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RESEARCH ARTICLE

Assessment of the lower reaches of Tigris River by a development of a water quality index (WQI)

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ABSTRACT:
Water samples were collected monthly from three stations along of Tigris River northeast of Basra city from October 2015 to September 2016. Eight of the ecological parameters were used to assess of water quality, temperature of water (T), electric conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), total hardness (TH), chloride (Cl^-), turbidity and hydrogen ion (pH). The mean value of temperature was 24.8°C ± 10.4. Low rate of electric conductivity was (1.39 mS/cm) recorded in February and highest (3.27 mS/cm) in July with mean value 2.15mS/cm ± 0.559. The average value of dissolved oxygen was 7.5mg/l ± 0.951. Total dissolved solid was varied from 966mg/l in February to 1710mg/l in July with average 1454.7 mg/l ± 282.4. The results of TH ranged from 675 mg/l in February to1258.33 mg/l in July and mean value 948.8 mg/l ± 104.9. Minimum value of Chloride was (183.30 mg/l) obtained in February, while the maximum value was (496.50 mg/l) observed in December and averaged 298.07 mg/l ± 104.9. The mean value of turbidity was 75.62 NTU ± 38.33. The pH values were always within alkaline direction and mean 7.9 ± 0.315. The monthly variations of water quality index were different among months and the seasons in study stations, with a general mean of 2.02, noted that water in Tigris River can be considered acceptable. In the seasons, the best level of WQI indicated in the winter (2.53) and spring (2.16) was seasons were good.
Keywords:

KEY WORDS: Water Quality Index, Freshwater, Tigris River, Basrah, Iraq.

INTRODUCTION:
Fresh water quality is one of the six national-level environmental indicators that were deemed appropriate as indicators that would be reported annually (CCME, 2001) .Water of rivers and reservoirs are important for domestic activities, industry and livestock production (Rubio – Arias et al. 2013). Nowadays, anthropogenic activities have contributed in pollution at ecosystems; consequently it is necessary to employ new tools and methodologies to determine levels of pollution of any ecosystem at a given time (Ma et al. 2013). One alternative is the estimation of the water quality index (WQI) (Liou et al. 2004).The quality of maintain ecosystems health is largely a function of natural background condition. Some aquatic ecosystem are large changes in water quality without any detectable effects, whereas others ecosystem are sensitive to small changes in the physicochemical properties of the body of the water and this can leads to degradation of ecosystem services and loss of biological diversity (Al-Janabi et al. 2012).The concept of water quality index (WQI) was first proposed by (Horton, 1965), which developed the first WQI and then this tool has used to determine water quality in rivers (Qian et al. 2007). Water quality index (WQI) has considered as a mathematical tool instrument used to transform a large of water quality data into a single number, usually dimensionless which is expresses the relative magnitude of some complex phenomenon (Lohani

and Maw Sen, 1987).Ideally, however, water quality should be assessed using physical, chemical parameters in order to provide a full spectrum of information for adequate water management (Diaz and Lopez 2007). Any number of water quality measurements can serve, and have already been used, as indicators of water quality (UNESCO/WHO/UNEP, 2007).The particular problem in the case of water quality monitoring is the complexity associated with analyzing the large number of measured variables and high variability due to anthropogenic and natural influences (Simeonov et al. 2002). In some cases WQI values allow for identifying pollution variables, consequently for recommending preventive action in the water ecosystem (Srivastava et al. 2011).This methodology had been used in such countries as the United States (Rubio – Arias et al. 2013), Argentina (Almeida et al. 2012), Brazil (Coletti et al. 2010).The availability of water in Iraq shows great deal with spatial and temporal (Rahi and Halihan, 2010). In Iraq, there have been many studies about application of WQI to assess the water of Tigris River (Al-Obaidy et al. 2010a), Dokan Lake (Al-Obaidy et al. 2010b) and Euphrates River (Al-Heety et al. 2011; Hussein et al. 2015). The objective of study is to develop a WQI for the water of the Tigris River and to assess the spatial variability of the parameters.

