Suitability of Surface Water for Drinking purposes in Basrah City Using Water Quality Index (WQI)

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Abstract

The water quality index (WQI) is applying for the integrating the water quality variables into a single number to indicate the overall quality of water. Rivers is one of the essential water resources, the protecting and preserving for the quality of this resource is important and imperative. An evaluation of water characteristics of the Shatt Al Arab River in Basrah city was performed in order to determine the quality of water for drinking usage. In this research, monitoring of variation in the characteristics of water was accomplished by collecting monthly water samples for three years. The water samples from the Shatt Al Arab River is analyzed for eight Physical and chemical parameters such as pH, total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), calcium (Ca), magnesium (Mg), sulphate (SO4) and chloride (Cl) using standard methods. Utilizing the WQI discovered that the water quality of the studied river is ranked between very poor water type and not suitable water for drinking usage category. In the present investigation, the quality of water was revealed that the average of WQI value for the studied years was 318, 337.3 and 456.7, respectively.

Key Words: River, Physical and chemical parameters, Water quality Index, tool.

ملاءمة المياه السطحية لأغراض الشرب في مدينة البصرة باستخدام مؤشر جودة المياه (WQI)

د. أيمن علك حسن

الخلاصة

يعمل مؤشر جودة المياه (WQI) على دمج متغيرات نوعية المياه في رقم واحد للإشـارة إلى الجودة الإجمالية للمياه. الأنهار هي واحدة من الموارد المائية الأسـاسـية، وحماية والحفاظ على نوعية هذا المورد هو أمر حتمي ومهم. تم إجراء تقييم لخصائص مياه نهر شـط العرب في مدينة البصرة من أجل تحديد نوعية المياه المسـتخدمة للشرب. في هذا البحث تم رصد التباين في خصائص المياه عن طريق جمع عينات المياه الشهرية لمدة ثلاث سنوات. تم تحليل عينات المياه من نهر شط العرب لثماني معلمات فيزيائية وكيميائية مثل الرقم الهيدروجيني، المواد الصـلبة الذائبة الكلية، التوصـيل الكهربائي ، العسرـة الكلية ، الكالسـيوم، المغنيسـيوم ، الكبريتات ، والكلوريدات وذلك باستخدام الطرق القياسية للقياس والتحليل. وقد اكتشـف استخدام مؤشر جودة المياه أن نوعية المياه في النهر المدروسة تصنف بين فئة الماء الرديء جدا وفئة الماء الغير مناسب للاسـتخدام للشرب. في هذا البحث، تم الكشـف عن متوسط قيمة نوعية المياه و للسـنوات المدروسة حيث كانت ٣١٨، ٣٣٧,٣ و ٤٥٦,٧، على التوالي.

1. Introduction

Surface water is an essential natural source of water that available all over the world. The fresh water is one of a must issue for humanity since it is straight associated with the human survival and its use in domestic, industrial and irrigation usage. Water quality indices include information from several water quality parameters to put it into a mathematical equation that estimates the suitability of water for human survival with a number [Yogendra, K., & Puttaiah, E. T]. Based on some water quality parameters, Water quality index (WQI) offers a single number that shows overall water quality in time at a certain location. A single number is not adequate to identify the water quality, there are many various other water quality parameters that must be included in the index. Nevertheless, a water

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quality index depending on some essential parameters can provide a very easy indicator of water quality.

In general, water quality refers to the description of physical, chemical, and biological characteristics of water associated with intended uses and a collection of standards [Khalil et al.]. A water quality index is one of the greatest effective tools used to ascertain the quality of water for different purposes. Various water quality indices have been formulated to summarize water quality information in an easily expressible and simply recognized format.

