I.J.S.N., VOL.8 (4) 2017: 741 - 756 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

ASSESSMENT OF WATER QUALITY AND SUITABILITY OF EUPHRATES RIVER IN IRAQ FOR DRINKING PURPOSE BY APPLYING WATER QUALITY INDICES (WQIs) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) TECHNIQUES

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ABSTRACT
To understand the Iraqi surface water quality for drinking purpose or any intended use, it is important to study the quality of the water and concentration of several parameters by applying Water Quality Indices (WQIs) and Geographic Information System (GIS) techniques which can give an accurate and adequate evaluation as well as indicating pollution, saving required time, water quality management and decision-making. Therefore, three WQIs methods were adopted in this study to assess, compare and judge the suitability of Euphrates River at multi locations inside Iraqi land for drinking purpose. These methods include Bhargava Water Quality Index (BWQI), Weighted Arithmetic Water Quality Index (WAWQI) and Canadian Water Quality Index (CCMEWQI). The analysis includes several water quality parameters: pH, Temperature, Dissolved Oxygen, Biochemical Oxygen Demand, Orthophosphate, Nitrate, Calcium, Magnesium, Total Hardness, Potassium, Sodium, Sulfate, Chloride, Total Dissolved Solids, Electrical Conductivity and Alkalinity were used to WQIs determination. These parameters were recorded at the intakes of five water treatment plants (Al-Kifl, Al-Kufa, Al-Shamiya, Al-Manathera, and Al-Shannafiya) for the years 2015 and 2016. The quality of the river in study region classified as acceptable to severely polluted according to BWQI, good to poor according to CCMEWQI and good to very poor according to WAWQI. It was observed from this study that the impact of human activity, sewage disposal and industrial wastes in the river was severe on most of the parameters. Statistical analysis used to describe the relations between indices of water quality with Correlations Analysis done by using "IBM SPSS Statistics" software. The main results of Pearson Correlation Analysis showed that the correlation coefficient equal (+0.868) between Bhargava and Canadian, (-0.918) between Bhargava and Weighted Arithmetic and (-0.868) between Canadian and Weighted Arithmetic at significance level (0.01). The results of WQIs classification linked with "ArcGIS" software to produce layers and spatial distribution maps of these indices and to show the pollution zones in the river. The spatial analyst tool was employed for interpreting the data by applying Inverse Distance Weighted (IDW) interpolation method.

KEYWORDS: Euphrates River, WTP, WQIs, GIS, IDW.

INTRODUCTION

Water is necessary substance for life and any variations in the natural quality and distribution of water have ecological effects that can sometimes be devastating. Furthermore, access to safe drinking water is a fundamental need and a basic human right (WHO, 2006). The total freshwater is 3% from the total surface water of the Earth and approximately 0.3% of all freshwater is contained in river systems, lakes, swamps, and reservoirs (Kibona et al. 2009; Lui et al. 2011). Only about 0.0067% of the total water on Earth is fresh surface water that can be used for human consumption (Cassardo and Jones, 2011). In 2015, 663 million people still lacked improved drinking water sources services and among them almost 159 million people still collected unhealthy drinking water directly from rivers, lakes and other surface water sources (UNICEF, 2017). Climate changes, population growth, increasing water scarcity, demographic changes, limited environmental awareness, water conflicts and land occupation, and urbanization already pose challenges for water supply systems. By 2025, half of the world's population will be living in water-stressed places. Reuse of wastewater to recover water, nutrients, and energy is becoming an important strategy (UNESCO, 2017). In the last years, water resources management, problems, and water quality control received a lot of researchers' attention also it is an important environmental protection issue. The rapid growth of agricultural, municipal, and industrial activities especially in heavily populated urban areas and harmful effect of increasing drainage waters coming from agricultural lands upstream coupled with the decreasing in its discharge, so it is necessary then to make detailed studies to evaluate the suitability of the Euphrates River for drinking water purpose.

Organic and inorganic pollutants are of worldwide concern, increasing human land occupation and industrial pollution of river water and water conflicts and land occupation have made the river water quality evaluation a crucially important matter (Abdel-Shafy and Aly, 2002).

Water quality assessment is essential to prevent and control river pollution and to get reliable information on the quality of water for effective management (Koklu, et al., 2010). Water quality is based on the values of various physical, chemical and biological parameters in a water sample. Water Quality Indices (WQIs) used for monitoring programs to assess ecosystem health which has the potential to inform the general public and decision-makers about the state of the ecosystem. Also, it can be used to aggregate data on water quality parameters at different times and different places and to translate this information into a single value defining the period of time and spatial unit involved (Khan, et al., 2003). In Iraq, Water resources, especially in the last two decades have suffered remarkable stress in terms of water quantity and quality due to different reasons such as the dams constructed on Euphrates River in Turkey and Syria, the global climatic changes, decline in local annual rainfall rates and improper planning of water uses inside Iraq (Rahi and Halihan, 2010).

The flow of the Tigris and the Euphrates is expected to decrease further by 2025, with the volume of the Euphrates is expected to drop by at least half (UN, 2013). Water pollution is of worldwide concern and not only effects on water quality but also it threatens human health, economic development, and social prosperity so that it considered as the environmental problem that requires an effective and quick solution (Kumar, 2004). Furthermore, evaluation of water quality by using accurate techniques such as Water Quality Index (WQI) to estimate the status of water and maps by Geographical Information System (GIS) to represent the spatial distribution of parameters have become an important experimental and practical approach. Recently, with advance and increasing role of technology, new techniques and methods are developed for assessing water quality such as GIS which is a very helpful tool for developing solutions for water resources problems to evaluate water quality, determining water availability and understanding the natural environment on a local and/or regional scale. From GIS, spatial distribution mapping for various pollutants can be done. The resulting information is very useful for decision-makers to take remedial measures (Swarna and Nageswara, 2010).

Aims of the study

1. To study the effects of the water quality parameters of the Euphrates River in the study areas.
2. To determine the WQIs of the Euphrates River and comparison between them depending on Bhargava method, Weighted Arithmetic method, and Canadian method.
3. Discuss the suitability of the river in the study locations for human consumption based on computed WQIs values.
4. Create WQIs colored maps based on GIS techniques according to the classification of river water to show the pollution zones in the river.
5. To test the water quality parameters with the Iraqi standards for drinking purpose.

Study area

The Euphrates and Tigris Rivers are the only major source of drinking water in Iraq. Nevertheless, during the past 30 years, Iraq has shifted from being water secure to a water-stressed country. The water resources in Iraq are composed of surface water, groundwater, rain and snowfall, marshlands, lakes and reservoirs, and drainage water (Radhwan and Halim, 2012). Euphrates River is the longest river in western Asia. It originates in Turkey in the highlands of Eastern Turkey and discharges in Shatt Al-Arab "the confluence of the Tigris and Euphrates Rivers" (El-Fadel, et al., 2002). The length of Euphrates River from its beginning in Turkey to its end in Iraq is about 2,786 kilometers, of which 41% is in Turkey, 24% is in Syria, and 35% is in Iraq (Frenken, 2009). Five selected sampling stations located between latitudes (32^{o}13'32.8" North – 31^{o}34'47.4" North) and longitudes (44^{o}21'47.3" East – 44^{o}38'50.5" East) along the Euphrates River stretch were distributed over three Iraqi governorates: Babil, Al-Najaf, and Al-Qadisiyah inside Iraqi territory. The selected sampling stations of Euphrates River are: S1 (Al-Kifl), S2 (Al-Kufa), S3 (Al-Shamiya), S4 (Al-Manathera), and S5 (Al-Shannafiya). It is worth mentioning that the selected stations are located in the intakes of water treatment plants of the river which often represents the raw water quality entering to these plants.

There are several reasons for choosing a study area including the need for a tremendous increase in freshwater demand required due to the rapid growth in population and accelerated industrialization. As well as the pollution increase in the river stretch due to effluent discharges by various uncontrolled sources as domestic, industries and agriculture along the downstream stretch and most industrial institutions and factories are located on both sides of the river. The nature of the land around the river in the study area is a farming area, with some residential buildings and agricultural land. The climate in this region of Iraq is a typical dry desert climate in the last years. The summer months are hot and dry while moderate cold and wet in winter. The spring and autumn seasons are relatively short and characterized by a moderate temperature. Rainfall is very limited and concentrated in the winter months. Euphrates river water is considered the only source of potable water for cities along the river study region. Except for the area near the river, the region is sparsely populated.

