Assessment of Water Quality Indices for Shatt Al-Basrah River in Basrah City, Iraq

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ABSTRACT

Oil projects in the province of Basrah are widely spread and remarkably increasing as they are considered to be of a significant impact on the environment of this region in elements of air, water and soil. This is due to the presence of toxic elements in the air as a result of fuel, or waste thrown into the water. So, this research addresses to study the amount of the pollutants concentration that are discharged by Shuaiba refinery which is located in Basrah province and works for about 24 hours daily. To assess the impact of the refinery on the river, 36 water samples were collected for six months period (from December, 2014 - May, 2015) as well as field measurements and laboratory analyses in order to get appropriate solutions and proposals as much as possible. 180 field measurements have been achieved include electrical conductivity (EC), total dissolved solids (TDS), turbidity, water temperature, and hydrogen ion concentration (pH). In addition, 342 water samples have been prepared to measure several physical and chemical characteristics (NH_3, NH_4, NO_2, NO_3, SO_4, Cl and Ca, oil and grease, and total hardness TH) inside and outside Shuaiba refinery in the study area. Measurements of these pollutant concentrations were carried out on six sampling sites; one inside the wastewater collection tanks of the refinery and the remained five sites along the Shatt Al-Basrah River.

The locations of these sites were selected according to the land use map of Landsat 8 data 2015 and the coordinates of each sample location was measured precisely by GPS. The analysis, pollutants concentration maps and their locations on the satellite image were carried out using Arc GIS 10.3 and ERDAS 2013 software. The field and laboratory test results of water samples indicated high pollutants concentrations during December, April and May months, while there were a decreased pollutants concentration particularly during the month of March. It is noticed the high reflectivity values in areas that contain contaminants (turbidity) or oily spots with a purity of more sites. The calculations of water

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quality index (WQI) for all the study sites are within the range of 11.79 to 21.31. Accordingly, the overall WQI class of the study sites in Shatt Al- Basrah River can be emphasized within "poor category" in the polluted range according to studied types of water pollution. The deterioration of the Shatt Al-Basrah water quality is observed toward south of Basrah city due to the pollutants flow into the river.

Keywords: Pollutants; Water; Water Quality Index (WQI); Shatt Al- Basrah; GIS and GPS

INTRODUCTION

Water pollution is a qualitative term that describes the situation when the level of contaminants impedes an intended water use. Major sources of surface water contamination are construction, municipalities, agriculture, and industry. Thus, the pollution of surface or ground water can occur in many forms, including hazardous industrial organic compounds, fuel components, heavy metals and salinity [1]. Environmental pollution of water causes actual or possible hurt or damage to individual health or to damage or harm nonhuman nature without justification [2]. An integral part of any environmental monitoring program is the reporting of results to both managers and the general public. This poses a particular problem in the case of water quality monitoring because of the complexity associated with analyzing a large number of measured variables [3]. Thus, the study of water pollution by major cations and anions concentrations and many others (total dissolved solids TDS, total hardness TH, turbidity, oil and crease etc.) are necessary for environmental assessment.

Since Basrah city contains many national and international oil projects (such as Shuaiba refinery on Shatt Al-Basrah) which cause environmental deterioration in the surrounding environment (particularly water) by its wastes, so this work will be focused on the impact of Shuaiba refinery wastes on the Shatt Al- Basrah water by studying the main pollutants and their environmental impact on water surrounding the refinery and to determine the water quality index (WQI) for Shatt Al-Basrah. The main studied pollutants are major cations (NH_3^+, NH_4^+, and Ca^{2+}) and anions (NO_2^-, NO_3^-, SO_4^{2+}, Cl^-) concentrations and many others (such as water temperature, electrical conductivity EC, total dissolved solids TDS, total hardness TH, hydrogen ion pH, turbidity, oil and crease).

Location, Climate and Geology

Basrah City is located in the extreme south eastern part of Iraq on the territory of Mesopotamian Plain. Geographically, it is situated between Latitudes circles of (29° 3' 0" N) and (31° 12' 0" N), and longitudinal circles of (40° 27' 36" E) and (48° 18' 0" N).

Basrah area is considered as the solely Iraqi sea port and it makes an important portion of Iraq for its economic potentialities represented by its historical preservation of oil fields including Rumaila, Shuaiba, West Qurna, Nahr Umr and Majnoon fields. Moreover, it is characterized by the fertility of its soil as it is being situated in the plain of Mesopotamia. It is one of the main centers for the cultivation of the date palm and in second order for rice, barley, wheat, millet. Also it is famous by its breeding cattle. Figure (1) shows the location of Basrah province.

The climate of the area is an arid with medium total mean rainfall in winter and very low to absent in summer. The predominant wind is NW-SE. The area is hot and humid in summer and cold in winter. Temperature, wind speed and rainfall affect the concentrations of pollutants. Table 1 shows the monthly means of some meteorological parameters [4].

The area is characterized by its variable aquatic environments; fresh, brackish and marine represented by Shatt Al-Arab, the marshes (Hor Al-Hammar) and Khor Al-Zubair respectively. Khor Al-Zubair is connected at its north reaches with the marshes through Shatt Al-Basrah canal since 1983, which discharges Euphrates water that comes out Hor Al-Hammar to Khor Al-Zubair ending into NW Arabian Gulf in the south. It is connected with the Arabian Gulf by means of Khor Shittana and Khor Abdullah [5].

Topographically, Basrah area is relatively flat with very gradual and gentle rises in elevation from east to west and from south to north. The rise in elevation along Shatt Al-Arab is gentle, whereas in the south west of Basrah from Shatt Al-Arab to Iraqi Saudi borders, the rise in elevation is 5 times. This is represented by Zubair uplifts and Jabal Sanam near Safwan area toward the Iraqi-Kuwaiti borders. Physiographically, the region has been subdivided into several provinces such as: Mesopotamian alluvial fan, sand dune belts, Dibdibba gravel and sand region [6]. Basrah is characterized by its different types of soil namely: sedimentary soil in the north and east, sandy soil in the west, and salty and arid soil in the south east.

Theoretical Background

Spatial Analysis and Distribution of Data

GIS is a modern powerful tool that facilitates linking spatial data to non-spatial information [7]. With its embedded relational database component, the system assists in storing, mapping and analyzing geo-referenced data in an organized structure [8]. The database and the geographical base both form the two major components of the GIS system that helps in visualizing the data in a map format. The spatial analysis modeling process of GIS involves interpreting and exploring the interactions, associations and relationships among GIS data types specific to a geographic location. The recent development of spatial data management in the framework of GIS has created a new era of environmental modeling.

The process of production thematic maps to show the locations and concentrations of any pollution element by using the inverse distance weighted (IDW) interpolation in the Arc GIS 10.1 program.