The insufficiency of surface water is a result of point source and non-point source pollution jeopardize the water supply and aquatic ecosystems [Darradi et al.]. The pollution of point source mostly contains discharges of municipal wastewater and the loads of industrial wastewater. Whereas the pollution of non-point source occurs when irrigation water or rainfall, snow melt water runs over the land. Thus, water hauling and transferring pollutants into rivers, coastal waters, and lakes. There is an issue of the pollution of non-point source of agriculture because it is regarded as the major result of the surface water quality degradation [Tang, J. et al.]. WQI reflects the influence that is composite of water quality parameters and it is determined through the perspective for the suitability of human consumption [I.S.Akoteyon et al.]. WQI is extremely efficient method for evaluating the suitability of water quality. It is also invaluable for interacting the information on overall quality of water to the citizen and policy makers. Hence, WQI becomes a significant parameter this is certainly essential in the evaluation and management of quality water.

Assessment of surface water quality and its suitability for human consumption is the aim of the present research by comparing the results against drinking water quality standards laid down by the World Health Organization (WHO). The suitability of surface water for drinking use has been assessed based on computed water quality index values. WQI defines the overall scenario of water bodies by changing the levels of water quality variables into a rating score by making use of mathematical tools.

For the investigation of the water pollution condition of the surface water in the city of Basrah, the following water quality parameters were analysed: (1) pH, (2) Electric Conductivity, (3) Total Dissolved Solids, (4) Total Hardness, (5) Calcium, (6) Magnesium, (7) Sulphate and (8) Chlorides. The determined WQI value ranges between 0 and 300, and categorizes water bodies as excellent (0–50), good (50–100), poor (100–200), very poor (200–300) or unsuitable (more than 300) [Mohebbi, M. R. et al.].

2. Materials and Methods

The water samples from the monitoring station were collected each month for three years started from 2010 to 2012. The collected samples were analysed for 8 physical and chemical parameters by following the standard procedures. The parameters pH, total dissolved solids, and electrical conductivity were monitored at the sampling station and the other parameters were tested and analysed in the laboratory according to techniques as outlined in the standard procedure of APHA [APHA (1995)].

The WQI has been determined using the standards of drinking water quality advised by the World Health Organization (WHO) [8].

3 Study Area

For the present work, Basrah city was selected. Basrah is located in the Shatt Al Arab between Iran and Kuwait. The latitude, longitude coordinates for Basrah city are: 30°31'58.87"N, 47°47'50.89"E. It covers an area of 181 sq.km with an altitude of 5 m above the sea level (see Figure 1).

The main interest to survey this monitoring station in the city is to study the physical and chemical characteristic of the water of the Shatt Al Arab River in that area and to discover how the pollution impact the quality of the Shatt Al Arab River, which indicates in analysis of this research.

4. Analysis of samples

This sampling study for 36 months and one monitoring site were carried and parameters: pH, Electric Conductivity, Total Dissolved Solids, Total Hardness, Calcium, Magnesium, Sulphate and Chlorides. All parameters were examined according to the standard method [APHA (1995)].

5. Drinking water quality

The physical and chemical parameters considered for this study include pH, total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), calcium (Ca), magnesium (Mg), sulphate (SO_4) and chloride (Cl). The evaluation of suitability of the Shatt Al Arab water for drinking purpose was assessed by comparing the studied parameters with the drinking water quality standards as per the WHO (1992) [WHO (1992)] standards for drinking and public health objectives as introduced in Table 1 which shows the summary of the physical and chemical characteristics of the monitoring station and the standard values are as per WHO requirements for the water safe for drinking.