Euphrates River passes through many towns and villages in the study area thus it represents the main source for different uses such as:

I. Water supply systems: The river represents the supply source for many water treatment plants such as Al-Kifl, Al-Kufa, Al-Shamiya, Al-Manathera, and Al-Shannafiya Water Treatment Plants.
II. Irrigation: The river is the main source of the irrigation for large agricultural areas locating on both sides of the river.
III. Industrial purposes: The river represents the main source for all industrial activities in the area.

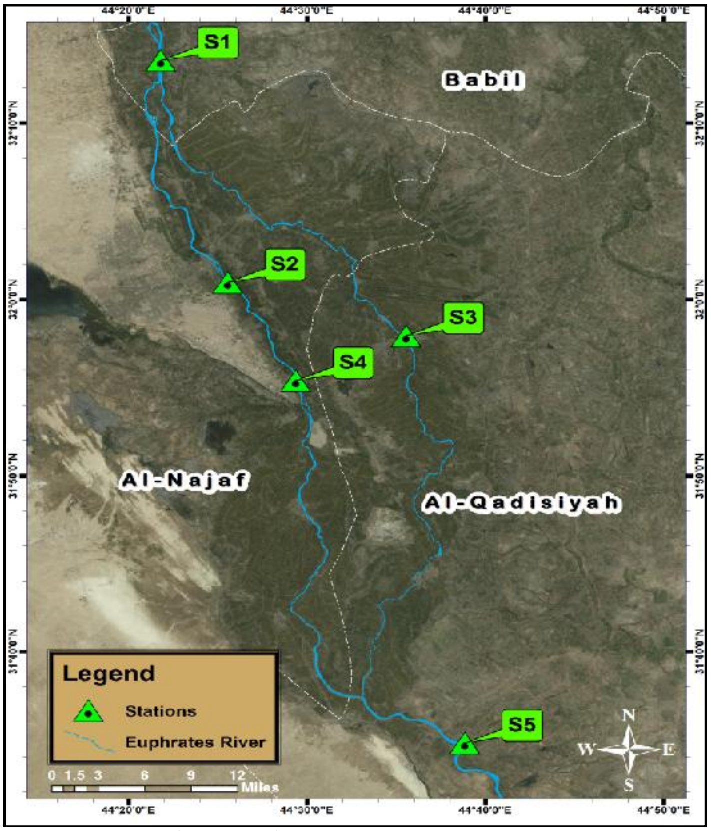


FIGURE 1: study area of stations for water quality monitoring along Euphrates River

Data collection

The data used in this research were provided by Ministry of Water Resources in Iraq for the years 2015 and 2016 which represented the monthly average values for sixteen water parameters that are used to find water quality indices.

Table (1) shows the description of the stations' location for water quality monitoring along Euphrates River. These stations were selected to carry out the present study along 174 km as a total study length of Euphrates River.

Therefore, river water quality monitoring is necessary to evaluate the water quality for drinking purpose in the case of the study area.

METHODOLOGY

The objectives of this work were achieved through the following steps:

1. After sampling collected from stations at certain dates, physical and chemical parameters were examined in laboratories of Ministry of Water Resources.
2. Calculate WQIs by using functions of "Excel" software.
3. The data of all sampling locations were stored in Excel (2016) format file then exported to ArcGIS (10.4.1) and used for the analysis. The Spatial Analyst Tool in the GIS software was employed for interpretation the data by applying interpolation (IDW) method.
4. Statistical analysis by using IBM SPSS Statistics (24.0) to descriptive statistics, tests of normality and describe the relations between indices of water quality... etc.

TABLE 1: Description of the selected monitoring stations along Euphrates River

Station No.	Station Name	Governorate	Location	UTM Coordinates (38N)	
				Easting (X)	Northing (Y)
S1	Al-Kifl	Babil	Al-Kifl city \ near intake of Al-Kifl Water Treatment Plant	439992.26	3565639.66
S2	Al-Kufa	Al-Najaf	Al-Kufa district \ near intake of Al-Kufa Water Treatment Plant	445763.85	3542388.27
S3	Al-Shamiya	Al-Qadisiyah	Al-Shamiya city \ near intake of Al-Shamiya Water Treatment Plant \ (Al-Shamiya - Al-Najaf) bridge	461502.28	3536717.15
S4	Al-Manathera	Al-Najaf	Al-Manathera district \ near intake of Al-Manathera Water Treatment Plant	451738.89	3532064.57
S5	Al-Shannafiya	Al-Qadisiyah	Al-Shannafiya city \ Al-Shannafiya Water Treatment Plant \ Al-Shannafiya bridge	466539.59	3493918.18

Water Quality Index (WQI)

Water quality can be extensively defined as the physical, chemical, and biological composition of water as related to its intended utilize for such objectives or purposes such as drinking supply, recreation, agricultural (irrigation and livestock watering), industrial, fisheries... etc. (Singh and Kaur, 2017). The water quality of rivers changes with the seasons and geographic regions, even when there is no pollution existent and there are several major impacts that reflect the quality of the river water at any location, such as lithology of the river basin, climatic conditions, global warming phenomena, atmospheric inputs and anthropogenic activities (Kumar, et al., 2015). In general, water quality index (WQI) can be described as a single number that expresses overall water quality at a specific location and time based on various water quality parameters (Kotoky and Sarma, 2017). The target of WQI is to convert complex water quality data into useful data that is understandable and usable by people in general and it is also a very helpful tool for communicating the information on the overall quality of water to the policymakers and involved citizens to assess variations in water quality, to classify the purpose different water utilizes and to identify water trends (Tiwari et al., 2017).

In recent years, the water quality indices are considered as strong tools for the development and converging raw environmental information to assess the degree of pollution that might adversely affect aquatic systems (Iwuoha, et al, 2012).

Water quality index idea was first presented in Germany over 170 years prior in 1848 where existence or absence of certain organisms in water was utilized as a pointer of the fitness or otherwise of a water source (Mustapha and Aris, 2011). In 1965, Horton was developed and expanded WQI concept in the United States (Horton, 1965). He was chosen ten most commonly utilized water quality parameters like dissolved oxygen, pH, alkalinity, coliforms, specific conductance, and chloride… etc. This idea has been approved and accepted in European, African and Asian countries (Tyagi, et al., 2013). Also, Horton put the rating scales and the weightings for the determinants to give the relative importance of each parameter in the water quality (Al-Saffar, 2001). The formula which he used was expressed as:

$$WQI = \left[\frac{\sum_{i=1}^{n} C_i * W_i}{\sum_{i=1}^{n} W_i} \right] * M_1 * M_2$$

Where:

WQI: water quality index;

Ci: the rating of the i^{th} determinant;

Wi: the weighting of the i^{th} determinant;

n: number of determinants;

M_1, M_2: additional determinant parameters.

In 1970, Brown developed the Horton's formula (Brown, et al., 1970). The arithmetic weighted formula is given as:

$$WQI = \sum_{i=1}^{n} Q_i * W_i$$

Where:

Qi: represents the rating for the i^{th} determinant, this value varies from (100 to 0);

Wi: represents the weighting for the i^{th} determinant and this value varies from (0-1) and $\Sigma W_i = 1$;

n: number of determinants.

In 1976, the general WQI was improved and developed by The Scottish Research Development Department (SRDD), suggested a modified arithmetic weighted formula (SRDD, 1976). It was considered as a sufficiently sensitive formula for water quality conditions in Scotland and was expressed as:

$$WQI = \frac{1}{100} \sum_{i=1}^{n} \left(Q_i * W_i \right)^2$$

Water Quality Indices Methods:

1- Bhargava Water Quality Index (BWQI)

Bhargava studied water quality index to evaluate the water quality for various activities in Ganga River in India using the sensitivity function method. Bhargava method is simple to deal with relative parameters for several utilizes by using sensitivity functions curves which pick the value between 0 and 1 and the results are accumulated by using the geometric mean. Bhargava method was selected since it was more detailed in its dealing with many sensitive functions; he gave a detailed description to analyze the water quality index for different purposes: drinking, irrigation, and industrial uses (Bhargava,1983).

