Application ArcGIS on Modified-WQI Method to Evaluate Water Quality of Euphrates River, Iraq Using Physic-Chemical Parameters

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Abstract. The global interest of the water bodies due to the water scarcity crisis encourages researchers to study the details water environment in different aspects. Consequently, this study objective to evaluate the water quality in Euphrates River through adopted eleven physic-chemical parameters measured at sixteen locations during the three years (2009 – 2011) for both seasons (dry and wet). In this study, the water quality index model (WQIM) was calculated after modifying the weighted arithmetic method to define as MWQI. The chosen parameters were comprised of Cl, SO4, HCO_3, NO_3, Na, K, Ca, Mg, T.H., T.D.S., and EC. For the river section of locations (L.1 – L.10), All readings of the selected parameters (expected HCO3) were increased more and more. Then, all concentrations of parameters were recorded the high increasing after location (L.10) at locations (L.11 – L.14). The concentrations situation of HCO_3 were verse vice at all locations. For the average values of three years (wet, dry, total), the MWQI of section length of Euphrates River at locations (L.1 - L.10) were classified as good water quality (class, C-II). The river section at locations (L.11 - L.16, excepted L.13) was classified as poor water quality (class, C-III), while the location (L.13) was classified as very poor (class, C-IV). The interpolation prediction maps of the average readings (total, dry, and wet) of Euphrates River were output in GIS using the interpolation model of IDWM.

Keywords: Modified-WQI, ArcGIS, IDWM, Physic-Chemical Parameters, Euphrates River, Iraq

1. Introduction

Global warming affects climate Change and then on river basins environment in the arid and semi-arid region especially in the East Mediterranean, the Middle East, and region. Climate change is shown the effecting on the annual streamflow of the basins of Tigris and Euphrates Rivers through the increased temperatures, minimized precipitation, moreover, fluctuation in the state of weather [1].

Iraq suffers from complicated water crisis risk of quantity and quality due to water shortages such as sequence wars, conflicts sectors, and the sanctions by the United Nations, neglect supporting infrastructure projects from governments and limited awareness for the environment, bad monitoring of industrial and agricultural wastes that disposals directly into the river. Most sources of water that supply the main rivers in Iraq (Tigris and Euphrates) come from outsides of the Iraqi borders. This crisis effects on properties of rivers water, consequently, this may be reflected in human, social, financial, and environmental [2, 3]. Water in Iraq exists in various forms, including surface water, rain, and groundwater, and each of them differs from others in terms of quantities, physical, chemical, biological characteristics, and its economic importance [3].

The optimal use of these sources has not been achieved due to many problems, including obsolescence of the irrigation and drainage systems, and the huge amount of water that is lost especially from the Euphrates River with the tributaries that flow into it that originates from the neighboring countries lands. This makes Iraq vulnerable to threatening neighboring countries by using water as a force available to them, as well as Iraq is located within dry and semi-arid regions with a severe shortage of rain falling. Moreover, desertification factors have been taken to cover large areas of Iraq [3].

The water of the Euphrates River inside Iraq is divided into two parts according to the concentration of ions in it. the first part is the chemical water type which is existed in the upper part and its contents are sulfate/bicarbonate, while the chemical water type in the lower part of it is sulfate/chloride [4].

The length of the Euphrates River is 2786 km and its average discharge at Syria-Iraq borders before the construction dam in Syria 983-1046 m3/s [5, 6]. Murat and the Karasu Rivers in the highlands in Turkey form the Euphrates river that meets at Keban city, Turkey that including Keban-Dam. In Turkey, the total flow of river feds by 88% of its tributaries besides from melting snows. In April and May, the maximum flows of the Euphrates River occurred which represented 42% of the total annual flow [6-8]. Then, the river flows toward southward of the Syrian plateau after passed 455 km within turkey lands, where three tributaries flow into the Euphrates River, where that the water source of tributaries come from turkey [8, 9]. These tributaries add 10% of the total flow to the river before entering the Iraqi borders [6, 10]. After the Euphrates River passing 661 km within Syria lands, the river enters the Iraqi border at Qaim city. The river flows through a limestone desert known as the Jazirah plateau reaching the downstream of the river and join with the Tigris River at Al-Qurnah-city, Al-Basrah