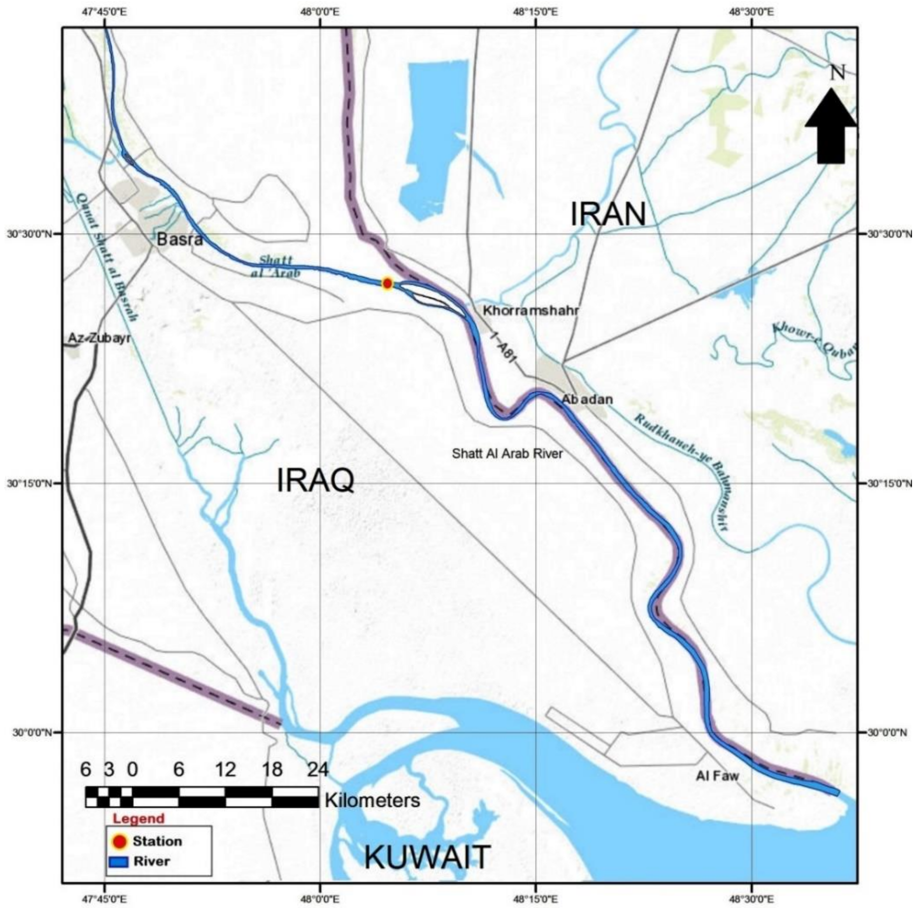

Figure 1: Surface water sampling location in Basrah city

Table 1: Summary of the physical and chemical characteristics of the Shatt Al Arab River water during three years and standard values as per WHO requirements.

Sl. No.	Parameter	Minimum	Maximum	Average	Std.Dev.	Standard Permissible Value (Sn)
1	pH	7.1	8.1	7.634	0.214	8.5
2	Ca ($mg.L^{-1}$)	144.3	504.0	289.061	111.676	75
3	Mg ($mg.L^{-1}$)	240.3	863.0	463.645	153.422	50
4	Total hardness ($mg.L^{-1}$)	381.0	1455.5	763.095	248.139	500
5	SO_4 ($mg.L^{-1}$)	191.0	994.5	451.248	172.062	250
6	Cl ($mg.L^{-1}$)	427.1	1498.7	839.481	254.188	200
7	TDS ($mg.L^{-1}$)	1060.0	3670.0	2062.139	651.988	500
8	EC (µS/cm)	2016.1	11723.3	5602.160	2298.326	1000

6. Water quality index

Water quality index (WQI) can be defined as a method of rating that offers the composite effect of individual water quality parameters on the total quality of water. It lowers the large quantity of water quality data into a single value this is certainly numerical [Lohani, B. N., & Todino, G.]. It is calculated through the true viewpoint of human consumption. For calculation of WQI, water quality and its viability for drinking purposes have been viewed. The Higher values of the WQI suggest better quality of water and the lower values reveal poor quality of water. The parameters tend to be weighted according to their considered importance of total water quality. The weightage for assorted water quality parameters is assigned proportionally to the recommended requirements for the matching parameter in method of computing the WQI [Vasanthavigar, M. et al.].