MATERIALS AND METHODS:

The Tigris River is one of two major rivers of the Middle East stretching for over 1900 km, of which 1415 km are within Iraq, it originates in the Toros mountains of southeastern Turkey (Rzoska, 1980). There are many tributaries flow into the river; these include Botmanse, Kessora, Al- Khabur, the Greater and Lesser Zabs and Al-Adhaim and Diyala Rivers and main river source of drinking, irrigation, agriculture and fishing (Mutlak et al. 1980). The present study was carried at the Northeast Basrah in Quran city and is located between latitude 31° 09' 53.45" N and longitude 47° 26' 23.23" E, with a distance (30 km). The present study area included three stations on Tigris River. The first station located between latitude 31° 09' 53.45" N and longitude (47° 25' 56.89"E in the north-east Quran city in Aljewber village, the second station located after first station by 7 km in Abu-Aran village between latitude 31° 07' 48.15" N and longitude 47° 26' 38.79" E. The Third station located between latitude 31° 00' 42.71" N and longitude (47° 26' 23.23" E (Fig. 1). Water samples were collected from the mid of the river during 2015 to 2016; the water samples collected monthly and seasons from each stations by using clean polypropylene bottles.

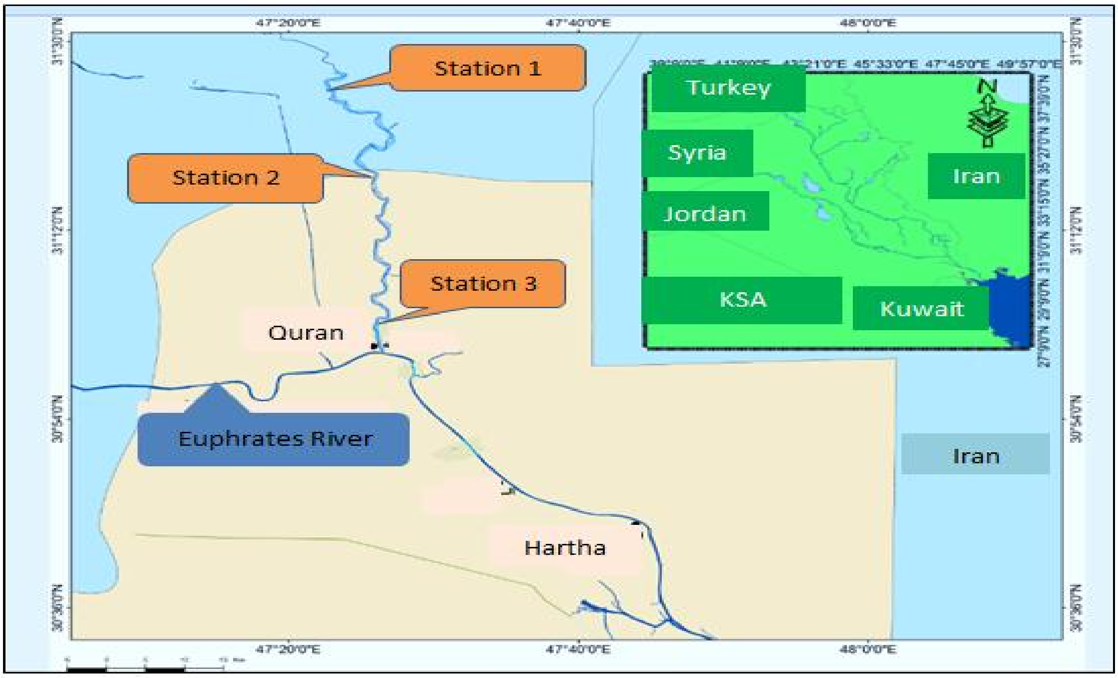


Fig. 1: Map of the study area with the location of the 3 sampling stations.

The WQI was calculated following the methodology recommended by (Rubio – Arias et al. 2013). The following variables were evaluated in *situ*; Ion hydrogen (pH), electrical conductivity (EC). Total dissolved solids (TDS) and temperature (T) were measured by a Hanna instruments (a waterproof HI-9146 pH/EC/TDS/ temp. model), turbidity was estimated with a turbid meter HI- 93703C. The pH level is reported in PH units, EC in µ.Sm, TDS in mg/l, temp. In Celsius degree (°C), turbidity is reported in nephelometric turbidity units (NTU). The following variables were evaluated in the laboratory: dissolved oxygen (DO) was determined according to the (Welch, 1964) and the results are expressed in mg/l, total hardness (TH) was estimated by EDTA titration and the result are expressed in mg/l, while Chloride (Cl^-) was determined using the Mohr method for describe in (APHA, 2005).