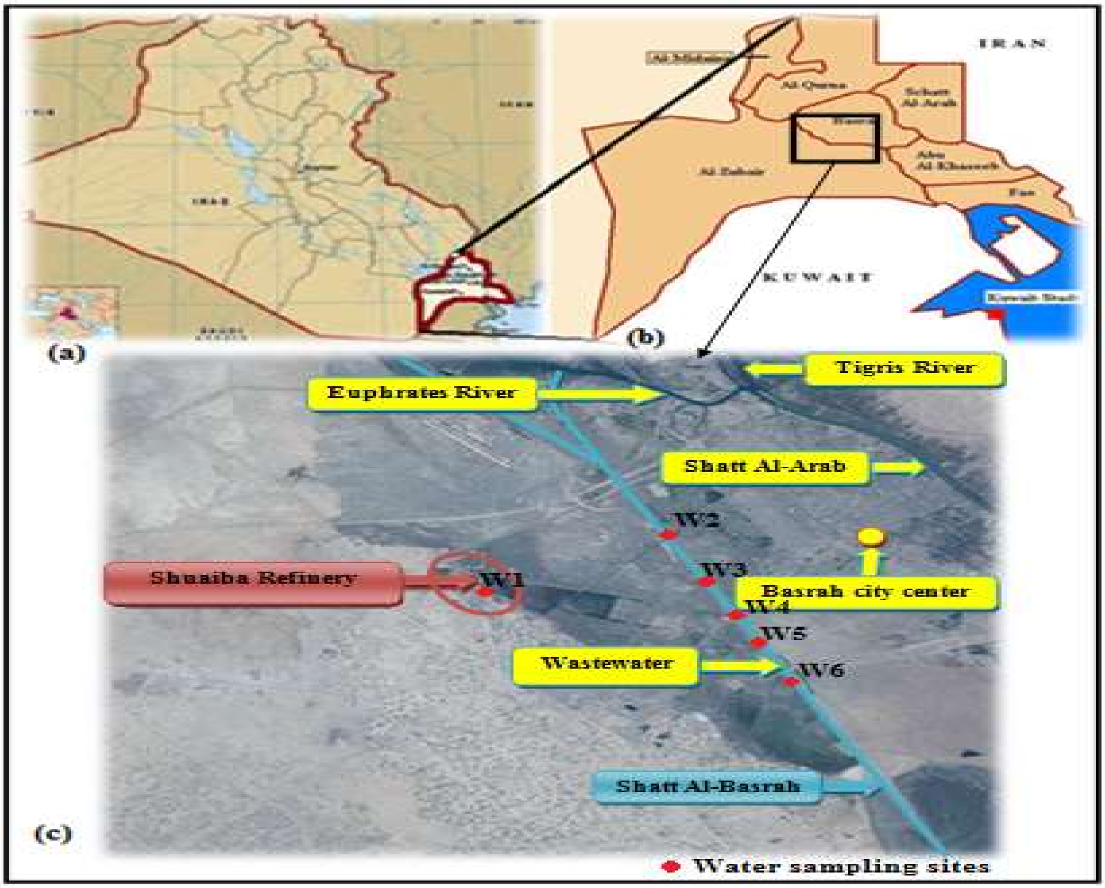

Figure (1) (a) Map of Iraq showing the location of Basrah Governorate; (b) A map showing the locations of cities in Basrah Governorate; (c) Satellite image of the study area with water sampling sites.

Table (1) monthly means of some meteorological parameters of the study area [4]

Month	Wind Speed[1] (m/s)	Rainfall[1] (mm)	Air Temperature[2] (Co)	Relative Humidity[2] (%)	Evaporation [1] (mm)
December	3.84	20	14.28	64.28	73.07
January	4.08	23.84	13.2	65	80.77
February	4.38	13.46	16.43	57.14	96.15
March	4.65	3.23	21.43	42.86	200
April	4.69	11.5	25.71	37.86	250
May	4.84	6.15	32.85	25.71	376.92

[1] Monthly: means for the years 2002-2014.
[2] Monthly: means for the years 2002-2015.

The first element that has to be calculated is the Inverse distance weighted (IDW) interpolation which determines cell values by using a linearly weighted combination of a set of sample points. This weight is a function of inverse distance [9]. The output value for a cell is limited to the range of the values used to interpolate. Because (IDW) is a weighted distance average, the average cannot be greater than the highest or lower than the lowest input [10]. The IDW method is used widely with cases of GIS application in many fields as this method is suitable in use and contains less distortion when there is enough measured point [11].

The Inverse Distance Weighted (IDW) was used in a method of data analysis within the program with the objective to produce maps to show the locations and concentrations of pollutants. This method can be summarized as follows [3]:

1. Prepare a file for the sites and average concentrations of pollutants using excel program.
2. Add the file points to Arc GIS 10.3 program.
3. The definition of the coordinate system of the points.
4. Export points format Shape file.
5. Determine the save site of layer.
6. For the purpose check of the data entered for the program can be displayed.
7. Interpolation process for an ideal distribution analysis of the concentration of pollutants Layer raster values by IDW methods.
8. Import satellite image to Arc GIS 10.٣ program.
9. Determine the work area of the interpolation.
10. Analysis result.
11. Production thematic map to show the locations and concentrations of pollution elements.

Calculation of Water Quality Index

A mathematical model for evaluation the condition of the ambient water quality with respect to the water quality objectives has been given by the Canadian Council of Ministers of Environment Water Quality Index (CCME WQI). This model is flexible relative to the number and to the type of water quality variables. Hence the water body, time period, variables, and other appropriate objectives need to be defined prior calculating the WQI index. The water body for which the WQI index will be applied can be defined by sufficient obtainable data for a single station or by a number of different stations. The selected period of time will depend upon the amount of the available data and the desired requirements by the user. For determination the calculation of the CCME WQI index needs, at least four variables must be utilized and sampled four times in minimum.

The index equation is based on the water quality index (WQI) endorsed by the Canadian Council of Ministers of the Environment (CCME, 2001) [3]. The index allows measurements of the frequency and extent to which parameters exceed their respective guidelines at each monitoring station. Therefore, the index reflects the quality of water for both health and acceptability, as set by the World Health Organization. The index is determined on an annual basis resulting in an overall rating for each station per year. This will allow both spatial and temporal assessment of global water quality to be undertaken.

The Canadian Water Quality Index (CWQI) equation is calculated using three factors as follows [3, 12]:

$$CCMEWQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right) \quad \text{…. (1)}$$

In the above equation, the denominator number (1.732) is used for normalization. That means to normalize the values of output result to be within a range between 0 and 100. In this range, the 0 number represents the "worst" water quality and the 100 number represents the "best" water quality.

After defining the water body, the time period, the variables and the objectives, each of the three factors that make up the WQI index must be determined. The calculation of F_1 and F_2 is relatively straightforward; while the calculation of F_3 requires some additional steps.