The Water Quality Index (WQI) for drinking is a mathematical method applied to convert the data of water quality to a single number. Then, the gained single number symbolizes the status of the overall drinking water quality. Frequently, the calculation of Water Quality Indices (WQIs) are done in two steps. The first step is using the sub-index functions, whereas, the second step is using some aggregation function forms.

The sub-index formation is one of the greatest significant step in the approach of WQI. The sub-index is a value function which is usually used to convert the various dimensions and units of the water quality parameters into typical scale. In sub-index formation, each parameter is given a rating value based on its acceptable limits of guideline values prescribed by WHO (2006) (Table 2).

Table 2: WHO Guideline (Max. acceptable values) for drinking water quality.

Sl. No.	Parameter	Acceptable values
1	pH	8.5
2	Ca ($mg.L^{-1}$)	75
3	Mg ($mg.L^{-1}$)	50
4	Total hardness ($mg.L^{-1}$)	500
5	SO_4 ($mg.L^{-1}$)	250
6	Cl ($mg.L^{-1}$)	200
7	TDS ($mg.L^{-1}$)	500
8	EC (µS/cm)	1000

First, the temporary weight (w) was given to each parameter from the water quality parameters according to its benefits to drinking water quality assessment. Afterward, relative weight factor (Wi) can be determined by dividing the specific temporary weight of each parameter by the sum of temporary weight [Gupta et al., 2003; Debels et al., 2005; Boyacioglu, 2007] (as shown in Eq. (1)).

Table 3: Weight factors assigned to individual parameters.

Sl. No.	Parameter	Temporary weights (w)	Relative Weight factors (W_i) DWQI
1	pH	3	0.1250
2	Ca ($mg.L^{-1}$)	2	0.0833
3	Mg ($mg.L^{-1}$)	2	0.0833
4	Total hardness ($mg.L^{-1}$)	3	0.1250
5	SO_4 ($mg.L^{-1}$)	3	0.1250
6	Cl ($mg.L^{-1}$)	3	0.1250
7	TDS ($mg.L^{-1}$)	5	0.2083
8	EC (µS/cm)	3	0.1250

$$W_i = \frac{w}{\sum_{i=1}^{n} w} \quad (1)$$

Where: Wi is the relative weight factor of the water quality parameter.
w is the temporary weight of that water quality parameter.
n is the total number of water quality parameters (i.e. n=8)

The sub-index is calculated according to following equation

$$S_i = Qi.Wi \quad (2)$$

Where: Si is the sub-index value of selected parameter
Qi is the quality rating, which can be computed from the following formula

$$Q_i = \left(\frac{m_i}{c_i}\right) * 100 \quad (3)$$

Where, mi is the measured value of the concentration for the selected parameter
ci is the max. WHO standard value of selected parameter (table 2)
Subsequently, to compute the WQI, the following equation can be use

$$WQI = \frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} W_i} \quad (4)$$

The aggregation function is another criteria being essential in the strategy of WQI. To calculate the WQI, the weight factors and sub-indices of all used parameters are aggregated making use of aggregation function. The well-known aggregation methods in the WQI technique are additive and multiplicative aggregation functions.

WQI is determined due to the weighted average of all the observations of importance [Tsegaye, Sargaonkar, Pesce, Liou, and Ŝtambuk-Giljanović]. The computed WQI is supposed to produce an easy way to understand ranking of water quality on a score scale ranged between 0 and 300 (as shown in Table 4).

Table 4: Water Quality Classification Based on WQI Value

Water Quality Status	WQI value
Excellent	<50
Good Water	50-100
Poor water	100-200
Very poor water	200-300
Water unsuitable for drinking	>300

The subjective water quality index (WQIsub) is another equation used for the calculating of WQI as proposed by Rodriguez de Bassoon [Pesce and Wunderlin 2000] is:

$$WQI_{sub} = k \frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} \quad (5)$$

Where, n is the total number of water quality parameters,

Ci is the value given to parameter i following normalization process.