Statistical analysis and WQI calculation

Data analyses were carried out in two steps (Rubio – Arias et al. 2013). First step, an analysis of variance (ANOVA) was performed for each variable. Second step WQI was collected. In first step, each parameter a specific weight in a range of 1 to 4 according to the level of importance water quality parameter. Four represented the most important and one the least important. The WI values were assigned as follows: pH, DO, and EC were assigned 4; T and turbidity were assigned 3; TDS and TH were assigned 2; and Cl was assigned 1. This information show in table 1. In the second step, the result of each variables were obtained previously from the ANOVA were examined independently to scrutinize the specific weights of the parameters according to a range of tolerance (Pi). Pi= 1 assigned to the variables with values in the ideal ranges, while values outside the ideal range were given Pi= 2. (Table 1). The WQI was calculated with the following Equation (1) by (Rubio – Arias et al. 2012).

$$WQI = \frac{\sum_{i=1}^{n} Pi*wi}{\sum_{i=1}^{n} Pi} * k \quad (1)$$

Where:

WQI = water quality index

Wi = specific weight of each variable (1-4).

Pi = Range tolerance

K = constant (1; 0.75; 0.50)

Table (1) Values were assigned for water quality index parameters (Rubio – Arias et al. 2013)

Parameters	Units	Wi	Pi	Range Tolerance
T	°C	3	1	20-25
			2	<20
			2	>25
EC	mS/cm	4	1	2.50-5.00
			2	<2.50
			2	>5.00
DO	Mg/l	4	1	5-7
			2	<5
			2	>7
TDS	mg/l	2	1	120-500
			2	<120
			2	>500
Total hardness	mg/l	2	1	150-300
			2	<150
			2	>300
Cl^-	Mg/l	1	1	250-300
			2	<250
			2	>300
Turbidity	NTU	3	1	5-10
			2	<5
			2	>5
pH	-	4	1	6.5-8.5
			2	<6.5
			2	>8.5

*Wi (Specific weight), **Pi (Range of tolerance)

K; represents a constant according to the level of contamination when the sample was taken. A value of 1 was assigned to clear water without apparent contamination; 0.75 to water with a low of turbidity from natural processes; and the 0.50 to contaminated water.

The calculated WQI was classified according to the following range : >2.5 were excellent; 2.0 to 2.5 good quality water; and < 2.0 poor quality water.

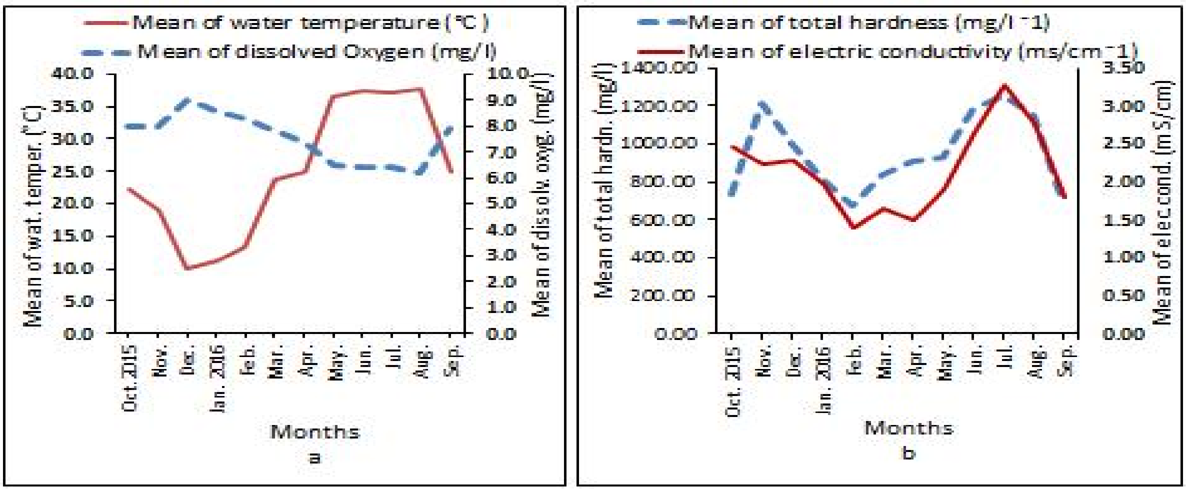
RESULTS:

Physicochemical environment

There were ecological factors attributes that showed rates monthly and standard deviations of eight variations during the sampling of period in three stations (Table 2) (Fig. 2). The lowest rate of water temperature 10.0 °C in December and highest 37.6°C in August and mean value 24.8°C± 10.4 (Fig. 2a). Low rate of Electric conductivity (1.39 mS/c) was recorded in February and the highest (3.27 mS/cm) in July with mean value 2.15 mS/cm ± 0.559 (Fig. 2b) in among stations. Dissolved oxygen values ranged from 6.2 mg/l in August to 9.0 mg/l in December of the mean value 7.5mg/l ± 0.951(Fig. 2a). Total dissolved solid varied from 966 mg/l in February to 1710 mg/l in July with average 1454.7 mg/l± 282.4(Fig. 2c). The result of Total hardness varied from 675 mg/l in February to1258.33 mg/l in July and mean value 948.8mg/l ± 104.9. (Fig. 2b). Minimum value of Chloride (183.30 mg/l) was recorded in February, while maximum value (496.50 mg/l) was observed in December and average 298.07 mg/l ± 104.9 (Fig. 2c) in among three stations. The results showed that turbidity was higher (128.67 NTU) in January and lowest (10.72NTU) in June with mean value 75.62 NTU± 38.33 (Fig. 2d). During the study period, the pH varied from 7.45 in October to 8.5 in January with mean 7.9 ± 0.315. (Fig. 2d). The ANOVA of water temperature and dissolved oxygen exhibits no significant differences between three stations ($F= 0.057$, $F= 2.06$, $P>0.05$) respectively. The Electrical conductivity weren't significant differences for the months in studied stations ($P>0.05$). There were statistical differences for the variable turbidity ($P<0.05$) in among stations. The ANOVA of TDS was no statistically significant for the months ($F=0.118$, $P>0.05$) during study period. Total hardness variable was significant differences for sampling months ($F= 3.014$, $P<0.05$). The results showed no significant differences ($F= 1.753$, $P>0.05$) in Chloride (Cl^{-2}) concentrations between three stations. No significant differences values of pH were detected during the period times of the study.

Table 2: The results of the statistical analysis of the eight physico-chemical parameters at the lower reaches of Tigris River during 2015- 2016

Parameter	Units	Mean	STD	Minimum	Maximum
Water temperature	° C	24.8	± 10.41	10.0	37.6
EC	mS/cm	2.15	± 0.559	1.4	3.3
DO	mg/l -1	7.5	± 0.951	6.2	9.0
TDS	mg/l -1	1454.7	± 282.4	966	1710
TH	mg/l -1	948.8	± 209.4	675.0	1258.3
Cl	mg/l -1	298.07	± 104.9	183.3	496.5
Turbidity	NTU	75.62	± 38.33	10.7	128.0
pH	-	7.9	± 0.315	7.5	8.5



