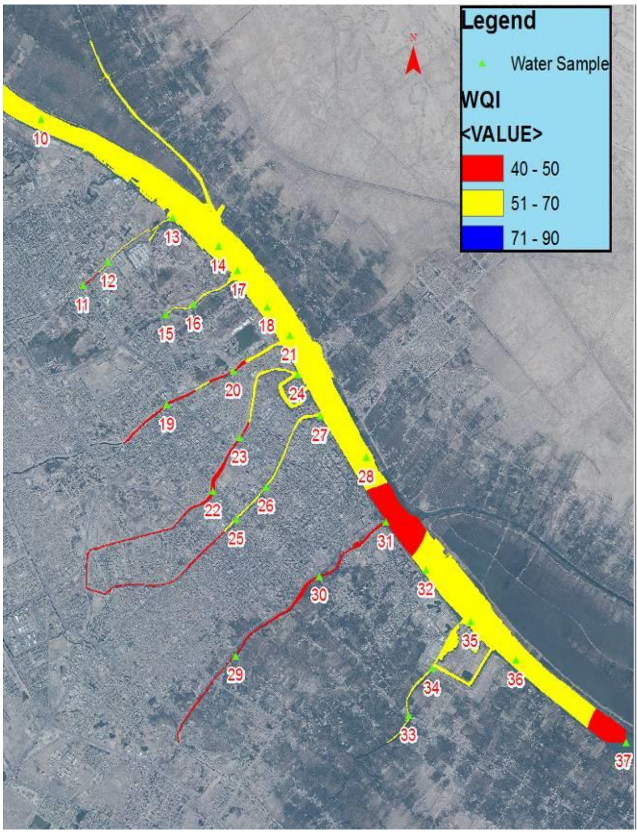

Fig. 14. WQI in the lower side of Shatt Al-Arab River and its branches

its branches and ranged between Bad and Good (as shown in Table 5). The WQI distribution map shows that the water of Shatt Al-Arab River was medium in most sites of the main channel, and bad in the Al-Ribat, Al-Khandaq, Al-Ashar and Al-Khora branches. The deterioration of water quality was mainly due to the input of municipal and industrial wastes and/or agricultural activities discharge at the bank of the river (especially in branches). It is also noticed that the quantity of impurities get diluted when branches poured into the main river and it becomes medium water quality. According to calculations, the highest mean effective weights value belongs to DO and pH parameters with 27.63% and 20.76%, respectively and these parameters are the most effective parameters in the WQI calculations.

6 Conclusions

The water quality of Shatt Al-Arab River was evaluated based on the water quality analysis data for December in 2016. The main conclusions are as follows:

- Results from this work presented that water quality of the Shatt Al-Arab River was generally influenced by the activities that occur along its watershed. The worst water quality of the river was found at the branches, whereas most of the Shatt Al-Arab River water quality was medium.
- The deterioration of water quality is mainly due to the input of municipal and industrial wastes and/or agricultural activities discharge at the bank of the river (especially in branches).
- The highest mean effective weights value belongs to DO and pH parameters with 27.63% and 20.76%, respectively and these parameters are the most effective parameters in the WQI calculations.
- It can also be concluded that WQI is an effective tool for classifying the water of the river for its different beneficial uses and gives an accurate idea about the pollution load in the Shatt Al-Arab River.
- The results revealed that GIS was a good and efficient technique to create WQI map and to give an expected picture to help the decision maker to take the appropriate actions to improve the river water quality.