Pi is the relative weight given to each parameter (the value range from 1 to 4)

The objective water quality index (WQIobj) is the final equation of the subjective water quality index that was determined using (k=1) in above equation (equation 5) and it can be simplified written as:

$$WQI_{obj} = \frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} \quad (6)$$

7. Results and Discussions

The physical and chemical characteristic of water quality parameters that analyzed and their minimum, maximum, mean and standard deviation values are reported in Table 1. The pH value of the surface water samples vary from 7.1 to 8.1 at the location of monitoring station with an average of 7.6, while the ranges of TDS and EC were 1060 mg/L to 3670 mg/L and 2016.1 µ-s/cm to 11723.3 µ-s/cm at the location of monitoring station with mean values of 2062.14 mg/L and 5602.16 µ-s/cm respectively (Figure 2). The mean values of both TDS and EC are above the permissible limit and the minimum values of both TDS and EC are above the permissible limit. The TH values during the three years vary from 381 mg/L to 1455.5 mg/L at the location of monitoring station with an average value of 763.1 mg/L (Figure 3). The mean values of TH are above the permissible limit and the minimum value of it is below the permissible limit. Chloride and sulphate values at the location of monitoring station vary from 427.1 mg/L to 1498.7 mg/L and 191 mg/L to 994.5 mg/L with mean values of 839.5 mg/L and 451.3 mg/L (Figure 4). The mean values of chloride and sulphate are observed above the permissible limits, while the minimum value of sulphate is below the permissible limit. The range of magnesium and calcium were 240.3 mg/L to 863.0 mg/L and 144.3 mg/L to 504.0 mg/L at the location of monitoring station with mean values of 463.6 mg/L and 289.1 mg/L respectively (Figure 4). The concentrations of both magnesium and calcium are found above the permissible limits.

The minimum, maximum, mean and standard deviation values of the calculated WQI are presented in table 3, and the individual years of WQI in the location of the monitoring station is shown in table 4.

Table 3: Summary of the calculated WQI values at the location of the monitoring station.

Sl. No.	Year	Minimum	Maximum	Average	Std.Dev.
1	2010	256.1	448.2	318.0	256.1
2	2011	244.6	399.2	337.3	244.6
3	2012	251.0	644.6	456.7	251.0

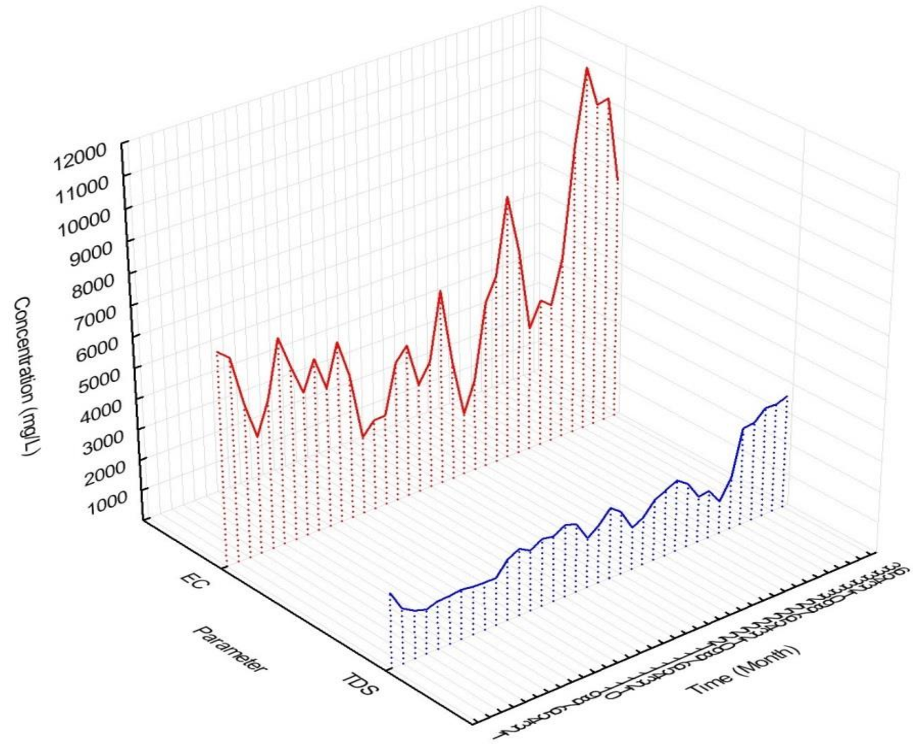

Figure 2. EC and TDS concentrations at the location of the monitoring station during the study period.

