ASSESSMENT OF PHYSICO-CHEMICAL PARAMETERS AND WATER QUALITY INDEX FOR SHATT AL ARAB RIVER, IRAQ

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Abstract- Shatt Al Arab River is one of the most important rivers in Iraq. It is formed by the concourse of the Tigris and the Euphrates in the small city of Al-Qurnah in the Basrah province of the southern part of Iraq. It is the main source of irrigation water for many towns and cities. The current work aims at evaluating the water quality index (WQI) in the surface water of the Shatt Al Arab River in Basrah province by monitoring five sampling locations within the River (namely, SH1, SH2, SH2B, SH3 and SH4) for a period of two seasons in winter and summer 2014. WQI was employed to assess the water quality of the River based on drinking, irrigation and aquatic life water usages. The water samples were exposed to comprehensive physico-chemical analysis, including pH, total dissolved solids (TDS), electrical conductivity (EC), Dissolved Oxygen (DO), alkalinity (Alk.), total hardness (TH), phosphate, magnesium, calcium, sodium, potassium, nitrate, chloride and sulphate. For determining the WQI, 12 parameters namely, pH, EC, TDS, K^+, Na^+, Mg^{2+}, Ca^{2+}, Alk., TH , Cl^-, NO_3^-, and SO_4^{2-} were considered. Moreover, it is evident from WQI values that ranging from poor to unsuitable for drinking water, poor to unsuitable for irrigation water , and poor to the unsuitable for aquatic life water.

Keywords- Water quality index; physico-chemical parameter; Shatt Al Arab River.

I. INTRODUCTION

Over the last decades, there was a need for increasing demand to monitor the water quality of several rivers by frequent measurements of different water quality parameters. The water quality for the water resources tends to be a topic of ongoing concern. The evaluation of changes in long-term water quality is further problem that is challenging. Simultaneously, the uncontrolled discharges of wastewater are causing instant and long-term water quality health impacts regarding the users.
As it is known, the river water is used for different uses, such as irrigation, domestic and industrial uses and it is the basic principle source of drinking water supply for people. For water resources, the regular water quality monitoring is definitely required to evaluate the quality of water for environmental health and hygiene, domestic use, industrial use, and agricultural use [1].

Principally there are four primary approaches that can be applied for water quality evaluation of a water body, these approaches are: water quality index, trophic status index, statistical analysis of the water quality data and biological analysis with other different biological indices [2]. The evaluation of water quality may be a difficult application in compound variables causing anxieties that are numerous general in the quality of water [3]. The monitoring of water quality is needed to provide an overview of water quality and to keep track of trends for long-range of the selected water quality parameters. The water quality monitoring is used to detect actual or possible problems for water quality and to find specific causes and to determine the effect of any kind of convective activity. Nowadays, computer systems offer the opportunity of handling and manipulating databases in many ways that have not been formerly an option that is practical. Nevertheless, in recent decades, population growth, runoff of sewage from urban areas, and agricultural practices, increases nutrient inputs to the level of their natural occurrence, causing accelerated eutrophication [4-5].

The water of branches for Shatt Al Arab River contains all the proceeded contamination discharged into the main river. These branches have many sources of pollution which possibly impacts and deteriorates of water quality regarding the river. In the center of Basrah province, there are many water treatment plants distributed on the right bank of the Shatt Al Arab River which is a source of caused dramatic changes in the river water quality by throwing waste water rich with Aluminium, Iron and chemical materials. In addition to waste disposals seepage from septic tanks and the villages which distributed very close to the river course and the agricultural effluents, are the major sources of contamination. Additionally, Hartha and Najabia electric power stations discharge its wastewater into the river. Finally, the pollution of the Shatt Al Arab River is may be referred to the effluents of various industrial wastes incoming at the river water. The pollution of the Shatt Al Arab River is also due to the increase of water withdrawals and the wastewater discharges, specially in its branches into the river that threatened the aquatic life of the river

Water quality index (WQI) is one of the most effective tools [6-7] to connect information on water quality to the interested residents and policy makers. WQI is a significant parameter to evaluate and manage surface/ground waters. The objective of the WQI is to transform complicated water quality data into reasonable and applicable information by the public. In this paper, the WQI values of the Shatt Al Arab River are assessed for drinking, irrigation and aquatic life utilizations. Hence, the current work has been performed with a focus to evaluate relatively the existing water quality of the Shatt Al Arab River by analysing the physico-chemical parameters as well as estimating WQI

II. MATERIALS AND METHODS

The surface water samples were two-times monthly collected (2014) at five monitoring sites along the Shatt Al Arab River (Fig.1). Details of the location of the surface water sampling along with their latitude and longitude are presented in Table 1.