F_1 (Scope) represents the variables percentage that do not meet their objectives at least once during the period of time under study ("failed variables"), with respect to the total measured number of variables [3]:

$$F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables} \right) \times 100 \quad \text{… (2)}$$

While, F_2 (Frequency) represents the percentage of individual tests that do not meet objectives ("failed tests"):

$$F_2 = \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests} \right) \times 100 \quad \text{… (3)}$$

And, F_3 (Amplitude) represents the extent (excursion) to which the failed test exceeds the guideline, i.e. the amount by which failed test values do not meet their objectives. The calculation of F_3 can be performed in three steps.

i. The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum). Here, the objective is termed as an "excursion" which is expressed as follows when the test value must not exceed the objective:

$$excursion_i = \left(\frac{Failed\ Test\ Value_i}{Objective_j} \right) - 1 \quad \text{…(4a)}$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left(\frac{Objective_j}{Failed\ Test\ Value_i} \right) - 1 \quad \text{… (4b)}$$

ii. The collective amount by which individual tests are out of compliance is calculated by adding the excursions of individual tests from their objectives and dividing by the total number of tests (including both those are meeting the objectives and those are not meeting these objectives). This variable, which is called the normalized sum of excursions or *nse*, is calculated as follows:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\#\ of\ tests} \quad \text{…(5)}$$

iii. Then, F_3 is determined by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to get a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} \right) \quad \text{…(6)}$$

The index equation generates a number between 1 and 100, with 1 being the poorest and 100 indicating the best water quality. Within this range, designations have been set by CCME (2005) [13] to classify water quality as poor, marginal, fair, good or excellent. These same designations were adopted for the indices developed here. The designations are presented in Table 2.

Materials and Methods

First, it is worth to mention that water samples collection, field measurements have been carried during flood time and clear weather for the six months (December 2014 to May 2015). Besides, the procedure presented by the American standard methods (American Public Health Association APHA, 2015) [14] has been followed for these issues. The above objectives will be done through two main stages field work and laboratory measurements which can be summarized in the following sections.

Table (2) Water quality rating [3, 12]

Designation	Index value	Description
Excellent	95-100	All measurements are within objectives virtually all of the time
Good	80-94	Conditions rarely depart from natural or desirable levels
Fair	65-79	Conditions sometimes depart from natural or desirable levels
Marginal	45-64	Conditions often depart from natural or desirable levels
Poor	0-44	Conditions usually depart from natural or desirable levels

Field Work

This stage was carried out during a period of 6-months starting from December, 2014 until May, 2015. Thirty six surface water samples were collected during 6-months from December 2014 to May 2015. Clean bottles screw-cap tops were used for sampling. Few drops of chloroform were added to the water samples just after sampling for preservation and to avoid the organic materials activity. Several specialized portable equipments have been used for monthly testing and measurements of 14 water pollutants in 6 selected sites of study. This stage includes the following:

a. Locate sampling sites on satellite image (Landsat 8 with resolution 15 m) for water using GPS.

b. Collect 36 surface water samples from six sites for 6-months.

c. Achieve 180 field measurements for 5 physical characteristics (electrical conductivity EC, total dissolved solids TDS, turbidity, water temperature, and hydrogen ion concentration pH) for 6-months following the procedure of the American standard methods [14].

d. Prepare and collect satellite images of the study area which are corrected by applying the rectification and correction to the selected image with the map of Basrah.

e. Apply remote sensing and GIS techniques to present the digital elevation model DEM in order to present the water pollutant concentrations.

For the site location of these samples which have been carried out every month for the same period: one sample taken from water of Wastes Collection Basin inside the refinery which is thrown later to Shatt Al-Basrah river after treatment. The other 5 samples were taken from outside the refinery of Shatt Al-Basrah. Some points have been considered in choosing sampling sites such as their locations with respect to waste water thrown to the river as well as the direction of water flow, the effect of tide due to its nearness from the Arabian Gulf, and the time of sampling. Table 3 shows the coordinates of the sampling sites, while Figure 2 shows the water samples location on satellite image of the study area. Figure 3a shows collection basin unit and wastewater treatment in the Shuaiba refinery before thrown into Shatt Al-Basrah, while Figure 3b shows a polluted area in Shatt Al-Basrah and nearby land bank of the river.

Table (3) coordinates of the water sampling sites using GPS

Site No.	Easting (m)	Northing (m)
1	756196	3371980
2	762827	3376145
3	764353	3372646
4	765334	3370484
5	766132	3368609
6	767178	3366304

Laboratory Measurements of Water Pollutants

The experimental work consists of several stages summarized as follows:

1. Prepare 342 water samples collected from 6 sites through six months from December 2014 to May 2015 to measure several physical and chemical characteristics.
2. It is worth to mention that site locations are selected with respect to waste water thrown to the river, the direction of water flow, occurrence of tide phenomenon, as well as the sampling time.
3. The main tested environmental water pollutants were (NH_3, NH_4, NO_2, NO_3, SO_4, Cl and Ca, oil and grease, and total hardness TH) inside and outside Shuaiba refinery in the study area.
4. The American standard methods [14] were followed for chemical analyses of water samples including total hardness, total dissolved solids (TDS), and the concentrations of the major anions (Cl, SO_4, NO_2, and NO_3), and cations (NH_3, NH_4, and Ca).

RESULTS AND DISCUSSION

Table 4 shows a summary for the average pollutants concentration for the 6-months from December 2014 to May 2015 for samples from Shuaiba refinery draining basin to Shatt Al-Basrah River. The Iraqi and international water quality standards [15, 16] (including: hydrogen ion, nitrate, sulfate, total dissolved solids, ammonia, ammonium, water temperature, turbidity, chloride and calcium) are shown in Table 5. The analysis results of the data have been presented using Arc GIS 10.3 by IDW method. Figures 4 to 17 represent the thematic maps showing the location and the average concentration of pollutants in the river for six months started from December, 2014 to May, 2015.

Regarding Ammonia (NH_3), the maximum value of NH_3 concentration was 16.85 mg/l during February in site 2, while the minimum value was 1.37 mg/l during March in site 6. It is clear from Table 4 and Figure 4 that the maximum average value (8.87 mg/l) in the second site (W2), while the lowest rates (2.24 mg/l) in the fifth site (W5). The increase in ammonia in site 2 may be due to the decomposition of organic matter, thus sewage and organic matter lead lifting of ammonia levels in the water [17]. Besides, ammonia is provided to the water from agricultural and industrial wastewater [18], as many industrial plants are wide spread near this site which drains their wastes directly to the river. In most sites, it is also found that NH_3 values exceed the limits of Canadian standards which is about 1.37 mg/l as presented in Table 5. The values of ammonium (NH_4) are ranging from 1.48 during March in site 3 to 17.85 mg/l during February in site 2 in all study stations. The highest average value was 9.24 mg/l in site 2 and the minimum average value was 2.37 mg/l in site 5 (Table 4 and Figure 5). All concentrations exceed the limits of Iraqi standards (Table 5). The increase in NH_3 and NH_4 values in site 2 for all the study period because it is near the place of sewage discharge.