Governorate to form Shat Al-Arab with a length of 190 km and then discharges into the Arabian Gulf [9]. Part of the water river flows into the marsh (south of Iraq) [6, 9, 11]. The Tigris River is provided the Euphrates River with water due to the decreasing flows in the Euphrates River through a canal that is connected to the Tigris River across the Tharthar Lake with the Euphrates River [9]. The Basin of Euphrates consists of 440,000 km2, where 28% is situated in Turkey, in Syria is 22%, and 47% in Iraq [8]. Eight Main dams were constructed on the Euphrates River five dams in turkey (Keban-Dam, Ataturk-Dam, Karakaya-Dam, Karkamis-Dam, and Birecik), three dams in Syria (Al Baath-Dam, Tabqa-Sam, Tishreen-Dam), and one dam in Iraq (Haditha-Dam) [8].

Euphrates River suffers from deteriorating its water quality due to the effects of agricultural and domestic sources, additionally, the salinity increases severely along the river within Iraq lands [8]. The important issue to protect the river water stream from degradation is controlled on water quality. This is done by analyzing the physical, chemical, and biological properties in the water bodies of rivers to enable the makers to decide to reduce water pollution [6]. The requiring for water is become a main and valuable element for life due to the rapid growth rate, urbanization, and climate change, water becomes more and more precious.

Characteristics changes in rivers led to an increase in the contamination of river water environment that resulted from inappropriate human activities also to the effects of natural factors (e.g. nature of the soil that the stream of the river passing through it and drought conditions due to building projects and dams at upstream of the river in Turkey and Syria) form season to season and from year to other [6]. So, the discharge of the Euphrates River is changed seasonally and yearly because the water sources of Euphrates River come from precipitation through the river rout in Turkey, Syria, and Iraq, where that the changeable in discharge leads to high variation in the parameter's concentration [2, 6].

The last dry years is represented the big problem that the Euphrates River suffered from it due to building large dams and reservoirs upstream of the river which caused reducing the water level. additionally, the wrong politic of series governments and the effects of wars and adopt an ancient irrigation system. These factors contributed to the increasing salinity in the Euphrates River rout inside Iraq to be more than the allowable limit according to WHO (1500 mgL^{-1}) [6, 12].

[6] studied the changes in the quality of the Euphrates River water inside the Iraqi borders for the period from 2009 to 2010. Twenty concentrations of parameters were selected along the river. The results were compared with the concentrations between three sites and with similar parameters from earlier studies. The study found a large variance in water flow rate for the selected years and within the year itself due to the discharge of Euphrates water is entirely controlled by upstream countries (Turkey and Syria). The results showed that the pollutant concentration increase compared to the results with previous studies, and the quantities of discharge were fluctuated and decreasing toward the downstream. [4] conducted the concentration of T.D.S. in Euphrates River within Al-Muthana and Al-Qadisiyah governorates during 2015 and it was selected fourteen stations on the river. This study found that the T.D.S. concentrations in Al-Qadisiyah Governorate were between 527 - 3110 mgL^{-1} and 1130 - 8020 mgL^{-1} in Al-Muthana Governorate. The water quality index (W.Q.I.) study

related to the Al-Diwanyiah River part of the Euphrates river was occurred from 2015 to 2016 by measuring the concentrations of nine parameters from selected four locations on the Diwanyiah River. This study found the water quality index for the river was between marginal to poor according to the guideline of the Canadian Water Quality Index (GC-WQI) [13]. [14] carried out the study on the Euphrates River within the Southeast part of the DhiQar Governorate to determine the water quality index using the ANOVA model. Eight concentrations of parameters (temperature, dissolved oxygen, total hardness, total dissolved solids, hydrogen ion, turbidity, chloride, and electrical conductivity) were measured at three selected stations (monthly and seasonally). The results showed that the W.Q.I. was poor at sites (S.1 and S.3), while at the site (S.2) the W.Q.I. was classified as good. [15], conducted study between 2008 and 2009, seventeen parameters at eleven locations in the upper section of the river (Heet - Al-Ramadi). They adopted the WHO standards to compare with their results. In this study, they reached that the parameters of T (0C), PH, K, SO4, HCO3, Cl, D.O., NO3, E.C., PO4 were less than the limits of WHO standards. Otherwise, the parameters of Ca, Na, T.H., T.S.S., T.D.S., B.O.D., and Turbidity were over the upper limit.
The aims of this study are evaluating the concentrations of physic-chemical parameters for estimating the (W.Q.I.) after modifying of Euphrates River (MWQI). For the years of 2009, 2010, and 2011 from upstream to downstream, as well as producing the prediction maps of the MWQI using the GIS Software 10.5.