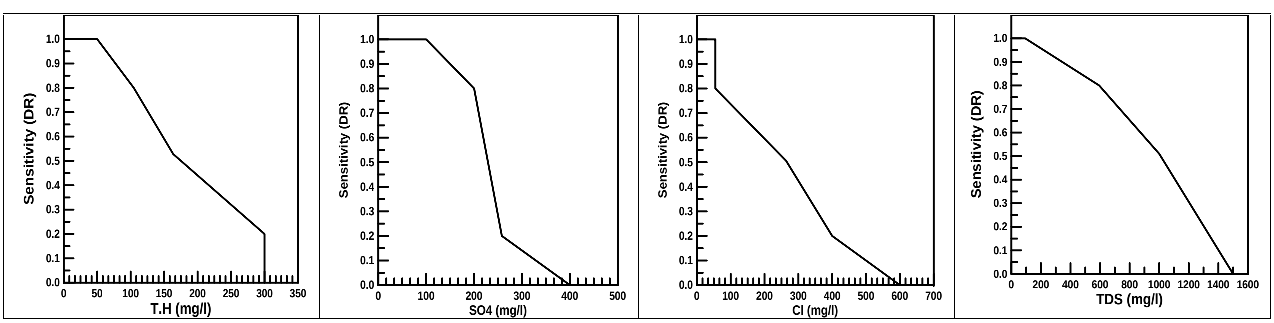
The geometric mean formula was suggested by Bhargava which expressed as:

$$BWQI = \left[\pi_{i=1}^{n} \; fi\left(P_i\right) \right]^{1/n} * 100$$

Where:

fi (Pi): the sensitivity function for each variable including the effect of variable weight concentration which is related to a certain activity and varies from 0 to 1 ;n: the number of variables.

The nature of the sensitivity functions is determined by the impact of a change in the value of the parameter on water quality as in figure (2) which represents the sensitivity function curves to T.H, SO_4^{-2}, Cl^{-1}, TDS, Ca^{+2}, pH, and BOD for drinking purpose. These curves are used to evaluate the quality of river water and give the importance with weight to every parameter.



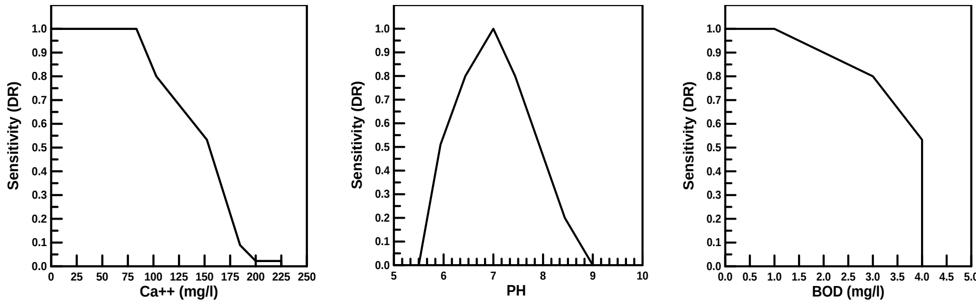


FIGURE 2: Sensitivity functions curves according to Bhargava WQI method for drinking purpose.

Depending on the quality of water in the region, the river could be classified into five classes that correspond to specific levels of water quality impairment and WQI range between 0 to 100 according to Bhargava method for drinking water specifications as shown in the table (2).

TABLE 2: Water quality classification for drinking purpose according to Bhargava WQI method

Class	WQI Value	Water Quality
A	100-90	Excellent
B	90-65	Good
C	65-35	Acceptable
D	35-10	Polluted
E	10-0	Severely Polluted

2- Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI)

The CCMEWQI is a well-accepted and universally applicable model for evaluating the water quality index. This method is a most important formula and commonly used by researchers (Noor, 2016). The Canadian Council of Ministers of the Environment has evolved the water quality index to simplify the reporting of complex and technical water quality data (CCME, 2001). This index is a science-based communication tool that tests multi-variable water quality data against specified water quality benchmarks determined by the user (Awachat and Salkar, 2017). So, this acts as an advantage of the index which can be applied by the water agencies in different countries with little modification.

The CCMEWQI is useful for many different purposes including drinking water quality data evaluations, analysis, planning and management, and assess the effectiveness of best management practices for making decisions (Khan, et al., 2005).

The CCMEWQI formula which expressed as:

$$\text{CCMEWQI} = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

Where:

F_1 *(Scope Factor)*: The number of variables that are not compliant with the water quality standards over the period of interest, which calculated as:

$$F_1(Scope) = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right) * 100$$

Where variables indicate those water quality parameters with objectives which are tested during the study period for the index calculation.

F_2 *(Frequency Factor)*: This factor represents the percentage of individual failed tests values that are not met the objectives, which calculated as:

$$F_2(Frequency) = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right) * 100$$

Where tests indicate those water quality tests for parameters with objectives which are tested during the study period for the index calculation.

F_3 *(Amplitude Factor)*: This factor represents the amount by which the failed test values are not met their objectives. This is calculated in three steps:

Step 1: Calculation of Excursion

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

$$excursion_i = \left(\frac{\text{Faild test value}_i}{\text{Objective}_j}\right) - 1 \quad \text{(Test value<objective)}$$

$$excursion_i = \left(\frac{\text{Objective}_j}{\text{Faild test value}_i}\right) - 1 \quad \text{(Test value>objective)}$$

Step 2: Calculation of Normalized Sum of Excursions

The normalized sum of excursions (nse) is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (those which do and do not meet their objectives). The nse is expressed as follows:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\text{No. of tests}}$$

Step 3: Calculation of F3

F3 is then calculated below by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100. The CCMEWQI is finally calculating as the show above.

$$F_3(Amplitude) = \frac{nse}{0.01nse + 0.01}$$

The factor of 1.732 in water quality index formula arises because each of the three individual index factors can arrive at 100. So, to keep the range of CCMEWQI to 100 as maximum, therefore division by 1.732 to prevent access to the error as shown in the following example:

$$\sqrt{100^2 + 100^2 + 100^2} = \sqrt{30000} = 173.2 \; >100 \text{ (error)}$$

CCMEWQI also uses five categories or levels that correspond to specific levels of water quality impairment, which is shown below in table (3).

TABLE 3: Water quality classification for drinking purpose according to Canadian WQI method

Class	WQI Value	Water Quality
A	100-95	Excellent
B	95-80	Good
C	80-65	Fair
D	65-45	Marginal
E	45-0	Poor

3- Weighted Arithmetic Water Quality Index Method (WAWQI)

Weighted Arithmetic Water Quality Index (WAWQI) method one of the oldest methods of water quality indices was proposed by Horton in 1965 and was developed by Brown in 1972. This index was classified the water quality according to the degree of purity by using the most commonly measured water quality variables. (Tyagi, et al., 2013).

This method has offered advantages over other methods such as in this method multiple water quality parameters are incorporated into a mathematical equation that rates the health of water body through a number called water quality index as well as it describes the suitability of surface and groundwater sources for human consumption (Chandra, et al., 2017).

The methodology in calculating WAWQI method was used in steps to arrive the WAWQI formula as below (Brown, et.al, 1972):

Step 1: Collect data of various physicochemical water quality parameters according to the period of study required.

Step 2: Setting the standards or guidelines permissible values (Si) of the n^{th} parameters and calculate (1/Si).

Step 3: Calculate the proportionality constant (K) value by using the following formula:

$$K = \frac{1}{\sum (1/Si)}$$

Where:

S_i: the standard permissible for n^{th} parameter.

Step 4: Calculate the unit weight (Wi) for the n^{th} parameters by using the following formula:

$$Wi = \frac{K}{Si}$$

Calculate the quality rating scale (Qi) for n^{th} parameters by using this expression:

$$Qi = \left[\frac{(Vn - Vi)}{(Si - Vi)} \right] * 100$$

Where:

Vn: the estimated value of the n^{th} parameter at a given sample location.

Vi: the ideal value of the n^{th} parameter in pure water. In most cases Vi=0 (except pH =7.0 and DO = 14.6 mg/l).