The mean, minimum, maximum, range and the standard deviation of analytical results for each studied parameter for each period of analysis (i.e., January and August 2014) for the Shatt Al Arab River are summarized in Table 2. The water quality analysis of surface water samples was carried out to determine physico-chemical parameters in the river.

Five surface water samples were collected from different stations along the Shatt Al Arab River twice a month in January and August, 2014. The collected water samples were analysed for significant physico-chemical parameters following standard procedures [8]. pH , Dissolved oxygen (DO), electrical conductivity (EC), and total dissolved solids (TDS) were measured in the field immediately after sampling, alkalinity (Alk.), total hardness (TH), phosphate, magnesium, calcium, sodium, potassium, nitrate, chloride and sulphate were measured in the examined in the lab of environment according to the methods of the American Public Health Association [8]. All measured concentrations are expressed in the unit of mg/l, except pH and EC. Based on the results of physico-chemical analyses of parameters, statistical analyses were carried out by using the Statistica Software (ver.10). The results were evaluated in compliance with the norms recommended under World Health Organization ‘WHO’ [9].

Fig.1 Samples locations at the Shatt Al Arab River in Basrah

Basrah province is situated in South-part of Iraq, lies between $47^{\circ}40'$ and $48^{\circ}30'$ in the east and latitudes in $29^{\circ}50'$ and $31^{\circ}20'$ in the north. Basrah province covering an area extent of land for about 181 km^2. Basrah province bordered on the south by Kuwait and the Arabian Gulf, in the north by Maysan province, in the east by Iran, and in the west by the Dhi-Qar and Muthanna provinces. The climate of Basrah is classed as semi-arid climate which is dry and warm. Its rainfall distributed in an irregular manner over the eight months of the year. In general, the principal features of the climate of Basrah is always semi-arid climatic that prevail in the province. Basrah is the hottest cities in Iraq with summer temperatures frequently exceeding 50 °C with also a high humidity that sometimes exceeding 90%.

Station	Location of station	Latitude	Longitude
SH1	Before Garmat Ali River	30° 39' 0.684" N	47° 45' 33.48" E
SH2	Near 25 Million Basrah Water Project	30° 34' 27.12" N	47° 46' 45.77" E
SH2B	At Sanker, Abu Al-Khaseeb District	30° 27' 59.77" N	47° 56' 32.32" E
SH3	Near Sehan Water Project, at Seabah	30° 19' 36.26" N	48° 11' 39.44" E
SH4	At Boat Anchorage, Fao District	29° 58' 30.04" N	48° 29' 03.84" E

TABLE I Location of surface water sampling along the Shatt Al Arab River and the coordinates of stations.

Parameter	Winter season 2014				
	Mean	Min	Max	Range	SD
pH	7.87	7.45	8.10	0.65	0.25
DO	9.26	8.48	9.92	1.44	0.52
PO_4^{3-}	0.29	0.27	0.31	0.04	0.02
NO_3^-	8.41	6.97	10.03	3.06	1.50
Ca^{2+}	187.30	152.00	218.50	66.50	26.39
Mg^{2+}	82.00	53.00	106.00	53.00	24.94
TH	812.30	731.00	869.50	138.50	58.89
K^+	11.56	7.50	15.00	7.50	3.28
Na^+	654.50	490.00	950.00	460.00	176.41
SO_4^{2-}	455.00	350.00	525.00	175.00	75.83
Cl^-	732.50	567.50	1075.00	507.50	200.84
TDS	2592.00	2141.00	3254.00	1113.00	433.66
EC	3681.00	3185.00	4455.00	1270.00	515.62
Alk.	179.80	170.50	190.50	20.00	9.05
Parameter	Summer season 2014				
	Mean	Min	Max	Range	SD
pH	7.98	7.65	8.20	0.55	0.20
DO	6.65	5.14	7.67	2.53	1.02
PO_4^{3-}	0.34	0.28	0.45	0.17	0.07
NO_3^-	10.76	7.74	15.92	8.18	3.11
Ca^{2+}	302.40	160.00	680.00	520.00	220.94
Mg^{2+}	488.10	79.50	1416.00	1336.50	577.90
TH	2790.00	730.00	7600.00	6870.00	2954.12
K^+	81.96	8.20	300.00	291.80	123.25
Na^+	3742.00	450.00	12600.00	12150.00	5188.55
SO_4^{2-}	562.00	360.00	1200.00	840.00	358.51
Cl^-	4638.20	494.00	16150.00	15656.00	6690.30
TDS	10780.60	1915.00	35663.00	33748.00	14395.45
EC	14673.00	2835.00	46650.00	43815.00	18610.08
Alk.	169.70	146.50	189.50	43.00	20.75