2. Methodology

The main items in this study can be seen in the schematic diagram (Fig. 1). The first part includes the assessment of physic-chemical parameters and the second part is employed to compute the MWQI for sixteen locations on the river. Then, the third part comprises creating the maps of the MWQI in GIS along Euphrates River using the IDWM model.

2.1 Study Area

Iraq is situated at a latitude between 34° 22' 52" N and 30° 00' 19" N, and at longitude between 41° 08' 55" E and 47° 25' 38" E (Fig. 2). The total area of Iraq is 438,317 km^2. The water area is around 950 km2 which is represented 0.22% of the entire area of Iraq. The population of Iraq is about 41 million inhabitants and its growth rate in 2019 is 2.5%. [16].
The climate is divided into the arid, semi-arid subtropical, and continental in central and southern Iraq. The climate in the north region of Iraq is changing to the Mediterranean [16-18]. Mean annual precipitation is about 216 mm in central and southern Iraq, while in the north part of Iraq can be reached to 1200 mm. Temperatures in Winter changes from 16 °C during the day to about 2 °C at night and recorded below 0°C in the north of Iraq, where that Winter is generally is mild to cool and so cold in northern Iraq. Summers in the central and southern of Iraq is extremely hot especially in the last years, the temperature in this season can be reached more than 55 °C in the

southern part of Iraq and it changes between 26 - 42°C in the north, and in the central and southern between 35 - 50°C [16, 17, 19].

Iraq is divided topographically into sevens sub-regions. sub-regions consist of High folded zone, Low folded zone, Al-Jazira zone, Western Desert zone, Thrust zone, Mesopotamia zone, and Southern desert zone [20]. Euphrates River flows inside Iraq approximately 1000 km until it joins in Basrah Governorate with Tigris River to form Shatt Al-Arab with a long of 190 km [19, 21].

The study of the hydrological system is reflected in the climatic factors and phenomena that prevail in the region. this fact states the great relationship between Climatology and Applied Hydrology on the basis that the hydrological system that the river basin now forms reflects the climate effect and its components over the times that the study area has gone through [4].

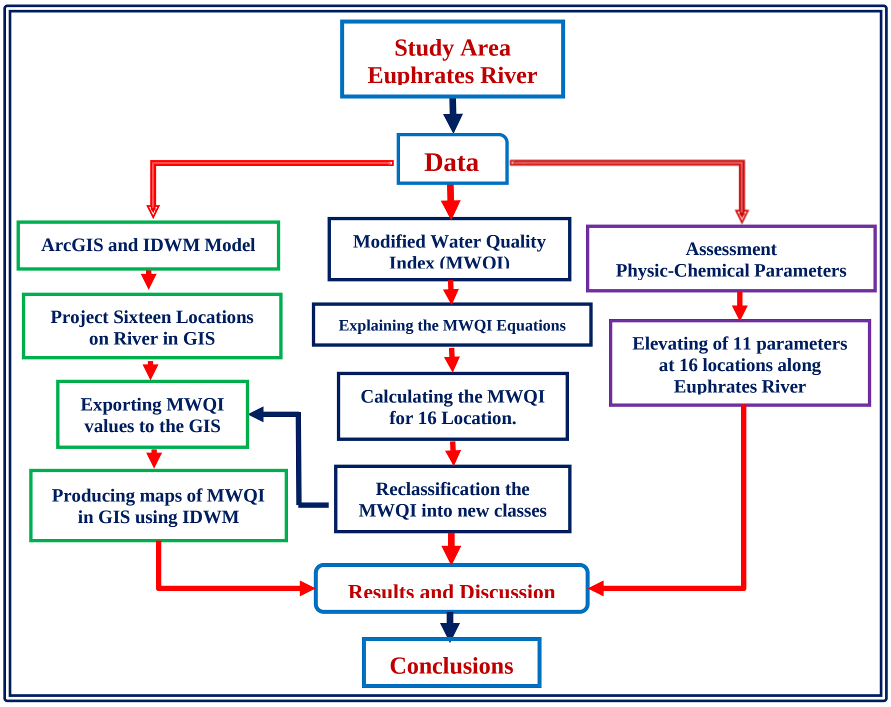

Fig. 1. The schematic diagram for research methodology.