Step 5: Calculate (Wi*Qi) of the n^{th} parameter and calculate Σ(Wi*Qi).

Step 6: Calculate of water quality index that was carried out by Horton's method. WAWQI is calculated by using the expression given in equation:

$$WAWQI = \frac{\sum (Wi * Qi)}{\sum Wi}$$

The rating of water quality according to WAWQI is given in table (4).

TABLE 4: Water quality classification for drinking purpose according to Weighted Arithmetic WQI method

Class	WQI Value	Water Quality
A	0-25	Excellent
B	25-50	Good
C	50-75	Poor
D	75-100	Very Poor
E	> 100	Unsuitable

Geographic Information System (GIS) tools used for water pollution mapping

GIS technology is a very helpful tool for improving solutions for water resources problems to evaluate water quality, determining water availability and understanding the natural environment on a local or regional scale (Al-Saqqar, et al., 2015). From GIS, spatial distribution mapping for various pollutants can be done, and the resulting information is very useful for decision-makers to take remedial measures (Swarna and Nageswara, 2010).

Raising public awareness, stricter measures, and promulgation of new rules in the area of water resources protection and quality management have made the utilize of advanced technologies indispensable (Avhad, 2016).

GIS is a powerful tool for storing, managing, developing solutions and displaying spatial data often encountered in sanitary and water resources management on a local or regional scale (Al-Anbari, et al., 2015). In order to stress the importance of GIS in water resources management, applications related to this area are addressed and evaluated for efficient future research and development.

GIS implementations are presented including water supply, groundwater modeling, surface hydrologic, water and wastewater network, sewer system modeling, stormwater modeling for urban and agricultural zones (Manjola et al., 2010).

GIS has several kinds of tools such as a statistical, a spatial and a geostatistical analysis. Tools of the spatial analyst, for instance, is one of the most important tools that interpolates points data which contain an attribute data and layout.

The result in a form of raster format that can take gradient color showing the difference between the stations' values. On the other hand, there are several algorithms that can be used in interpolation processes such as Inverse Distance Weighted (IDW), Spline, Kriging and Natural Neighbor. Geostatistical Analyst contains different tools to deal with point and area data. The geostatistical tools are more advanced than statistical tools which are just the basic statistical process such as mean, median and standard deviation tools (Matejicek, 2005) .

The results of WQIs analysis were then used as input data in ArcGIS 10.4.1. The sampling locations were integrated with the water data for the generation of spatial distribution maps. The present study used the IDW method for spatial interpolation of water quality indices. The weight assigned is a function of the distance of an input point from the output cell location. The greater the distance, the less influence the cell has on the output value (Childs, 2004).

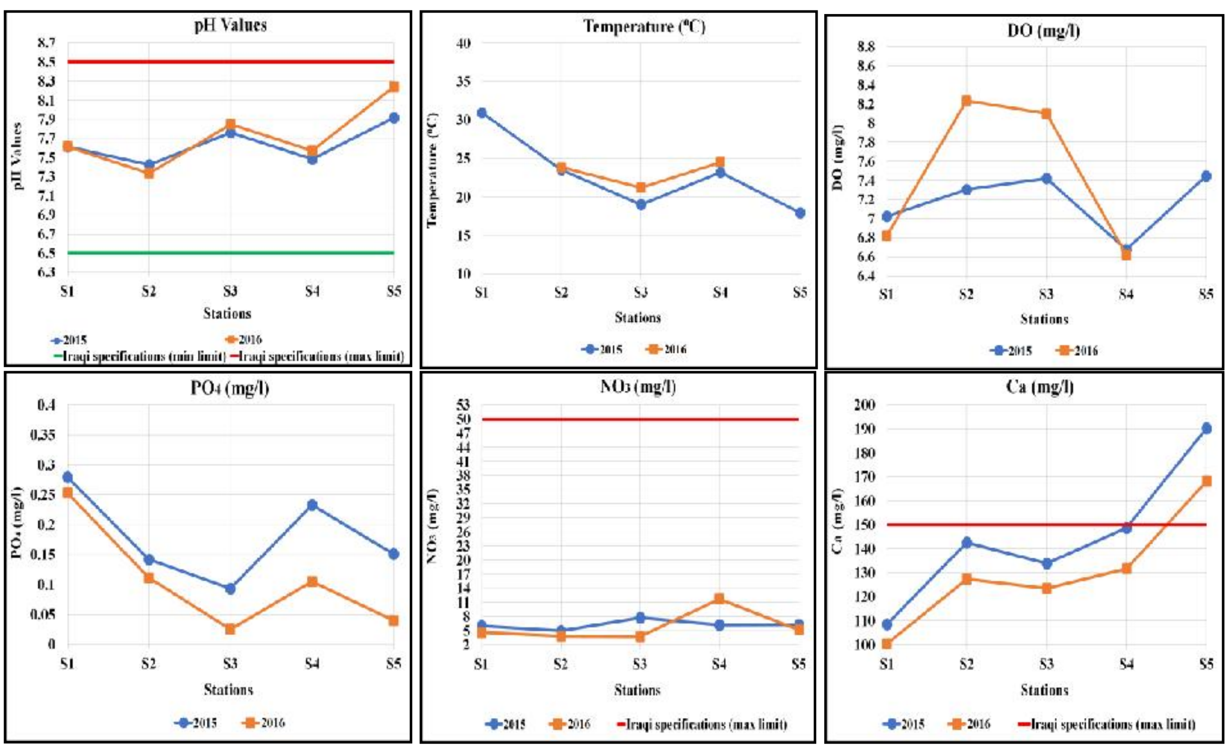
The approach of examining the locations, attributes, and relationships of features in spatial data through the overlay and other analytical techniques in order to address a question or gain useful knowledge. Spatial analysis creates new information from spatial data. The first element that must be calculated is the 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. The surface being interpolated should be that of a locationally dependent variable (ESRI, 2017).

The output value for a cell using IDW is limited to the range of the values used to interpolate. Because IDW is a weighted distance average, the average will not be greater than the highest or lower than the lowest input (Watson and Philip 1985). The reason behind the fact that IDW method is used widely with cases of GIS application in water pollution analysis is because that this method actually contains less distortion when there are enough measured points, and is convenient in the application (Song, 2008).

RESULTS

1- Physicochemical parameters of the river water

In this study, it has been found that most examined water samples had values, the parameters include pH, Temperature, DO, BOD_5, PO_4^{-3}, NO_3, Ca^{+2}, Mg^{+2}, T.H, K^{+1}, Na^{+1}, SO_4, Cl^-, TDS, EC, and Alkalinity. figure (3) shows the variation of each parameter in the selected stations of Euphrates River for the years 2015 and 2016. The results were compared with Iraqi drinking water quality specifications (IQS 417, 2009).