TABLE 2 Analytical results of water samples for the stations of the Shatt Al Arab River.

The study area is representing the Shatt Al Arab River, which is located in Basrah province. The river is located in the southern part of Iraq. Monthly discharge measurements and water quality variables properties of the Shatt Al Arab River have been monitored at different stations along the river. Because of the industrial and agricultural activities along the banks of the Shatt Al Arab River, large quantities of industrial wastewater, rural domestic wastes, and untreated urban municipal discharge into the river and its branches which became a simple dumping site for all sorts of wastes. A great quantity of the river water that used for irrigation is returned to the river by return flows and drainage. The return flows have actually a high concentration of heavy metals, fertilizers, suspended and dissolved solids, as well as the pesticides which break the national effluent standard. Agro-industrial effluents, agricultural return flows and domestic wastewater from the cities are the main pollution sources of the Shatt Al Arab River.

The using of WQI is providing an image that is comprehensive of the quality of surface/ground water for different uses. WQI is specified as a ranking that reflects the composite affect of different water quality variables [10]. WQI is calculated from the real point of view for the suitability of water for human consumption. Therefore, for computing the WQI in the existing study, 12 parameters among them, pH, EC, TDS, K^+, Na^+, Mg^{2+}, Ca^{2+}, alk., TH , Cl^-, NO_3^-, and SO_4^{2-} were considered.

For calculating of WQI of a water sample, a weight (w_i) was assigned for each studied parameter. The assignment weight was based on their sensed effects on primary health and its related importance in the overall quality of water. The major effects of importance parameter on water quality were assigned the highest weight of 5 (such as TDS and NO_3^-), whereas the variables that are regarded as not harmful, was assigned a lowest weight of 2 (such as K^+, Mg^{2+}, Ca^{2+} and TH). The other parameters were assigned a weight of 3. The relative weight (W_i) of each parameter computed using equation 1.

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad \text{--------------------------- (1)}$$

Where W_i is represents the relative weight, and w_i represent the weight of each parameter and n is the total number of studied parameters.

Next, for each parameter, a quality rating scale (q_i) is computed by dividing the concentration in each water sample by its respective standard matching the standard guidelines (shown in Table 3) and then, the result of the division was multiplied by 100 using Equation 2.

$$q_i = \left(\frac{C_i}{S_i}\right)100 \qquad \text{---------------------- (2)}$$

Where qi is quality rating, C_i is the concentration of the studied parameter in each water sample represented in mg/l, S_i is standard guidelines (Table 3) for each studied parameter represented in mg/l except for conductivity (µS/cm) and pH.

Finally, WQI was computing depends on the water quality sub-index SI_i for each studied parameter that is first determined, and then it was used to determine the WQI as per the equations 3 and 4.

$$SI = W_i \; q_i \qquad \text{---------------------- (3)}$$

$$WQI = \sum_{i=1}^{n} SI_i \qquad \text{---------------------- (4)}$$

Where SI_i represent the sub-index of i^{th} parameter; q_i represent the rating based on concentration of i^{th} parameter and n is the total number of parameters.

Parameter	Unit	Drinking water [a] [11]	Irrigation water [b] [12]	Aquatic live [c] [13]
pH	-	8.5	8.5	9
EC	µS/cm	1000	2000	
TDS	mg/l	500	2000	500
Alk.	mg/l	250		
TH	mg/l	500		
Ca^{2+}	mg/l	75	400	
Mg^{2+}	mg/l	50	60	
Na^+	mg/l	200	919	
K^+	mg/l	12	2	
Cl^-	mg/l	200	1063	120
SO_4^{2-}	mg/l	250	960	
NO_3^-	mg/l	45	10	2.93

TABLE 3 Analytical results of water samples for the stations of the Shatt Al Arab River.