Nitrite (NO_2) values are ranged from 0.01during April in site 1 to 6.38 mg/l during May in site 4 for all study stations. The minimum average value was 0.04 mg/l in site 5 and the highest average value was 2.13 mg/l in site 4 (Table 4 and Figure 6). For nitrate (NO_3) concentration, the values are ranged from 10.13 mg/l during April in site ٦ to 332.25 mg/l during December in site for all study sites. The minimum average value was 12.6503 mg/l in site ٣ and the highest average value was 149.71 mg/l in site 1 (Table 4 and Figure 7). The main source of nitrate is the organic activities and industrial and agricultural chemicals as stated by Karim (1998) [5]. Almost all the NO_3 concentrations are below the limits of Iraqi standards (15 mg/l) (Table 5) except the extreme value of site 1 as it is located inside the refinery (Waste Collection Basin). As nitrate is rarely exceed 10 mg/l in natural waters (lakes and rivers) as nitrogenous compounds which form most of the exploits of plants [19].

The concentrations of sulfate (SO_4) in the water of the study area ranged from 1100 mg/l in site 1 during March to 6700 mg/l in site 4 December. The minimum average value was 1528.67 mg/l in site 1 and the highest average value was 5041.67 mg/l in site 4 (Table 4 and Figure 8). All SO_4 concentrations in the water of the study area exceed the limits of Iraqi standards (200 mg/l as maximum) (Table 5). Gypsum and anhydrite of Injana formation may be considered to be the main sources of sulfate (SO_4) and calcium (Ca) in Tigris and Euphrates rivers and marshes region in turn in Shatt Al-Arab and Shatt Al-Basrah rivers [5].

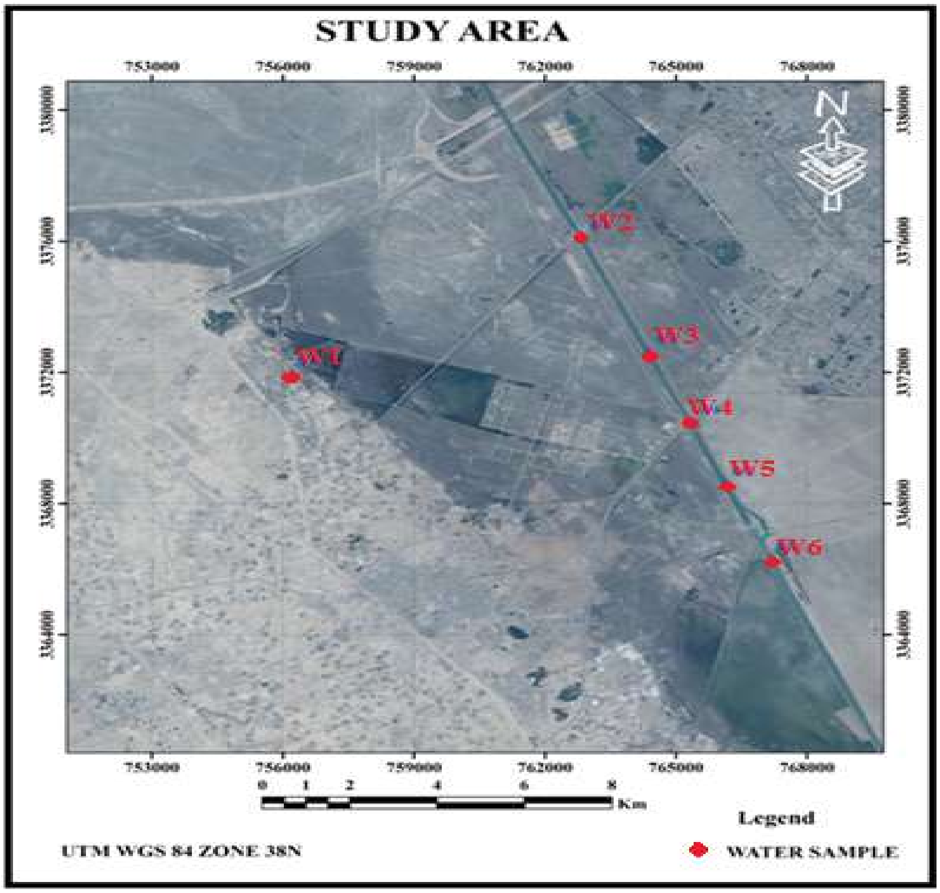

Figure (2) Water samples location within the study area.

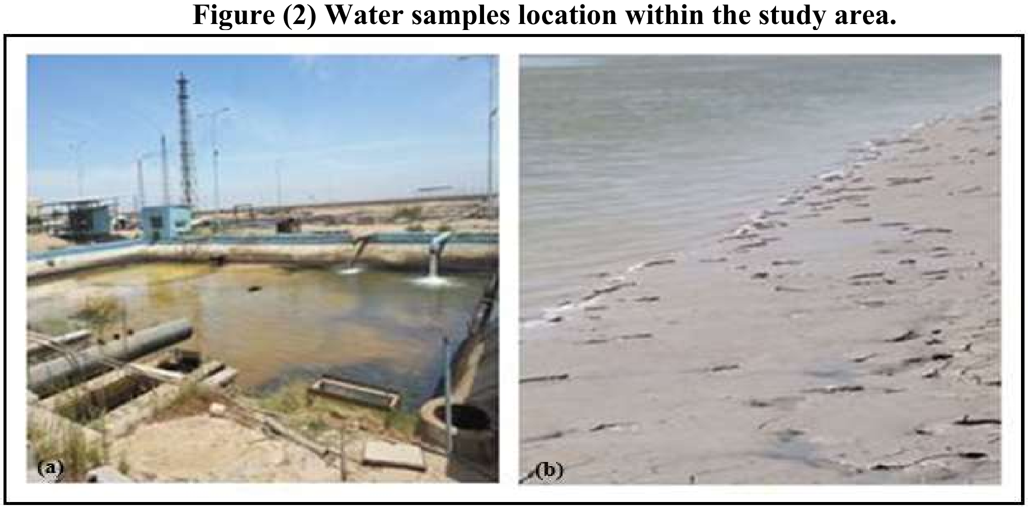

Figure (3) Collection basin unit and wastewater treatment in the Shuaiba refinery before thrown into Shatt Al-Basra River; (b) Polluted area in Shatt Al-Basra and nearby banks

Table (4) Average water pollutants concentration for all sites of the study area during six months