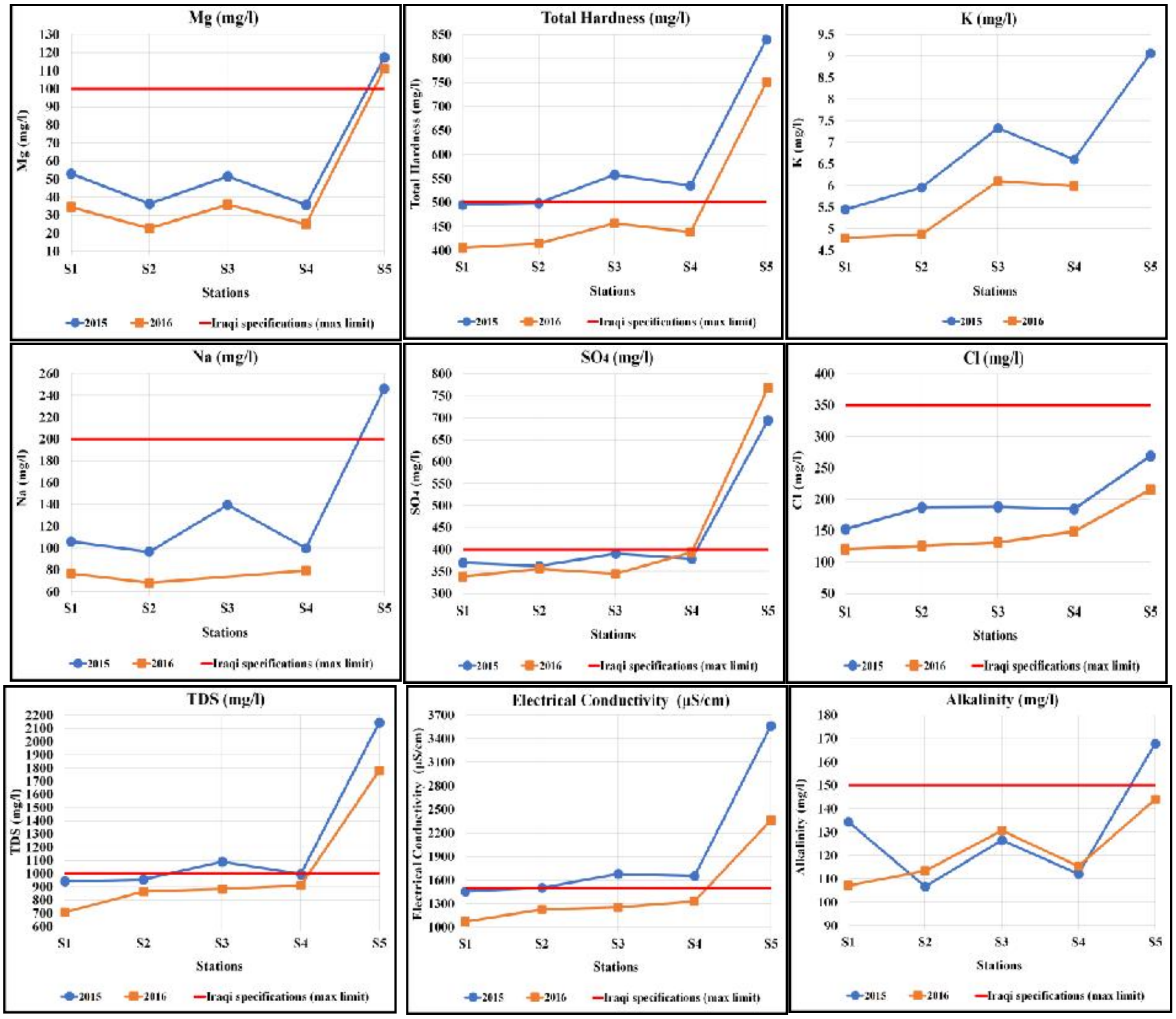


FIGURE 3: (pH, Temperature, DO, PO_4^{-3}, NO_3, Ca^{+2}, Mg^{+2}, T.H, K^{+1}, Na^{+1}, SO_4, Cl^-, TDS, EC, and Alkalinity) variations in the Euphrates River for the years 2015 and 2016.

2- Calculation of WQIs

Samples of WQIs calculations are shown in tables (5,6, and 7) for the selected stations in the years 2015 and 2016. It is noticed from tables that there is deterioration in the water quality of Euphrates River in the selected stations for drinking purpose. Figures (4,5, and 6) shows the variation of each WQI between stations during the study period.

TABLE 5: Calculations of Bhargava Water Quality Index (BWQI) for selected stations in the years 2015 and 2016.

Stations	2015				2016			
	WQI%	Class	Categorization	Parameters responsible for water quality deterioration*	WQI%	Class	Categorization	Parameters responsible for water quality deterioration*
S1	37.43	C	Acceptable	SO_4	59.16	C	Acceptable	SO_4
S2	48.2	C	Acceptable	SO_4, TDS	43.07	C	Acceptable	SO_4
S3	33.05	D	Polluted	SO_4, TDS	35.12	C	Acceptable	SO_4
S4	44.25	C	Acceptable	Ca, SO_4, TDS	32.18	D	Polluted	SO_4
S5	0	E	Severely Polluted	Ca, T.H, SO_4, Cl, TDS	0	E	Severely Polluted	pH, Ca, T.H, SO_4, TDS
Max	48.2				59.16			
Min	0				0			
Mean	32.586				33.906			

***** Parameters have sensitivity value less than 0.5 (according to Bhargava sensitivity functions curves for drinking purpose as figure 2).

TABLE 6: Calculations of Canadian Water Quality Index (CCMEWQI) for selected stations in the years 2015 and 2016.

Stations	2015				2016			
	WQI%	Class	Categorization	Parameters responsible for water quality deterioration[×]	WQI%	Class	Categorization	Parameters responsible for water quality deterioration[×]
S1	78.22	C	Fair	T.H, SO_4, TDS, EC	89.39	B	Good	T.H, EC
S2	70.62	C	Fair	Ca, T.H, SO_4, TDS, EC	84.12	B	Good	Ca, T.H, SO_4
S3	67.81	C	Fair	Ca, T.H, SO_4, TDS, EC	81.69	B	Good	T.H, SO_4, TDS
S4	68.54	C	Fair	Ca, T.H, SO_4, TDS, EC	78.74	C	Fair	Ca, SO_4, TDS, EC
S5	27.12	E	Poor	Ca, Mg, T.H, Na, SO_4, Cl, TDS, EC, Alk.	48.44	D	Marginal	Ca, Mg, T.H, SO_4, TDS, EC
Max	78.22				89.39			
Min	27.12				48.44			
Mean	62.462				76.476			

[×] Parameters have an average monthly test value greater than objective (Iraqi drinking water quality specifications IQS/417/2009) according to excursion formula.

TABLE 7: Calculations of Weighted Arithmetic Water Quality Index (WAWQI) for selected stations in the years 2015 and 2016

Stations	2015				2016			
	WQI%	Class	Categorization	Parameters responsible for water quality deterioration[c]	WQI%	Class	Categorization	Parameters responsible for water quality deterioration[c]
S1	43.72	B	Good		40.3	B	Good	
S2	34.22	B	Good	EC	27.94	B	Good	
S3	51.98	C	Poor	T.H, TDS, EC	51.09	C	Poor	
S4	37.67	B	Good	T.H, EC	41.06	B	Good	
S5	85.94	D	Very Poor	Ca, Mg, T.H, Na, SO_4, Cl, TDS, EC, Alk.	80.07	D	Very Poor	Ca, Mg, T.H, SO_4, TDS, EC
Max	85.94				80.07			
Min	34.22				27.94			
Mean	50.706				48.092			

[c] Parameters have an average annual test value greater than (Si) guidelines permissible value (Iraqi drinking water quality specifications IQS/417/2009).

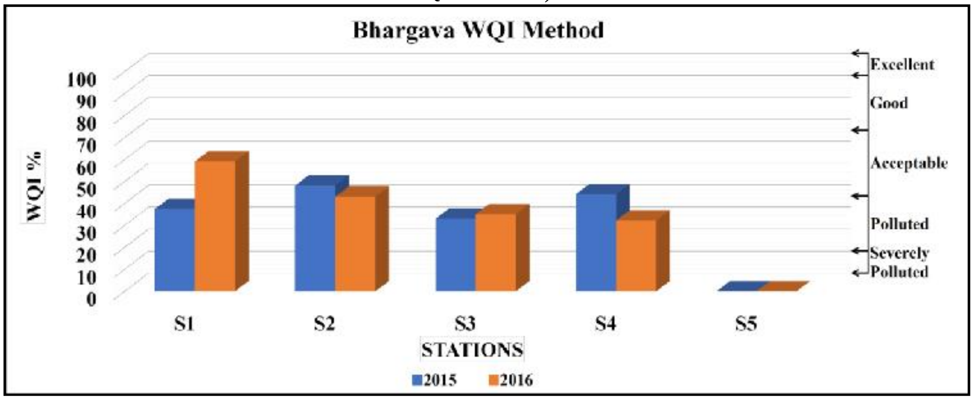


FIGURE 4: Variation of Bhargava Water Quality Index (BWQI) between selected stations in the years 2015 and 2016.