[a] (WHO , 2011) [11]
[b] (FAO , 1994) [12]
[c] (CCME, 2007) [13]

WQI has been classified into five classes; the water quality is rated excellent, good, poor, very poor and unfit when the value of the index lies between 0–50, 51–100, 101–200, 201–300 and > 300, respectively (Table 4).

WQI value	Rating of water Quality
< 50	Excellent
50–100	Good
101–200	Poor
201–300	Very Poor
> 300	Unsuitable

TABLE 4 Analytical results of water samples for the stations of the Shatt Al Arab River.

III. RESULTS AND DISCUSSION

pH is actually a numerical expression that implies the degree to which water is acidic or neutral or alkaline. When the pH value was low, it tends to make water corrosive and when its value was high, it provides taste problem and negative impact on eyes and skin [14]. pH value of water samples ranged between 7.45-8.10 and 7.65-8.20 during the winter and summer seasons, respectively. The mean pH of water samples was 7.87 ± 0.25 (winter) and 7.98 ± 0.20 (summer). pH range between 6.0 and 8.5 denotes the productive nature of any water body [15]. But, pH water samples in both seasons in the present study within the permissible limit of 6.5–8.5 [11]. DO is an significant parameter to evaluate the waste assimilative ability of the waters [14]. DO change daily, seasonally and with difference in water temperature [16]. Dissolved oxygen is the maximum dissolve concentration of oxygen in water. According to DO trophic levels, DO levels in Shatt Al Arab River were varied. The depletion of DO level in water perhaps is the most frequent result of the water pollution [17]. DO may vary from time to time and place to place, because DO is a function of water temperature. The mean DO concentration in the water samples ranged between 9.26 ± 0.52 mg/l (winter) and 6.65 ± 1.02 mg/l (summer). When the drop of DO levels in water be below 5.0 mg/l, different life forms are put under stress [18]. The mean DO values in the water of Shatt Al Arab River were above the desirable limit of 6 mg/l.

In water samples of Shatt Al Arab River, the phosphate concentration ranged between 0.27-0.31 mg/l and 0.28-0.45 mg/l for winter and summer, respectively. The average phosphate values of 0.29 ± 0.02 mg/l (winter) and 0.34 ± 0.07 mg/l (summer), were well and below the permissible limit for all guidelines. The concentration of nitrate in water is commonly low but it can attain high levels as a result of refuge dump runoffs, agricultural runoff, or pollution with animal or human wastes [19]. The mean nitrate concentration in the water samples was 8.41 ± 1.50 mg/l (winter) and 10.76 ± 3.11 mg/l (summer). Nitrate concentration in the water samples was ranged between 6.97 and 10.03 mg/l (winter) and between 7.74 to 15.92 mg/l (summer). The mean concentration of calcium in the water samples was 187.30 ± 26.39 mg/l (winter) and 302.40 ± 220.94 mg/l (summer). It is apparent that concentration of calcium in the water samples showed higher calcium content. However, calcium content in some water samples was below the permissible limit of 200 mg/l. The average magnesium values in the water samples was 82.0 ± 24.94 mg/l (winter) and 488.10 ± 577.90 mg/l (summer), while it is evident that the water samples had magnesium concentration above the permissible limit of 50 mg/l. Calcium and magnesium ranged between 152.00-218.50 mg/l and 53.00-106.00 mg/l, respectively during the winter season, and 160.00-680.00 mg/l and 79.50-1416.00 mg/l, respectively during the summer season. Most of the water samples exceed the permissible limits of WHO [9] regarding calcium and magnesium.
The values of total hardness was 812.30 ± 58.89 mg/l (winter) and 2790.00 ± 2954.12 mg/l (summer). Total hardness values in the water samples were above the permissible limit of 500 mg/L [11]. For drinking water, the degree of hardness has been classified in terms of its equivalent concentration of CaCO3 [20]. Table 5, show that all the water samples of the study area belong to the very hard category [21].