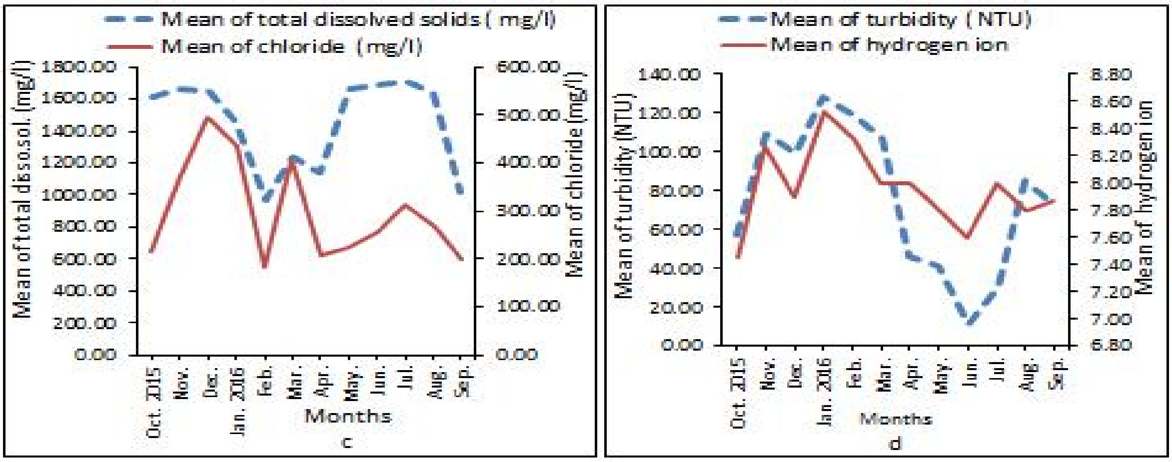


Fig. 2: Monthly variations of temperature, dissolved oxygen, total hardness, electrical conductivity, total dissolved solids, chloride, turbidity and hydrogen ion at the lower reaches of Tigris River during 2015-2016.

Table 3 shows the Pearsone's matrix, refers to the strong correlation (P<0.05) between DO and, pH, T (r =0.032, 0.001) respectively, from the other hand the result indicating that correlation between TDS and EC (r= 0.002) at level 0.05, while the strong positive correlation (P<0.05) between TH and T, EC, TDS (r= 0.048, 0.006, 0.005) in same order. The results indicate a positive correlation (P<0.05) between Cl and T (r= 0.05). Turbidity correlate (P<0.05) with T, DO, and TH (r= 0.035, 0.038, 0.029) respectively.

Table 3: Pearson's correlation matrix for the physical-chemical parameters at the lower reaches of Tigris River during 2015- 2016

Parameter	pH	T	EC	DO	TDS	TH	Cl
T	0.069						
EC	0.22	0.088					
DO	0.032*	0.001*	0.159				
TDS	0.274	0.232	0.002*	0.461			
TH	0.815	0.048*	0.006*	0.237	0.005*		
Cl	0.228	0.05*	0.681	0.068	0.246	0.381	
Turbidity	0.231	0.035*	0.235	0.038*	0.178	0.029*	0.166

Water Quality Index (WQI)

Monthly variations of Water Quality Index were differences among months in study stations (Table 4 and Fig. 3a), with a general mean of 2.02, was noted that the water in Tigris River can be considered as acceptable. The results exhibited, that water was poor during June, July, August and September because the index was below 2.0, it varied from 1.37 in August to 1.5 in September. Our results were show that the best water quality were in the October, November, December, January, March, April and May when the water classified as good. The highest WQI (2.7) as excellent was recorded in February 2016.

Table 4: Monthly variations of water quality index values at the lower reaches of Tigris River during October 2015 - September 2016

Months	WQI	Water Quality
October 2015	2.1	Good
November	2.2	Good
December	2.4	Good
January 2016	2.5	Good
February	2.7	Excellent
March	2.5	Good
April	2.3	Good
May	2.0	Good
June	1.4	Poor
July	1.35	Poor
August	1.37	Poor
September	1.5	Poor
mean	2.02	Good

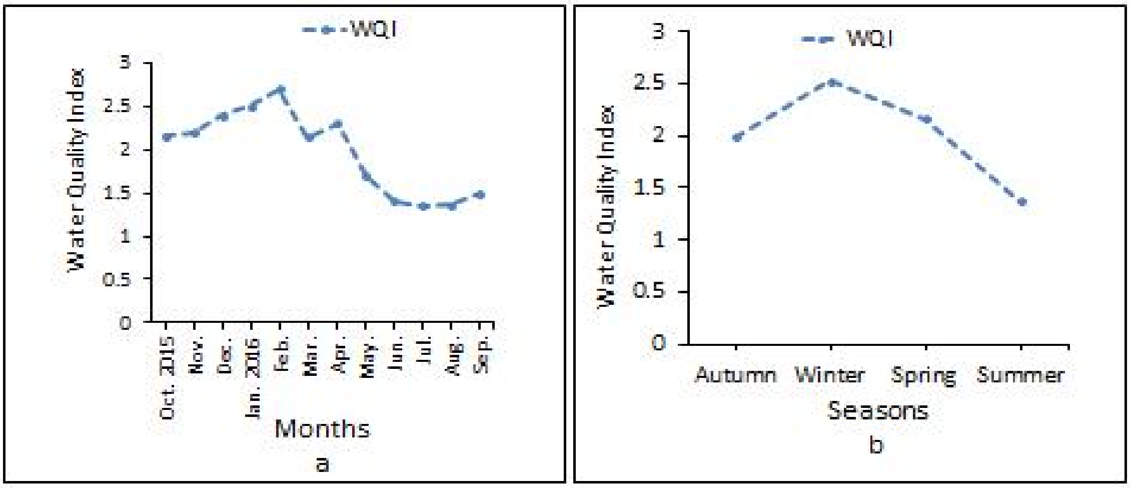


Fig. 3:Variations of monthly and seasons in values of water quality index at the lower reaches of Tigris River during 2015-2016.