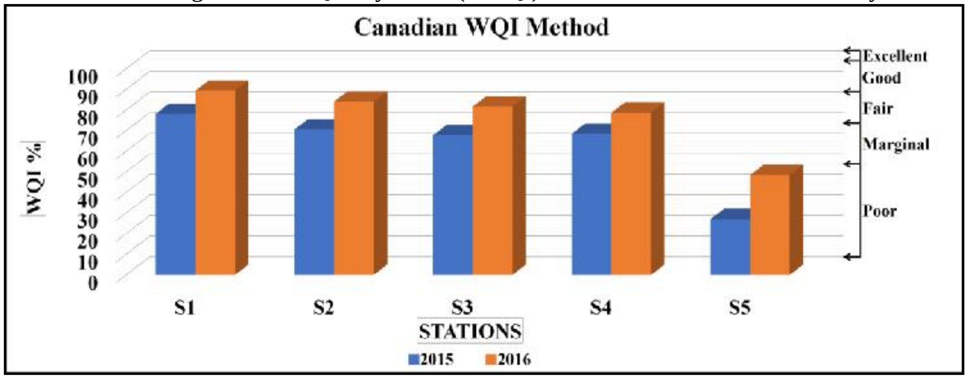


FIGURE 5: Variation of Canadian Water Quality Index (CCMEWQI) between selected stations in the years 2015 and 2016.

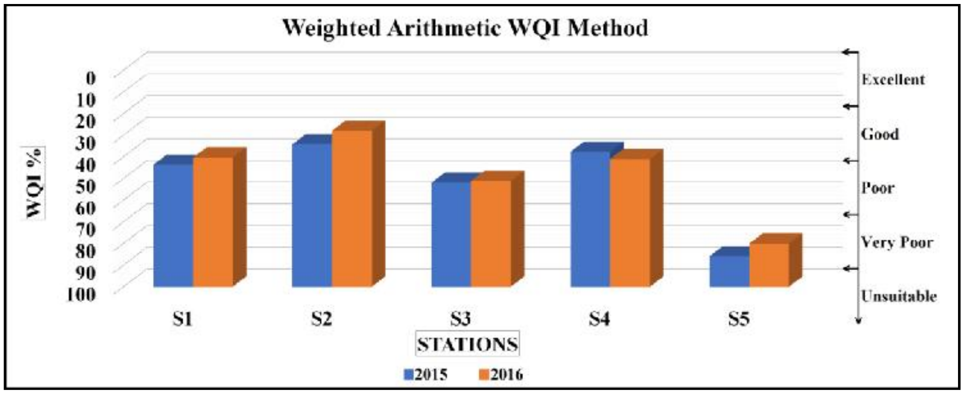


FIGURE 6: Variation of Weighted Arithmetic Water Quality Index (WAWQI) between selected stations in the years 2015 and 2016.

3- Data analysis

Data of Euphrates River in the study stations were collected, from the period extended from January 2015 to December 2016. Table (8) shows the data descriptive statistics of WQIs used for stations during the two years. Table (9) shows the data tests of normality according to Kolmogorov-Smirnov and Shapiro-Wilk tests. Finally, Pearson Correlation Analysis describes the relations between indices of water quality shown in the table (10).

TABLE 8: Description of statistical data of WQIs values in the selected stations during the study period.

Statistics		Weighted Arithmetic WQI Method	Canadian WQI Method	Bhargava WQI Method
N	Valid	10	10	10
	Missing	0	0	0
Mean		49.3990	69.4690	33.2460
Std. Error of Mean		6.05394	5.92919	6.09694
95% Confidence Interval for Mean	Lower	35.7040	56.0562	19.4538
	Upper	63.0940	82.8818	47.0382
Median		42.3900	74.4200	36.2750
Mode		27.94[x]	27.12[x]	0[x]
Std. Deviation		19.14424	18.74975	19.28022
Variance		366.502	351.553	371.727
Skewness		1.211	-1.494-	-0.976-
Std. Error of Skewness		0.687	0.687	0.687
Kurtosis		0.478	2.108	0.350
Std. Error of Kurtosis		1.334	1.334	1.334
Range		58.00	62.27	59.16
Minimum		27.94	27.12	0
Maximum		85.94	89.39	59.16

[x] Multiple modes exist. The smallest value is shown

TABLE 9: Tests of normality of WQIs values in the selected stations during the study period.

Methods	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Weighted Arithmetic WQI Method	0.246	10	0.087	0.847	10	0.054
Canadian WQI Method	0.265	10	0.045	0.854	10	0.066
Bhargava WQI Method	0.278	10	0.028	0.862	10	0.081

[a] Lilliefors Significance Correction

TABLE 10: Pearson Correlation Analysis between WQIs in the selected stations during the study period.

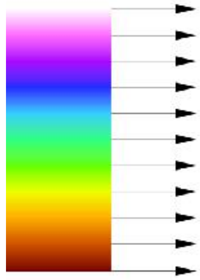
Methods		Weighted Arithmetic WQI Method	Canadian WQI Method	Bhargava WQI Method
Weighted Arithmetic WQI Method	Pearson Correlation	1	-0.868-**	-0.918-**
	Sig. (2-tailed)		0.001	0.000
Canadian WQI Method	Pearson Correlation	-0.868-**	1	0.868**
	Sig. (2-tailed)	0.001		0.001
Bhargava WQI Method	Pearson Correlation	-0.918-**	0.868**	1
	Sig. (2-tailed)	0.000	0.001	

** Correlation is significant at the 0.01 level (2-tailed).

4- Using the GIS software to build the colored model

The results of the study have been linked with ArcGIS 10.4.1 software to produce layers of representing the nature of the spatial distribution of WQIs in the form of colored maps to show pollution zones in the water of Euphrates River at the study area. Analysis has been to help in identifying the appropriate zones of water quality for drinking purpose and to a diagnosis of affected areas. The GIS maps are shown in figures (7 and 8) that representing WQIs of the Euphrates River for the years 2015 and 2016 between the intakes of selected stations. Table (11) shows the colors ramp indicator used in the GIS maps according to WQIs classification which is already mentioned in tables (2, 3, and 4).

TABLE 11: Colors ramp indicator for WQIs in GIS maps

WQI colors ramp	BWQI Values	CWQI Values	WAWQI Values
	100	100	0
	90	90	10
	80	80	20
	70	70	30
	60	60	40
	50	50	50
	40	40	60
	30	30	70
	20	20	80
	10	10	90
	0	0	>=100