Station \ Element	NH_3 mg/l	NH_4 mg/l	NO_2 mg/l	NO_3 mg/l	SO_4 mg/l	Oil and Grease mg/l	EC µS/cm	TDS mg/l	Turb. NTU	TH mg/l	Temp. °C	pH	Cl mg/l	Ca mg/l
Site 1	2.55	2.69	0.11	149.71	1529	2.12	5536	3002	665.33	1055	23.93	8.49	514	214
Site 2	8.87	9.24	0.04	13.87	3978	0.06	13777	7244	57.34	3482	16.83	7.79	1640	684
Site 3	2.39	2.52	0.45	12.65	4271	0.23	13401	7048	49.49	4047	16.60	8.13	1659	702
Site 4	2.66	2.82	2.13	13.08	5042	0.28	13410	7064	53.54	3978	16.65	8.09	1675	802
Site 5	2.24	2.37	0.13	13.07	5010	1.05	13528	7114	170.45	4132	16.85	8.28	1937	884
Site 6	2.41	2.55	0.15	13.10	4892	1.03	13914	7328	203.93	4150	16.75	8.28	2117	951

Table (5) Iraqi and international water quality standards

Water quality variable	Symbol	Unit	River maintenance
Hydrogen ion	pH	Min. – Max.	6.5 – 8.5*
Nitrate	NO3	mg/l	15*
Sulfate	SO4	mg/l	200 Max.*
Total dissolved solids	TDS	mg/l	500**
Ammonia	NH3	mg/l	1.37**
Ammonium	NH4	mg/l	1*
Temperature	Temperature	°C	15**
Turbidity	Turbidity	NTU	5**
Chloride	Cl	mg/l	20 *
Calcium	Ca	mg/l	1000**

* Iraqi Standards for System Maintenance Rivers, No. (25), 1967 [15].
** CCME (1999) [16] for overall purposes.

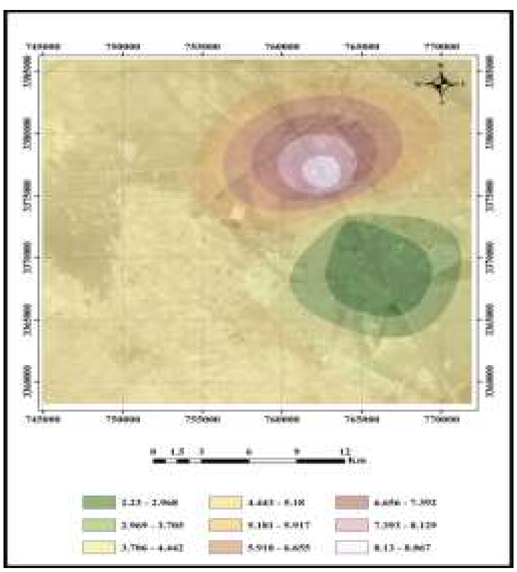

Figure (4) Average NH_3 concentration

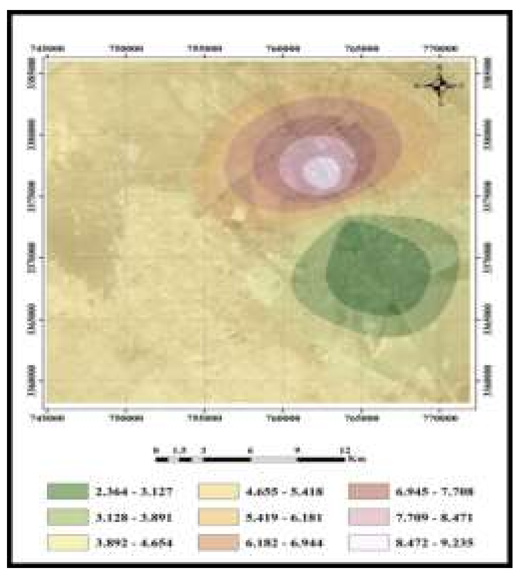

Figure (5) Average NH_4 concentration.