2.2 Assessment of Water Quality

Eleven parameters concentrations were measured at sixteen locations in the years of 2009, 2010, and 2011 along the Euphrates River [22]. These locations are Al-Qaim, Before Haditha Dam, Haditha Dam, Hit, Al-Ramadi, Al-Saqlawia, Al-Fallujah, Al-Yusufiyah, Sadat Al-Hindiah, Al-Kifl, Al-Shinafiyah, Al-Samawah, Al-Nasiriyah, Al-Madina, Al-Izz, and Al-Qurnah (Fig. 3). Table 1 shows the coordinates of the selected locations. The eleven values of parameter concentrations recorded at sixteen locations on the river for three years can be seen in Table 2.

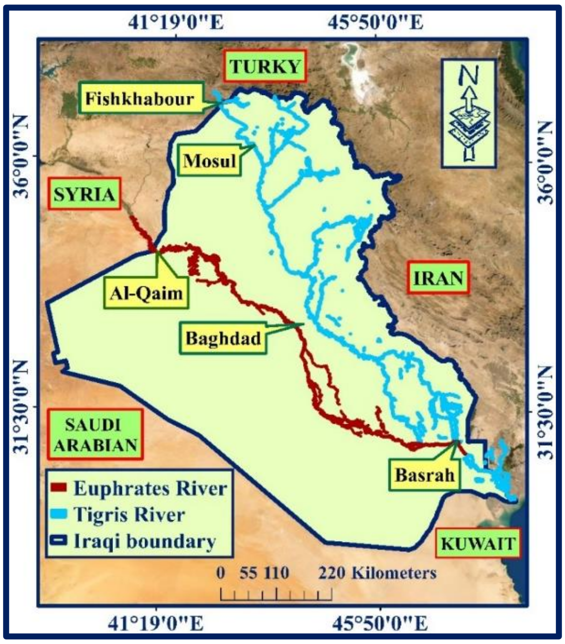

Fig. 2. Euphrates River Map within Iraqi borders.

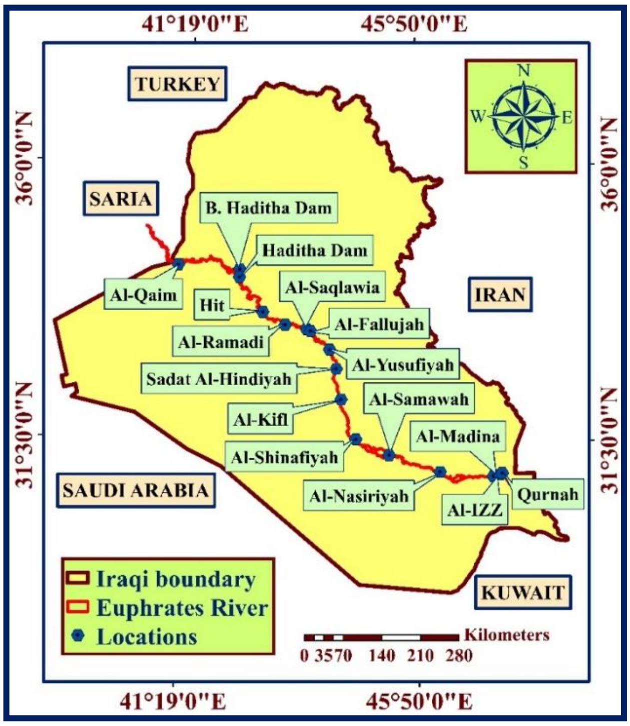

Fig. 3. Euphrates River and sampling locations, Iraq.

Table 1. Coordinates of the sixteen locations along the Euphrates River.