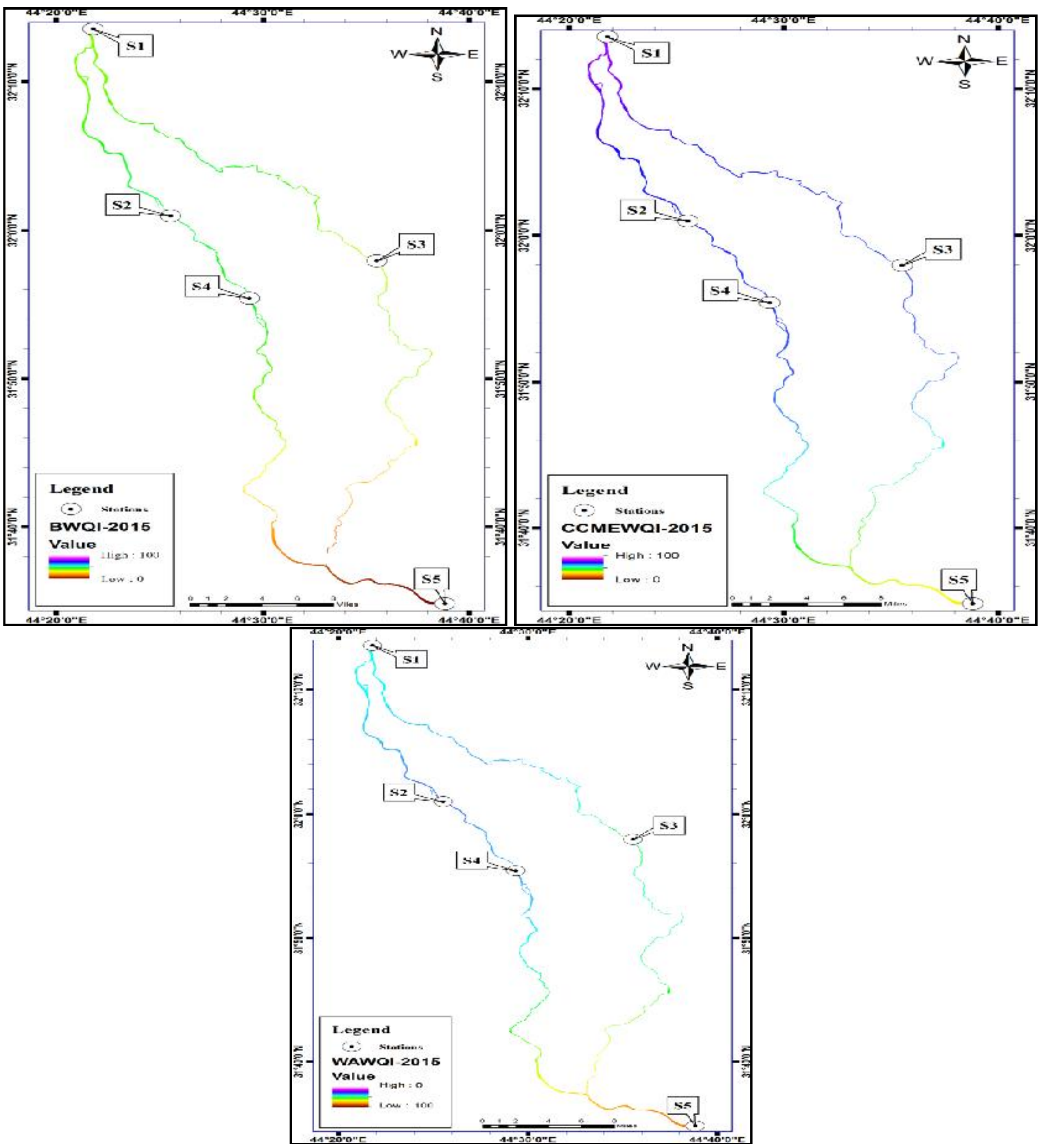


FIGURE 7: GIS Maps for WQIs variation in the Euphrates River for the year 2015.

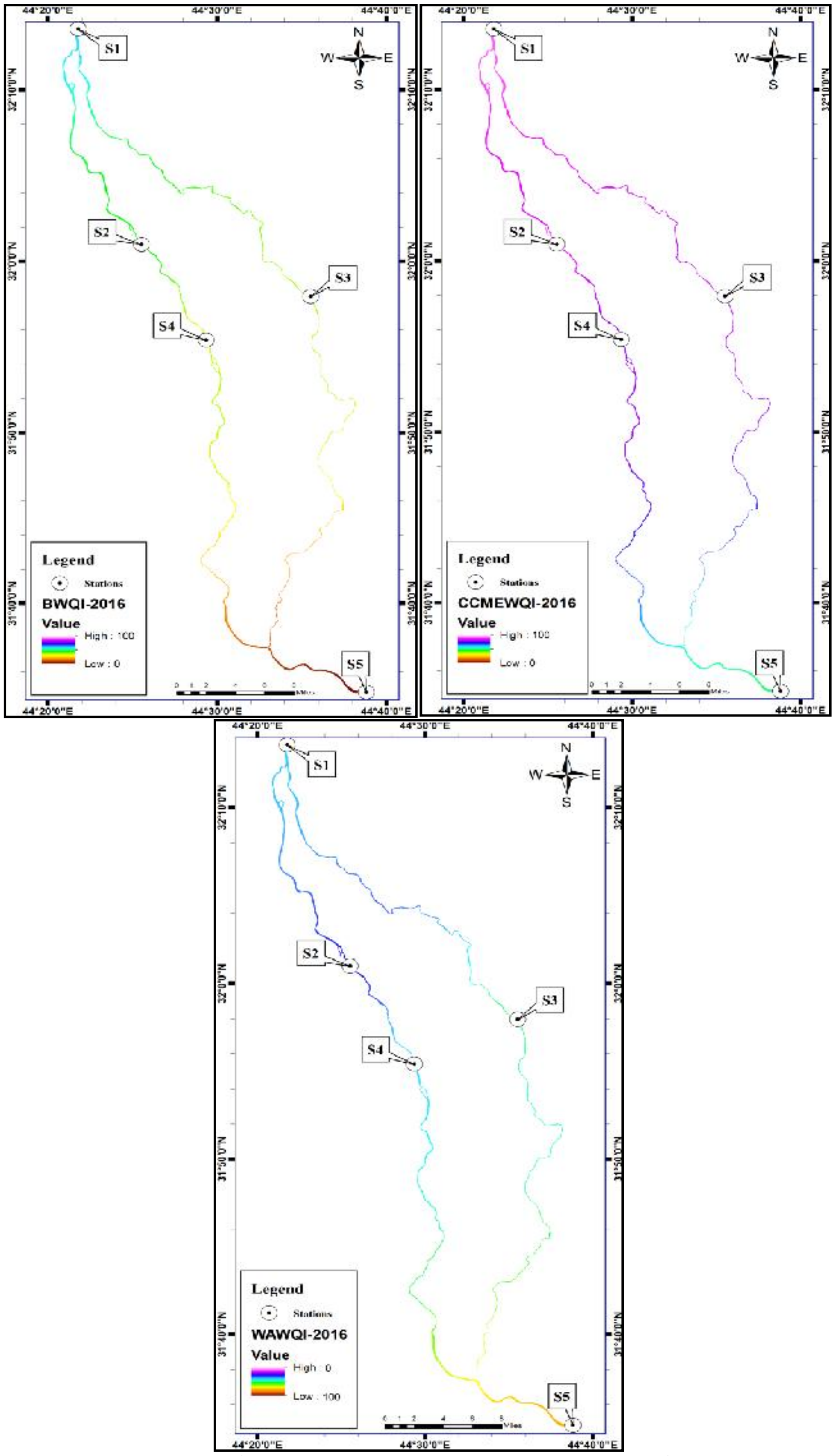


FIGURE 8: GIS Maps for WQIs variation in the Euphrates River for the year 2016.

DISCUSSION

From the results, it can be observed that the quality of the river in the selected stations during the study period classified from class "C" to class "E" according to BWQI method, class "B" to class "E" according to CCMEWQI method and from class "B" to class "D" according to WAWQI method for drinking purpose. The maximum WQIs values recorded 59.16%, 89.39%, and 85.94% for BWQI, CCMEWQI, and WAWQI respectively, while the minimum WQIs values recorded 0%, 27.12%, and 27.94% for BWQI, CCMEWQI, and WAWQI respectively. The main water parameters causing these degradations of WQIs values and responsible for deterioration of river water are the high concentrations of pH, Calcium, Magnesium, Total Hardness, Sodium, Sulfate, Chloride, Total Dissolved Solids, Electrical Conductivity and Alkalinity in the flowing water which noticed from the deterioration values of WQIs for each method.

In general, the main water parameter causing deterioration in results of water quality indices for selected stations is the high concentrations of Sulfate (SO_4). Sulfates are a combination of sulfur and oxygen and arrive at river water from gypsum and anhydrite or from the oxidation of sulfuric compounds that result from the industrial discharges, sewerage water, and groundwater (Jamil, et al., 1984). Sulfate minerals can cause a bitter taste in water that can have a laxative effect on humans when found above the permissible limit (Ley, 2008). The results of (SO_4) varied from 338.3 mg/l as minimum value for station "S1" in 2016 to 768.46 mg/l as maximum value for station "S5" in 2016, this indicates that most of (SO_4) values have exceeded the permissible limits in Iraqi standards (not exceed 400 mg/l) and classify with parameters responsible for water quality deterioration to all WQIs.

Total Hardness (T.H) is defined as the total amount of polyvalent cations mainly Ca^{+2} and Mg^{+2} found in water expressed in mg/l as $CaCO_3$. Other ions, such as strontium, barium, aluminum, manganese, iron, copper, zinc, and lead also are responsible for hardness, but to a lesser degree "low concentrations in nature" (NATC, 1968). Hardness usually divided into two categories: temporary or carbonate hardness and permanent or noncarbonate hardness. Sources of water hardness due to the entry of ions into a river by leaching from minerals within an aquifer such as calcite and gypsum that it's containing Ca^{+2} and dolomite containing Mg^{+2}. World Health Organization (WHO) reported that hard water may cause cardiovascular disease, although there were not enough researches for this finding to be conclusive (Marque, et al., 2003). The recorded data indicated that Total Hardness concentrations ranged from 405.5 mg/l as minimum value for station "S1" in 2016, while regarding 844.68 mg/l as maximum value for station "S5" in 2015 where the permissible limits in drinking water are 500 mg/L according to the Iraqi standards for drinking purpose.