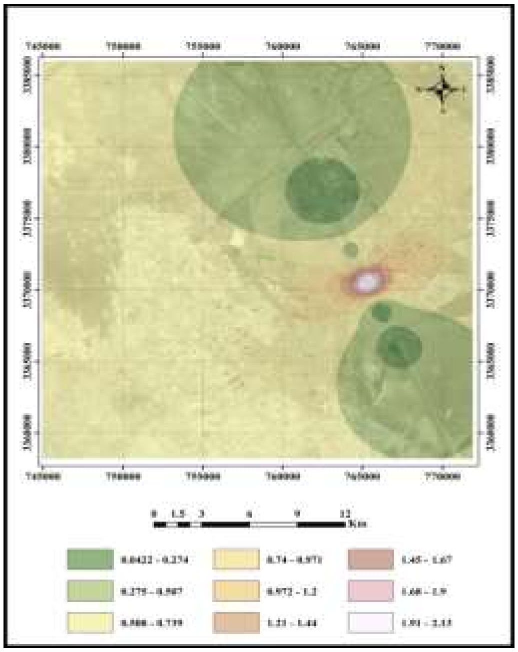

Figure (6) Average NO_2 concentration

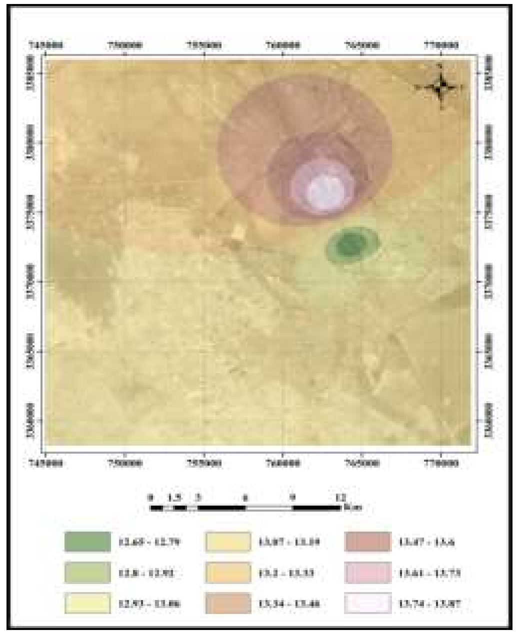

Figure (7) Average NO_3 concentration

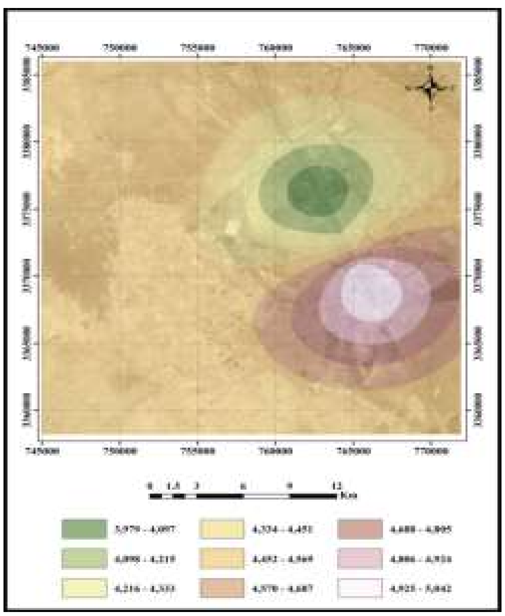

Figure (8) Average SO_4 concentration

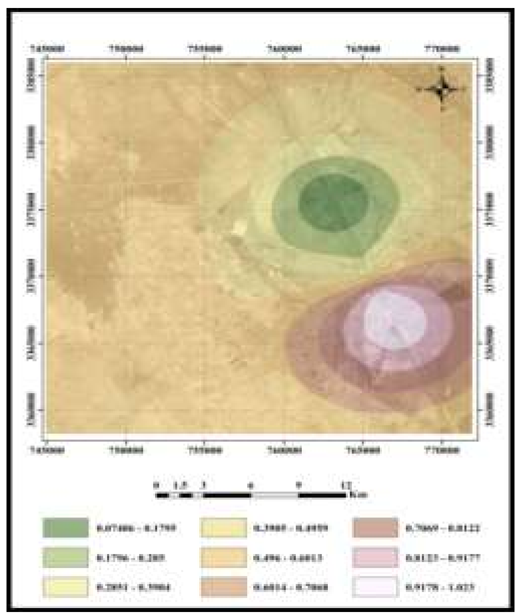

Figure (9) Average oil and grease concentration

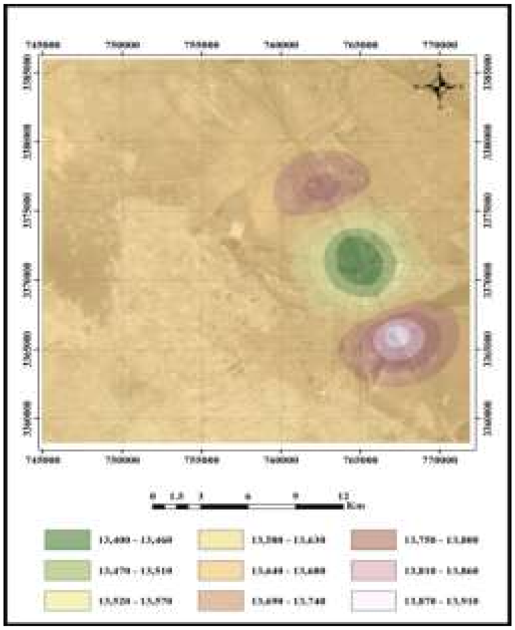

Figure (10) Average EC concentration

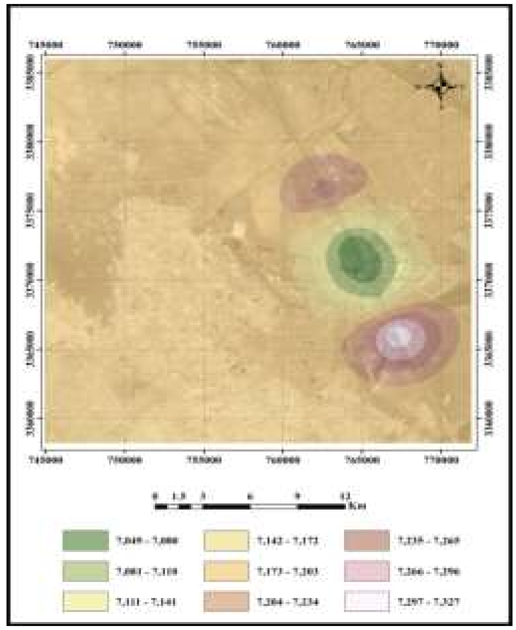

Figure (11) Average TDS concentration

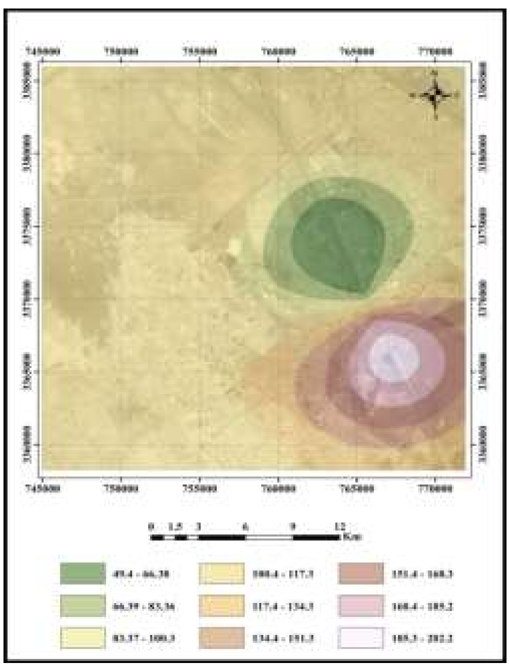

Figure (12) Average turbidity concentration

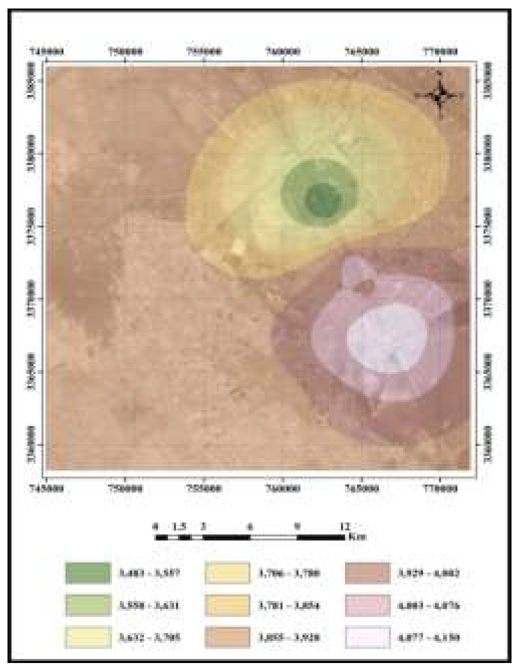

Figure (13) Average TH concentration

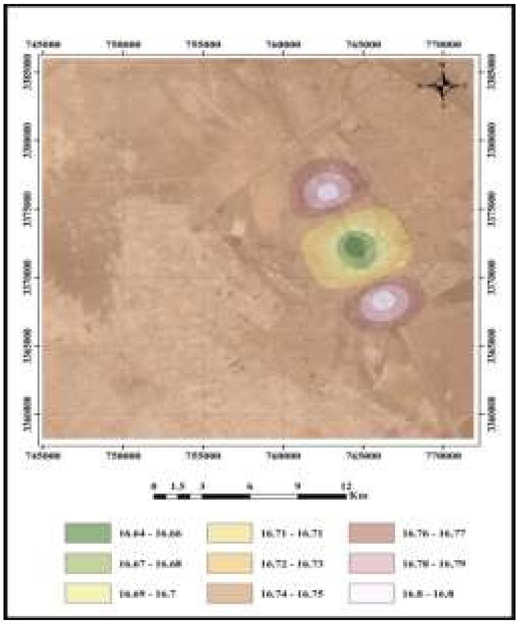

Figure (14) Average water temperature Concentration

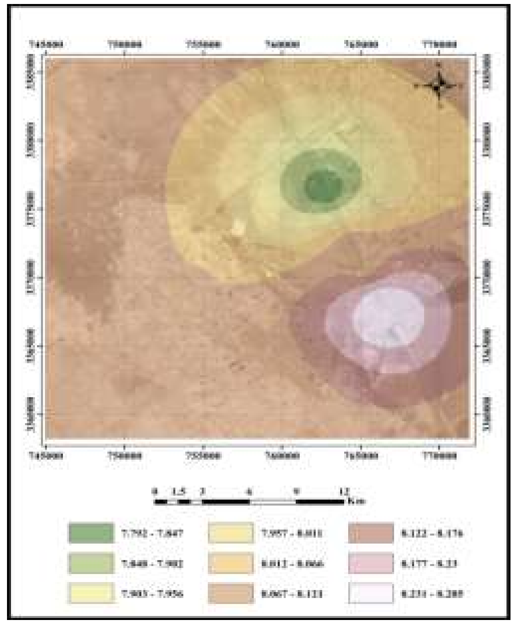

Figure (15) Average pH concentration

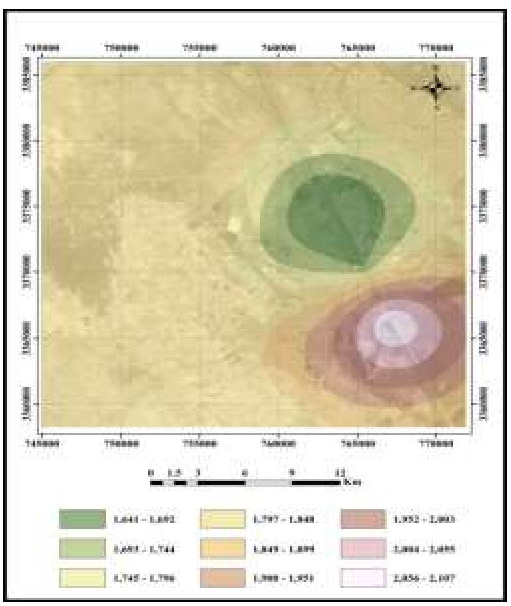

Figure (16) Average Cl concentration

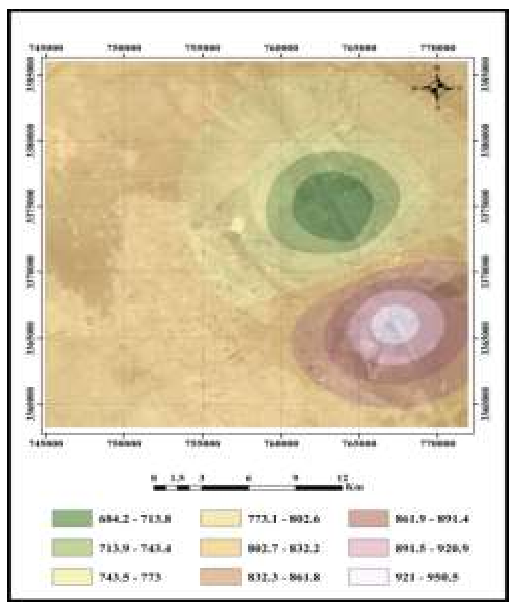

Figure (17) Average Ca concentration

Oil and grease values ranged from 0.02 mg/l during March in site 2 to 3.60 mg/l was during December in site 1 in all study stations. The minimum average value was 0.06 mg/l in site 2 and the highest average value was 2.12 mg/l in site 1 (Table 3 and Figure 9). The increase in oil and grease values in sites 5 and 6 for all months may be due to the wastewater drainage of the refinery thrown by the long pipe to Shatt Al-Basrah.

Electrical conductivity (EC) values ranged from 4810 µS/cm during March in site 1 to 15845 µS/cm during May in site 2 in all study stations. The minimum average value was 5536 µS/cm in site 1 and the highest average value was 13914 µS/cm in site 6 (Table 4 and Figure 10). It is clear that the electrical conductivity depends on the type and concentration of ions in water and increases with increasing temperature. These values are closely related to the chloride (Cl) concentrations which are ranging between 193 to 5548 mg/l in sites 1 and 6 respectively (with lowest and highest averages 514 to 2117 mg/l respectively). The chloride values and thus electrical conductivity values were greater in May than that in December owing to the rise of river water. Besides, the increase in EC values of Shatt Al-Basrah were attributed to the effect of saline water mixing from Khor Al-Zubair water and high chloride concentrations of Hor Al-Hammar [5].