Classification	Hardness range (mg/l)
Soft	0-75
Medium hard	75-150
Hard	150-300
Very hard	Above 300
Soft	0-75

TABLE 5: -Classification of water based on hardness (WHO, 2004) [20]

The average potassium concentration in the water samples was 11.56 ± 3.28 mg/l (winter) and 81.96 ± 123.25 mg/l (summer). Most of the water samples showed very high potassium content compared to the permissible limit of 2 mg/L [12] when the river water may be used for irrigation. The mean sodium concentration the water samples was 654.50 ± 176.41 mg/l (winter) and 3742.00 ± 5188.55 mg/l (summer). It is evident that the water samples of the Shatt Al Arab River in both seasons showed sodium values above the permissible limit of 200 mg/l. The concentrations were varied 7.50-15.00 mg/l for potassium, and 490.00-950.00 mg/l for sodium during winter and summer seasons, respectively. Whereas, the potassium content ranged 8.2-300.00 mg/l during the winter season, and the content of sodium was ranged 450.00-1260.00 mg/l during the summer season.

The largest portion of potassium content is due to fertilizers of agricultural activity and the intrusion of the saline water. In this study, it was revealed that the concentrations of calcium, magnesium, potassium and sodium were higher in summer than in the winter season The average sulphate concentration in the water samples was 455.00 ± 75.83 mg/l (winter) and 562.00 ± 358.51 mg/l (summer). All of the water samples showed sulphate contents above the permissible limit of 250 mg/l. The mean chloride concentration in the water samples was 732.50 ± 200.84 mg/l (winter) and 4638.20 ± 6690.30 mg/l (summer). All the water samples in the study area showed higher chloride values compared to the permissible limit of 200 mg/l. The sulphate concentration ranged between 350.00-525.00 mg/l and between 360.00-1200.00 mg/l for winter and summer season, respectively. While, the chloride concentration ranged between 567.50-1075.00 mg/l and between 494.00-16150.00 mg/l for winter and summer season, respectively. Total dissolved solids (TDS) generally contained inorganic salts and small amount of organic matter. The mean concentration of total dissolved solids in the water samples was 2592.00 ± 433.66 mg/l (winter) and 10780.60 ± 14395.45 mg/l (summer). Most of TDS values in the water samples were above the FAO permissible limit of 2000 mg/l except in one station (SH1) in summer that was within the permissible limit of 2000 mg/l.

Electrical conductivity of water is used as an index to express the total soluble salt concentration in water [22-23]. Excess electrical conductivity lead to corrosion, scaling in boilers, and quality destruction of the product. The average electrical conductivity values were 3681.00 ± 515.62 µS/cm (winter) and 14673.00 ± 18610.08 µS/cm (summer). Relatively higher electrical conductivity values were recorded in all water samples, attributed to the high degree of anthropogenic tasks such as sewage inflow, waste disposal and agricultural runoff [24].

Alkalinity is a measure of the capability of water for acids neutralization. Large amount of alkalinity offers a bitter taste, reduces crop yields because it is harmful for irrigation as it damages soil [25]. In the water samples, the mean of total alkalinity values was 179.80 ± 9.05 mg/l (winter) and 169.70 ± 20.75 mg/l (summer). It is evident that alkalinity values in the water samples were above the permissible limit of 45 mg/l [11] during both seasons.

Tables 6,7 and Fig. 2 show the values of the WQI for the water of the Shatt Al Arab River. The WQI ranking for Drinking water was calculated using the WHO guidelines [11], whereas, the FAO guidelines [12] were used to calculate the WQI ranking for irrigation water in the study area. The WQI of water for the aquatic life usage was calculated using CCME guidelines [13]. 12, 10 and 4 variables were used for the computation of WQI relating Dinking, irrigation and aquatic life requirements, respectively. The selected parameters for drinking water consist of pH, EC, TDS, K^+, Na^+, Mg^{2+}, Ca^{2+}, Alk., TH , Cl^-, NO_3^-, and SO_4^{2-} . The selected parameters of pH, TDS, EC, K^+, Na^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, and SO_4^{2-}, were selected for irrigation water. The selected variables for Aquatic life include pH, TDS, Cl^- , and NO_3^-.