Total Dissolved Solids (TDS) in water supplies can be from natural sources, sewage, urban and agricultural runoff, and industrial wastewater. There is no reliable data showing potential health effects when ingested of TDS in drinking water (WHO, 2016). In case of "S1" station, TDS value recorded 708.6 mg/l as a minimum in 2016, while maximum value recorded 2143.83 mg/l for station "S5" in 2015 where the permissible limits in drinking water are 1000 mg/l according to the Iraqi standards for drinking purpose.

Calcium (Ca) is naturally present in river water by dissolving limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is a determinant of water hardness because it can be found in water as Ca^{+2} ions (Abeliotis, et al., 2015). The high concentrations of calcium in drinking water have adverse health effect that can interact with elements such as copper, lead, iron, zinc, magnesium, and phosphorus within the intestine, thereby reducing the absorption of these minerals (Sengupta, 2013). The range of Ca concentrations were 101.4 mg/l to 189.78 mg/l for "S1" in 2016 and "S5" in 2015 respectively, this indicates that Ca values have exceeded the permissible limits in Iraqi standards (not exceed 150 mg/l) and classify with parameters responsible for water quality deterioration to all WQIs.

Electrical conductivity (EC) means water capacity to transmit current and expresses the amount of soluble salts in the water, it is influenced by the amount of Total Dissolved Solids (TDS) in the water. At high TDS values, the ratio TDS/EC increases, and the relationship tend toward TDS = 0.67 x EC. (Peterson, et al., 2013). High EC can cause dissolved salinity in drinking water. Salinity is measured depending on the electrical conductivity values, according to the method of Golterman (Golterman, et al., 1978). The recorded data indicated that EC concentrations ranged from 1091 μS/cm as minimum value for station "S1" in 2016, while regarding 3577 μS/cm as maximum value for station "S5" in 2015 where the permissible limits in drinking water are 1500 μS/cm according to the Iraqi standards for drinking purpose.

pH is an important ecological factor which affects the survival of aquatic organisms, solubility, and toxicity of many metals in the water. The acidity of water increases the solubility of many metals that cause adverse effects on aquatic organisms (Charles, 2006). Decreasing pH value during warm months may be due to elevation of temperature and water temperature due to increase the biological activity of microorganisms and increased the level of CO_2 in the water, while increased level of pH during cold months may be due to increasing the density of phytoplankton and increased level of dissolved oxygen in the water and consumption of CO_2 which causes elevating the pH (Zaidan, et al., 2009). pH values were within the allowable limits according to the Iraqi standards for drinking purpose but according to BWQI method classify with parameters responsible for water quality deterioration in 2016 for station "S5" which have sensitivity value less than 0.5 (according to Bhargava sensitivity functions curves for drinking purpose as figure 2).

Magnesium (Mg) and other alkali earth metals are responsible for water hardness. After sodium, it is the most commonly found cation in oceans (Raju, et al., 2014). A large number of minerals contains Mg, for example, dolomite $CaMg(CO_3)_2$ and magnesite $MgCO_3$. Magnesium is washed from rocks and subsequently ends up in water. Mg has many different purposes and consequently may end up in river water in many different ways such as chemical industries, fertilizer application, cattle feed, beer breweries, and magnesium hydroxide is applied as a flocculant in wastewater treatment plants (El-Rafie and Mohamed, 2014). There are no known cases of magnesium poisoning. At-large doses of magnesium in water may cause vomiting and diarrhea (Swaminathan, 2003). The range of Mg concentrations were 34.4 mg/l to 118.91 mg/l for "S1" in 2016 and "S5" in 2015 respectively, this indicates that Mg values have exceeded the permissible limits in Iraqi standards (not exceed 100 mg/l) and classify with parameters responsible for water quality deterioration to CCMEWQI and WAWQI.

Sodium (Na) is dissolved from rock, salts, and soil. It is also found in oilfield brine, seawater, industrial brine, … etc. Its salts and compounds are used in agriculture and industry, and the most common forms of sodium in the water and nature is sodium chloride (Kaveh, et al., 2011). Na affects the salinity of the water including salinity in freshwater mainly sodium salts if water containing high concentrations of magnesium, potassium and calcium salts do not give a salty taste, while little of sodium chloride gives a clear salinity (Headley and Bassuk, 1991). High levels of Na in drinking water have health effects for humans including high blood pressure (Hallenbeck, et al., 1981). The recorded data indicated that Na concentrations

ranged from 79.68 mg/l as minimum value for station "S1" in 2016, while regarding 245.7 mg/l as maximum value for station "S5" in 2015 where the permissible limits in drinking water are 200 mg/L according to the Iraqi standards for drinking purpose.
Chloride (Cl) is one of the major inorganic anions, or negative ions, in saltwater and freshwater. Chloride salts are available in the water more than other salts for ease solubility and the difficulty of adsorption of chloride on natural mineral surfaces. These salts and their resulting chloride ions originate from natural minerals, saltwater intrusion into estuaries, and industrial pollution also heavy sewage contains chloride (Bisogni and Lawrence, 1975). During rainy seasons, increasing concentrations of chloride in the water due to the solubility of chloride ions of land adjacent to the banks of the river as a result of soil erosion. This explains why high chloride values in the winter and spring seasons (Hem, 1985). Chlorides in drinking water usually create taste and odor problems, hypertension associated with sodium chloride intake appears to be related to the sodium rather than the chloride ion (DNHW, 1978). However, adverse effects related to high chloride concentrations are increased the number of polymorphonuclear leukocytes and disturbed blood cell counts in full blood count analysis (Bashir, et al., 2012). The range of Cl concentrations were 122.57 mg/l to 269.44 mg/l for "S1" in 2016 and "S5" in 2015 respectively. It is noticed from Cl values were within the allowable limits according to the Iraqi standards for drinking purpose but according to all WQIs classify with parameters responsible for water quality deterioration in 2015 for station "S5".
The alkalinity of water is a measure of how much acid it can neutralize, it may be due to the presence of one or more of a number of ions, these include hydroxides, carbonates, and bicarbonates (Panchagnula and Vunguturi, 2016). Most alkalinity in surface water comes from calcium carbonate $CaCO_3$ being leached from rocks and soil. This process is enhanced if the rocks and soil have been broken up for any reason, such as mining or urban development (Sarita and Rani, 2016). Alkalinity is significant in the treatment of wastewater and drinking water because it will influence treatment processes such as anaerobic digestion (Irshad, et al., 2015). Water may also be unsuitable for use in irrigation if the alkalinity level in the water is higher than the natural level of alkalinity in the soil. The high amount of alkalinity, pH, and hardness affect the toxicity of many substances in the water and results in unpleasant taste to drinking water (Patil, et al., 2012). In case of "S1" station, alkalinity value recorded 108.87 mg/l as a minimum in 2016, while maximum value recorded 169.1 mg/l for station "S5" in 2015 where the permissible limits in drinking water are 150 mg/l according to the Iraqi standards for drinking purpose.

CONCLUSION

In general, the results showed that the WQIs have the capability to reduce the extent of large information of parameters into a single value to express the data in a simplified and concept form. The results of WQIs can use to evaluate the effectiveness of river water and senses the need of protective practices.
These indices consider the river in the study area unfit for drinking water purpose, and this means the river water would need further treatments in the water treatment plants near the study area which reflects the effect of pollution due to domestic and industrial effluents (especially the river water near the station "S5").
In this study, application of GIS maps assisted to link the collected data and convert them into simplified and colorful maps together with its related analysis, calculation, graphs, and results. Besides, the GIS technique could represent the reliable picture of water quality which may be used in general without show the bulk of results data and it became easy to re-analyze and update.
Finally, further studies are needed in monitoring and controlling the sources of pollution to protect and enhance the water quality in Iraq especially in the next few years as the country is experiencing a potential water crisis.

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