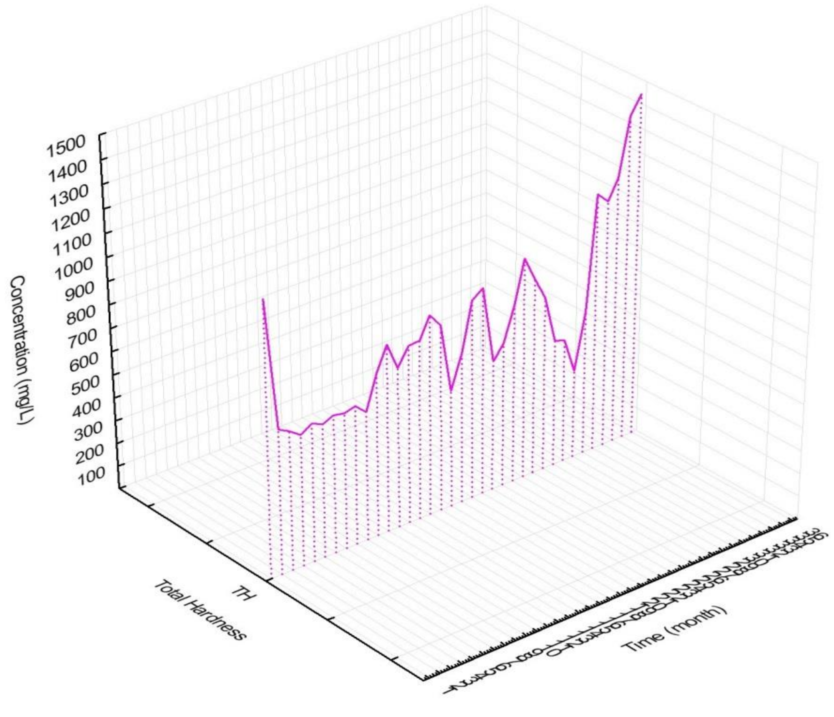

Figure 3. Total hardness (TH) concentrations at the location of the monitoring station during the study period.

