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

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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 gather knowledge 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
The main branches of which are Al Saraji, Al Khora, Al Ashar, Al khandaq, Al Ribat, Al Muffeah 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.

The environment parameters surveyed included pH, water temperature (T), Total Dissolved Solids (TDS), turbidity (Tur), Electrical Conductivity (EC), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), phosphate (PO₄³⁻), and nitrate (NO₃⁻).

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].

**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).
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 BOD5 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, NO3− and PO4− 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, NO3−, PO4−, BOD5, TDS, and turbidity. NSFWQI is obtained by the sum of multiplication of Wi by Ii, [8].

\[
\text{NSFWQI} = \sum Wi \cdot Ii \quad \text{(1)}
\]

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          |
| BOD₅       | 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
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       |
| NO₃ (mg/l)  | 1.56  | 10.24 | 3.97  | 1.98           |
| PO₄ (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 standar ds 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 |
| BOD₅, mg/L | <3 | <5 | <3 |
| COD, mg/l | 10 |
| NO₃⁻, mg/l | 0–45 | 0–40 | 25–50 |
| PO₄³⁻, mg/l | 0.1 | 0.4 | 0.4 |

DO, BOD₅, 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 BOD₅ 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 danger were in all branches, the high BOD₅ 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 assessment. The obtained PO₄³⁻ 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 PO₄³⁻ 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 PO₄³⁻ 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 phosphates. 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 NO₃⁻ 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 NO₃⁻ 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
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-Asihar 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.

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