In seasons, the best WQI level was noted in the winter and spring (2.53, 2.16) respectively were good and the lowest was recorded in Summer and Autumn (1.37, 1.99) in same order, when the water classified as poor, (Table 5 and Fig. 3b).

Table 5: Seasons variations in values of water quality index at study stations from October 2015 to September 2016

Seasons	WQI	Water quality
Autumn	1.99	Poor
Winter	2.53	Good
Spring	2.16	Good
Summer	1.37	Poor

DISCUSSION:

Temporal variations occur within an aquatic system, by relating to potential water used, the effect of this change on the system of environmental (Al-Janabi et al. 2012). Temperature effects of water quality were directly influences on dissolved oxygen in aquatic system (APHA, 2005). The monthly variations in water temperature in the present study area may be due to the variation in the sampling time at each station which confirmed by (Hussein et al. 2013). The results of Electric conductivity analyzed were higher in the summer than in winter season and the maximum of average values (3.27mS/cm) were recorded in July. Moreover, it is well documented that EC values are a good indicators that have been used to calculate WQI especially where high EC values indicate heavy levels of inorganic contamination (Rubio – Arias et al. 2012**).** EC of Tigris river with in (Standard Specification, 2001).The results indicated high rate of dissolved oxygen in a relatively cold months for the study due to the lack of consumption and velocity and turbulence in water speed, the minimum values of DO recorded at station 3, that may be received of the sewage to the river directly through discharge which lead to the depletion of DO (Rabee et al. 2011). TDS and TH in the study stations were found to be high during June, July and August and low during the February, March, April. The indicated of higher values could be attributed to the low amount of rainfall. High levels of TDS are caused by the presence of potassium, chlorides and sodium these result conformed by (Lawson, 2011). Chloride (Cl^{-1}) rates are affected by the activities derived from irrigation, drainage and the use of pesticides and fertilizer different source (Amteghy, 2014). The results noted that rates of Cl^{-1} in Tigris River with in (Standard Specification, 2009). Turbidity caused by runoff in aquatic ecosystem and as consequence, raises contamination levels (Whitehead et al. 2009).The highest values rates were recorded in November to March (Fig. 2d), this may be attributed to presence of organic matter pollution, heavy rain fall, other effluents and water current speed, this deduced by (UNESCO/WHO/UNEP, 2007).The turbidity values obtained at all selected there stations was found to be above standard limits of (WHO, 2008) and (Standard Specification, 2001). The pH is another important factor influencing the metabolism of organism inhabiting in aquatic ecosystem (Al-Saad et al. 2010).The pH, values were always within alkaline direction (Fig. 2d), this was recorded in Iraqi inland waters by (Hussein et al. 1992) and (Alkam and Abdumunem, 2011) and within limits natural waters, this pointed from (APHA, 2005).

Water quality is an aquatic ecosystem is determined by many physical, chemical parameters (Buhlool et al. 2014). The results were noted that water from Tigris River can be considered as acceptable. Although, the lowest values recorded, it varied from 1.35 in July to 1.5 in September (Table 3 and Fig. 3). The values of index below 2.0 during the summer season because some of variables outside the Pi range are vulnerable as a result the low of water quality (Rubio - Arias et al. 2013). These values were observed in dry seasons, and conformed by (Moyel, 2010), during of study on northern part of Shatt Al- Arab River. Moreover, the WQI values are effect by general of contamination, such as industrial, agriculture and human activities (Ismail et al. 2014). The best of water quality index rates were pointed in the winter and spring seasons in range 2.16 to 2.53 respectively (Fig. 3b) which noted by (Rabee et al. 2011), during of water assessment in Tigris River at Baghdad Region.

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