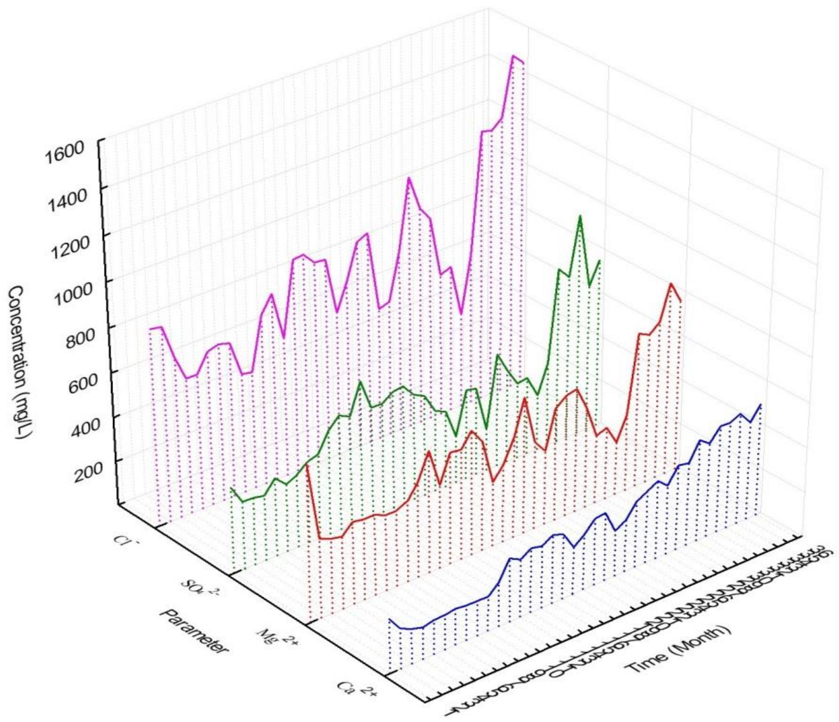

Figure 4. Cl–, SO42–, Mg2+, and Ca2+ concentrations at the location of the monitoring station during the study period.

The WQI values of the water samples were calculated for Shatt Al Arab River (Tables 3 and 4). WQI values in 2010 ranged from 256.1 to 448.2 with an average value of 318.0. Whereas, the WQI values in 2011 ranged from 244.6 to 399.2 with an average value of 337.3. Furthermore, the WQI values in 2012 ranged from 251.0 to 644.6 with an average value of 456.7. According to the obtained results and the water quality classification as shown in Table 2, all the three years are ranged in classification of quality with respect to WQI, water use in water supply for drinking and practically treatment is required.

Table 4: Summary of the calculated WQI values at the location of the monitoring station.

Sl. No.	Month	WQI value for the year		
		2010	2011	2012
1	January	448.2	304.7	409.1
2	February	333.3	359.5	455.2
3	March	287.0	354.9	388.5
4	April	256.1	399.2	289.3
5	May	287.0	383.9	303.3
6	June	310.7	272.5	251.0
7	July	305.0	315.7	339.0
8	August	285.8	393.7	573.2
9	September	287.9	380.2	595.7
10	October	280.8	244.6	620.0
11	November	352.8	270.2	644.6
12	December	381.3	368.9	611.3

Results showed that the average of WQI value for the year 2010 to 2012 was 318.0 244.6, and 251.0, respectively (Table 3). The results showed, the year 2011 has lower WQI value than the other two years (2010 and 2012). The results of water quality parameters revealed that the water of the Shatt Al Arab River in that location of the monitoring station was polluted with water quality status ranged between very poor water type and the water unsuitable for drinking type. Figure 5 shows the WQI values at the location of the monitoring station during the study period.

According to WQI values at the sampling station, there is a general progressive increase in WQI values with time, indicated that an increase in pollution is because of the wastewater discharge by different industries along the banks of the river. Hence, the very poor water quality index at the sampling station is because of the anthropogenic activities. The continuing monitoring of physical and chemical parameter for the Shatt Al Arab River waters and the quality of water river analyzed with different water quality indices was the best way in which is better for protecting river's water again pollution.

Water quality index calculated for the study area from the year 2010 to the year 2012 is presented in Table 4. The calculated WQI for 2010 indicate that the overall WQI was 318 as compared to 2011 that was 337.3 and the year of 2012 that was 456.7 respectively. The high values of the WQI have been noticed in summer season, whereas the lower values in winter season. The higher value of WQI in summer season is due to the high concentration of TDS, EC, magnesium and total hardness in surface water. But the water quality of the monitoring station in the study area of the Shatt Al Arab River is found to be poor to unsuitable for use in almost the months of the three years under investigation.