The concentration of TDS in the water ranged from 2557 mg/l during the month of March in site 1 to 8562 mg/l during May in site 2. The minimum average value was 3002 mg/l in site 1 and the highest average value was 7328 mg/l in site 6 (Table 4 and Figure 11). It is apparent that the TDS and EC values are strongly related to the discharges. The increase of TDS is due to mixing from saline Khor Al-Zubair waters. Accordingly, these waters are considered to be brackish (>1000 mg/l) [4, 20]. TDS values were as found in all stations exceed the limits of Canadian Standards (500 mg/l) (Table 5).

Turbidity values ranged from 9.12 NTU to 973 NTU in all study stations with higher values for water thrown to the river (site 1). The lowest value was during May in site 3 and the highest value was during April in site 1. The minimum average value was 49.49 NTU in site 3, and the highest average value was in site 1 and it was 665.33 NTU (Table 4 and Figure 12). The average turbidity values in all stations of the study area exceed the limits of the Canadian Standards (5 NTU) (Table 5).

The concentrations of total hardness (TH) during this study are variable, the values of TH range from 973 mg/l at location 1 during January to 4704 mg/l at location 5 during April. In general, all concentrations of TH in the water of the study area have high values (almost > 1000 mg/l) except for the station 1 which was much lower due to the decrease of Ca which is responsible for water hardness (Table 4 and Figure 13). The excessive increasing in the TH values at locations 5 and 6 are due to the increase in Ca besides their mixing with saline waters of Khor Al-Zubair. By comparing the measured TH with some suggested standards (e.g. Todd, 1980) [21], these waters are considered to be very hard waters.

Water temperature in the present current study showed differences between the water temperature inside the refinery before draining to the river and that of the river water. The highest temperature of the water was 24.50°C in site 1 during December while lowest temperature was 15.30°C measured in sites 2 and 4 during December and February respectively (Table 4 and Figure 14). The treated water (from Wastewater Collection Basin inside the refinery) is the source for the increase in water temperature in site 1 for all months. Water temperature values measured in all stations of the study area exceed the limits of Canadian standards (15°C) (Table 5).