Station	Drinking		Irrigation		Aquatic live	
	WQI	Type	WQI	Type	WQI	Type
SH1	196.03	Poor	108.57	Poor	273.08	Very poor
SH2	235.53	Very poor	135.07	Poor	305.16	Un-suitable
SH2B	238.57	Very poor	135.63	Poor	323.43	Un-suitable
SH3	202.73	Very poor	107.37	Poor	323.66	Un-suitable
SH4	286.21	Very poor	155.90	Poor	422.35	Un-suitable

TABLE 6:- the categories of WQI in the Shatt Al Arab River in winter season, for drinking, irrigation, and aquatic live usage.

The results show that WQI values of the studied stations on Shatt Al Arab River range between 196.03–286.21, 107.37–155.89 and 273.08–422.35 with respect to drinking water, irrigation water and aquatic life in winter season (Table 6). In summer season, the WQI values of the study area stations in Shatt Al Arab River range between 179.32–3104.73, 101.43–1961.05 and 265.29–3593.69 according to standard guidelines for drinking water, irrigation water and aquatic life (Table 7).

Station	Drinking		Irrigation		Aquatic live	
	WQI	Type	WQI	Type	WQI	Type
SH1	179.32	Poor	101.43	Poor	265.29	Very poor
SH2	231.07	Very poor	150.95	Poor	421.16	Un-suitable
SH2B	283.02	Very poor	213.06	Very poor	388.99	Un-suitable
SH3	1030.06	Un-suitable	540.63	Un-suitable	1224.51	Un-suitable
SH4	3104.72	Un-suitable	1961.05	Un-suitable	3593.69	Un-suitable

TABLE 7: -the categories of WQI in the Shatt Al Arab River in summer season, for drinking, irrigation, and aquatic live usage.

This study indicates that the water quality fluctuation of Shatt Al Arab River can be classified from poor to unsuitable water for drinking and can be classified from poor to unsuitable for irrigation water. Whereas, for aquatic life usage of water, the water of the Shatt Al Arab River can be classify from very poor to the unsuitable type.

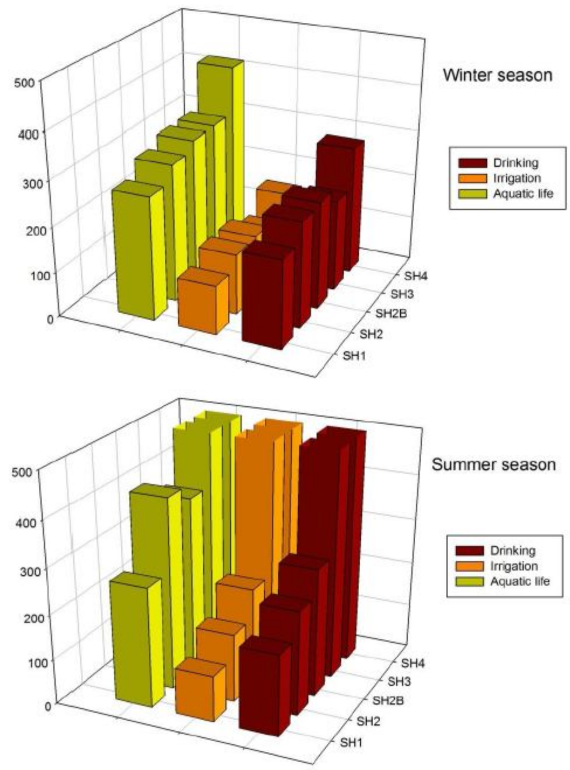

Fig.2 WQI values for drinking, irrigation, and aquatic live usage at the Shatt Al Arab River in Basrah (a) in winter season and (b) in summer season.

CONCLUSION AND RECOMMENDATION

Shatt Al Arab River is the main source of irrigation for Basrah province, cities and districts. Shatt Al Arab River is exposed to extraordinary damage in its water quality as a result of different wastes that discharge entering the water body. In this research, the water quality index method was used to assess the suitability of Shatt Al Arab water for drinking, irrigation, and aquatic life purposes. While WQI results show that the water quality of the river is poor for irrigation usage and poor to unsuitable for drinking and aquatic life usage according to some of the selected parameters in the existing study. Hence, the analysis disclosed that the water of the river for both season in 2014, requires the treatment of the water of the river before usage especially for drinking and it is important to protect water from the contamination. Therefore this study advises to constrain the control on the waste that discharged into the river, to the agreement with the discharge effluent to protect the Shatt Al Arab River and its waterways from the pollution.

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