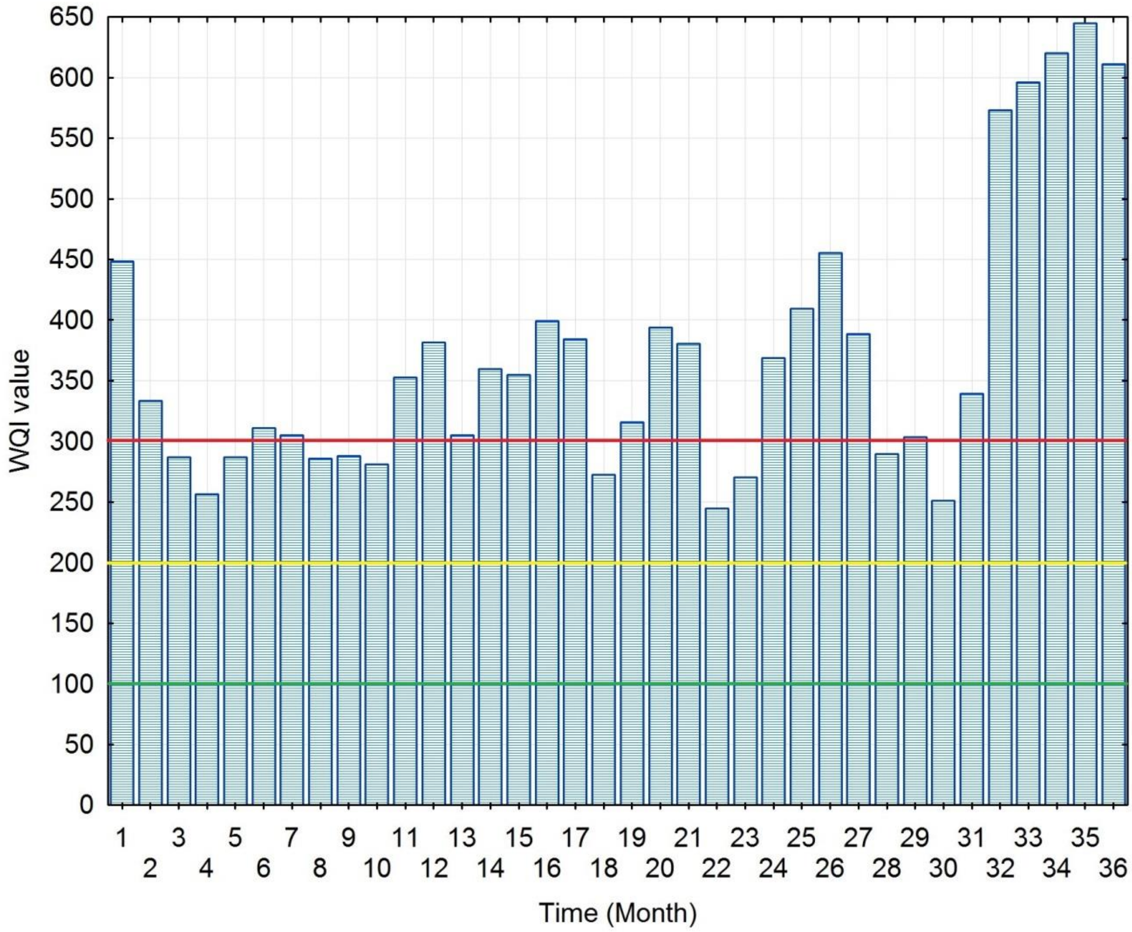

Figure 5. WQI values at the location of the monitoring station during the study period.

8. Conclusion

At the beginning, the overall WQI (year of 2010 – 318, year of 2011 – 337.3 and year of 2012- 456.7) values calculated during the study period falls under unsuitable water of Table 2, implies that the water quality is not good and unsuitable for drinking and other consuming purposes. The variations in seasonal of the water quality values are due to variation in physical and chemical characteristics of surface water. The study reveals that surface water at the location of the monitoring station need level of treatment before drinking or consumption purposes, except eleven months of WQI, during the study period, the value is less than 300 that is mean it is very poor water.

The application of water quality index in this research has been discovered useful in evaluating the overall quality of water. This process appears to be much more systematic and grants comparative assessment of the water quality in different months of the three years. It is really recommended that monitoring of the water of the river important for proper management. The utilizing of WQI is also proposing a very helpful tool in the field of water quality management and that allows the public and decision makers to assess the water quality of rivers in Iraq.

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