Hydrogen ion concentration (pH) values ranged from 7.20 during February in site 2 to 9.14 during December in site 1 in all study stations with narrow range values. The minimum average value was 7.79 in site 2 while the maximum average pH value was 8.49 in site 1 (Table 3 and Figure 15). In general, the concentrations are within the Iraqi Standards of pH concentration limits (Table 5) in all locations within the first four months, while at the stations 1 and 2 during April exceeded these limits, as well as at the station 1 during May.
Chloride (Cl) is the dominant anion with values ranging from 193 mg/l during December in site 1 to 5548 mg/l during May in site 6 in all study stations. The highest average value was 2117 mg/l in site 6 and the minimum average value was 514 mg/l in site 1 (Table 4 and Figure 16). All concentrations of chloride in the water of the study area exceed significantly the allowable limits (200 mg/l) (Table 5) except station 1 which was less than the Iraqi standards during December. The excessive increase in Cl value at location 6 belongs to refinery wastewater and is partly due to the mixing with saline marine waters of Khor Al-Zubair and Cl- rich inputs of Hor Al-Hammar.

Calcium values are ranging from 184 mg/l during December in site 1 to 1728 mg/l during May in site 6 in all study stations. The highest average value was 951 mg/l in site 6 and it, while the lowest value was 214 mg/l in site 1 (Table 4 and Figure 17). As stated above, Ca ions are responsible for water hardness. During the study period there was a decrease the concentration of calcium in the first two months of the study to be within the permissible standards (Table 5). The rise is observed during the other four months, and especially in stations 4, 5 and 6. Limestones and dolomites of Injana, Anah and Dammam formations are the probable main sources of Ca in Hor Al-Hammar and consequently Shatt Al-Arab and Shatt Al-Basrah rivers.

It is worth to mention that some extremely high pollutants concentration values appeared in sites 5 and 6 are due to wastewater discharged by the long pipe extended from the Wastewater Collection Basin inside the refinery to Shatt Al-Basrah between these sites. Finally, it can be concluded from the above field and laboratory test results that water samples indicate high pollutants concentrations during December, April and May months, while there was a decrease in pollutants concentrations particularly during the month of March.

Water Quality Index (WQI) of the study area

The CCME WQI relies on measures of three factors: the scope, frequency and amplitude of excursions from objectives. Based on the result findings, WQI calculation was carried out to determine the Shatt Al-Basrah River WQI. Ten parameters have been used to calculate the quality of water (WQI) for irrigation guide these are as follows: ammonia, ammonium, nitrate, sulfate, total dissolved solids, turbidity, water temperature, hydrogen ion concentration, chloride and calcium. After collecting water samples and in-situ inspections with the necessary laboratory examinations for the six sites during a period of six months, the differences in the results have been observed by location and period as presented in Table 3.

After finding these factors, the index itself can be determined by adding the three factors as if they were vectors. Therefore, for each factor, the sum of the squares is equal to the square of the index. With this model, the index changes in direct proportion to changes in all the three factors. Table 5 presents a summary for the calculated values of WQI and other related factors with stations involved in the study sites. The calculations show that all the study sites of WQI are within the range of 11.79 to 21.31. According to Water Quality Index Classification [3] (Table 2), all stations are categorized in the "poor category" in the polluted range of 0- 44. That means water quality is always endangered or deteriorated; conditions usually deviate from natural or desirable levels. Finally, the WQI for the study area is presented in Figure 18 for the period from December, 2014 to May, 2015. From the results obtained, the class of Shatt Al- Basrah River can be emphasized within Class V according to the studied types of water pollution. Finally, it can be stated that this method of water quality index assessment is seems to be more systematic; and it is easy for public understanding about the water pollution as well as a useful tool for water quality management in many ways.

CONCLUSIONS

The major conclusions drawn from the tests are summarized as follows:

1. Arc GIS map can be used as a basis for proper distribution of approbation location of water pollution measurement station. Arc GIS analysis distribution of water pollution maps showed that the highest concentration of pollutants in Shatt Al-Basrah.
2. The field and laboratory test results of water samples indicate high pollutants concentrations during December, April and May months, while there was a decrease in pollutants concentrations particularly during the month of March. Taking into consideration the impact of rainfall as well as some private water sewage outfall, as well as vulnerability to the phenomenon of tide as the study area is near to the Arabian Gulf.
3. It is noticed the high reflectivity values in areas that contain contaminants (turbidity) or oily spots with a purity of more sites.
4. Deterioration of the Shatt Al-Basrah river water quality is observed toward the south of Basrah city due to the flow of pollutants into the river.
5. The study also showed that the application of Water Quality Index (WQI) as a tool of assessing the overall surface water pollution was helpful and easily understandable.
6. Basically, decreasing the WQI value, show a higher level of water pollution in river. From the results obtained, the overall WQI class of the study sites in Shatt Al- Basrah River can be emphasized within Class V "poor category" in the polluted range according to studied types of water pollution.

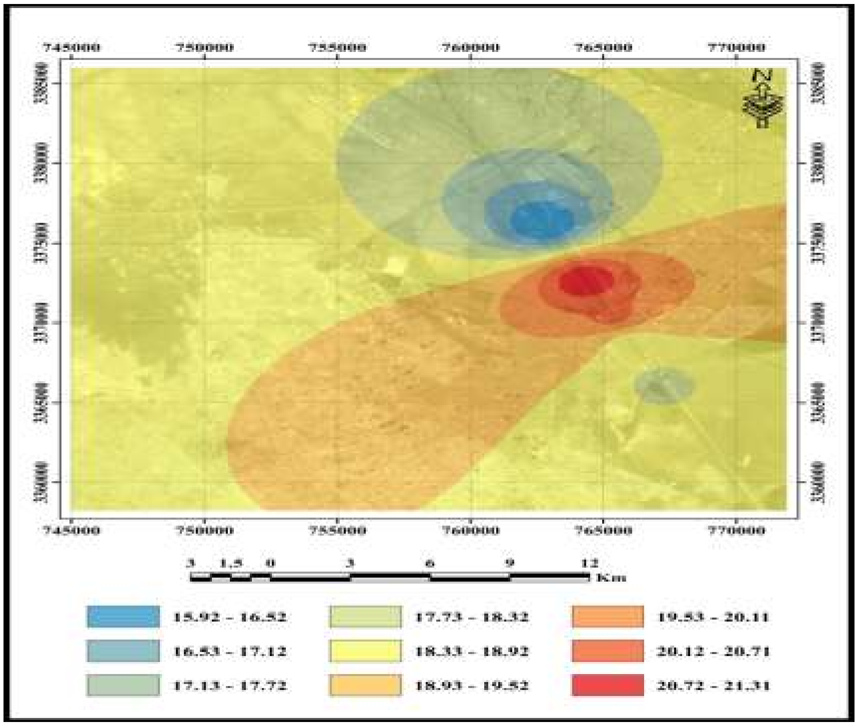

Figure (18) The WQI for Shatt Al-Basrah River within study area for the period from December, 2014 to May, 2015

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