References

1. C. G. Cude, JAWRA Journal of the American Water Resources Association, Oregon water

quality index a tool for evaluating water quality management effectiveness. 37(1): 125-137 (2001)

2. S. M. Liou, S. L. Lo, et al., Environmental Monitoring and Assessment. A generalized water quality index for Taiwan, 96(1): 35-52 (2004)
3. A. Said, D. K. Stevens, et al., Environmental management. An innovative index for evaluating water quality in streams, 34(3): 406-414 (2004)
4. A. A.Bordalo, R. Teixeira, and W. J. Wiebe, Environmental Management. A water quality index applied to an international shared river basin: The case of the Douro River, 38, 910–920 (2006)
5. P. Debels, R. Figueroa, R. Urrutla, R. Barra, and X. Niell, Environmental Monitoring and Assessment. Evaluation of water quality in the Chillan river (Central Chile) using physicochemical parameters and modified water quality index, 110, 301–322 (2005)
6. APHA, American Water Works Association/ Water Environment Federation, Standard Methods for the Examination of Water and Wastewater, 21st ed, American Public Health Association, Washington, DC, USA, (2005)
7. P. Zandbergen, and K. Hall, Journal of Water Quality. Analysis of the British Columbia Water Quality Index for watershed manager: a case study of two small watersheds, 33, pp. 519–525 (1988)
8. A. Shamsai, S. Urei, and A. Sarang, Journal of Water and Wastewater. Comparative of qualitative indexes and qualitative zoning of Karoon river and Dez river, 16, pp. 88–97 (2006)
9. Pur, S. Ebrahim, Mohammad Zadeh, H. and A. Mohammadi, paper presented at the 4th Iranian Water Resource Management Conference , Qualitative investigation of Zarivar lake water and it's zoning according to OWQI and NSFWQI by GIS, University of Amirkabir, Tehran, Iran (2012)
10. D. Fabiano, S. Santos, B. Altair, M. Sonia, G. Nobre, and J. Maria, Ecological Indicators. Water quality index as a simple indicator of aquaculture effects on aquatic bodies, 8, pp. 476–484 (2008)
11. E. Sanchez, Ecological Indicators. Use of the water Quality index and dissolved oxygen deficit as simple indicators of watershed pollution, 7, pp. 315–328 (2007)
12. World Health Organization. Guidelines for drinking-water quality. Vol. 1, (2004)
13. Tebbutt, Thomas Hugh Yelland, Butterworth-Heinemann. Principles of water quality control, (1997)

Table 5. WQI values and water types of the samples

Sample Num	Longitude	Latitude	WQI	Water type
1	47.841274	30.5224	7	Mediu
2	47.837922	30.5275	7	Good
3	47.836753	30.5323	7	Mediu
4	47.833374	30.5359	6	Mediu
5	47.828996	30.5403	6	Mediu
6	47.826236	30.5433	6	Mediu
7	47.819451	30.5468	6	Mediu
8	47.799987	30.5589	7	Good
9	47.772195	30.5804	6	Mediu
10	47.757204	30.5715	6	Mediu
11	47.763017	30.6066	4	Bad
12	47.759519	30.6672	5	Mediu
13	47.751258	30.7118	6	Mediu
14	47.699864	30.7482	6	Mediu
15	47.582071	30.8036	5	Mediu
16	47.504144	30.9033	6	Mediu
17	47.457534	31.0002	6	Mediu
18	47.857669	30.4914	6	Mediu
19	47.841116	30.5028	4	Bad
20	47.833216	30.5137	4	Bad
21	47.82934	30.5198	6	Mediu
22	47.818594	30.5238	4	Bad
23	47.822561	30.5362	4	Bad
24	47.809999	30.5414	7	Mediu
25	47.88627	30.4824	5	Mediu
26	47.870069	30.4924	5	Mediu
27	47.863405	30.4972	6	Mediu
28	47.856822	30.5035	5	Mediu
29	47.850880	30.5094	4	Bad
30	47.848036	30.5174	4	Bad
31	47.854305	30.4856	4	Bad
32	47.828713	30.4930	5	Mediu
33	47.828853	30.5098	7	Mediu
34	47.825413	30.5132	6	Mediu
35	47.828421	30.5279	6	Mediu
36	47.818544	30.5349	5	Mediu
37	47.806254	30.5385	4	Bad