Symbol	Location	Latitude	Longitude
L.1	Al-Qaim	34° 22' 52" N	41° 08' 55" E
L.2	B. Haditha Dam	34° 20' 10" N	42° 21' 23" E
L.3	Haditha Dam	34° 12' 24" N	42° 21' 18" E
L.4	Hit	33° 38' 44" N	42° 49' 32" E
L.5	Al-Ramadi	33° 26' 25" N	43° 16' 04" E
L.6	Al-Saqlawia	33° 22' 34" N	43° 41' 04" E
L.7	Al-Fallujah	33° 20' 36" N	43° 45' 39" E
L.8	Al-Yusufiyah	33° 2' 40" N	44° 8' 09" E
L.9	Sadat Al-Hindiah	32° 43' 45" N	44° 16' 05" E
L.10	AL-Kifl	32° 13' 47" N	44° 21' 45" E
L.11	Al-Shinafiyah	31° 34' 50" N	44° 38' 44" E
L.12	Al-Samawah	31° 19' 11" N	45° 16' 55" E
L.13	Al-Nasiriyah	31° 02' 31" N	46° 15' 00" E
L.14	Al-Madina	30° 57' 27" N	47° 15' 27" E
L.15	Al-Izz	30° 58' 54" N	47° 22' 58" E
L.16	Al-Qurnah	30° 00' 19" N	47° 25' 38" E

Table 2. Physic-Chemical parameters at 16 locations on Euphrates River in 2009 -2011 [22].

Parameters	Ca	Mg	Na	K	Cl	SO4	HCO_3	T.H.	T.D.S.	NO_3	E.C.
2009											
Iraqi Stand.	50	50	200	10	250	250	200	500	1000	50	2000
S.D.	41	59	271	3.98	423	329	12.8	342	1233	8.2	1794
Average	114	99	340	9.43	482	611	149	694	8.56	5.9	2783
Max.	203	214	853	17.8	1290	1234	171	1421	4188	24.3	6154
Min.	73	44	128	5.29	145	306	129	370	823	1.8	1304
2010											
S.D.	29	44	204	2.7	289	264	12.8	248	866	3.7	1243
Average	110	82	255	7.4	353	545	132	614	1470	5.01	2135
Max.	168	176	673	12.2	933	1091	151	1152	3354	11.6	4718
Min.	79	43	98	4.2	123	291	112	374	755	1.4	1111
2011											
S.D.	47	46	209	3.41	320	282	17.98	283	998	0.96	1429
Average	107	81	247	8.91	338	510	139	577	1439	2.16	2116
Max.	217	183	714	15.68	1055	1156	168	1183	3683	4.3	5273
Min.	59	46	93	5.39	104	269	96	349	675	1.1	1018

2.3 Computing of Modified-Water-Quality-Index

The modified weighted arithmetic method is applied so that compute the W.Q.I. in the current study. Eleven were adopted by measuring them sixteen locations along the Euphrates River to find the (W.Q.I.). According to [23], the WQI was computed at sixteen locations along the Euphrates River using equations (2), (3), and (4) as follows:

$$SBP_i = \left(\frac{D_i - D_0}{STV_i - D_0}\right) \times 100 \tag{1}$$

Where: SBP_i: Sub-index of the i^{th} parameter, D_i: Value of measured concentration for the i^{th} parameter, D0: Ideal value in water for each parameter that has a value of zero, except the pH of 7 and the DO of 14.6 ppm. STV_i: Value of Iraqi standard of rivers of the i^{th} parameter [24].

$$IWi = \frac{\mathbf{1}}{\boldsymbol{STV_i}} \quad (2)$$

IWi: Value of the inverse standard (STV_i) of the i^{th} parameter.

$$W.Q.I. = \left(\frac{\sum \boldsymbol{SBPi \times IWi}}{\sum \boldsymbol{IWi}}\right) \quad (3)$$

In the weighted-arithmetic-method, equation (3) by [23] was modified to equation (4) so that it was reclassified the ranges of the W.Q.I. to a new classification (MWQI-Range) with a range of (0 - 100). Furthermore, the new MWQI values were divided into six classes and each class was given the description that deserves (Table 3).

$$MWQI = \left[\mathbf{100} - \left(\frac{\sum \boldsymbol{SBPi \times IWi}}{\sum \boldsymbol{IWi}}\right)/\mathbf{5}\right] \quad (4)$$

Table 3. MWQI ranges, statement, and classification (modified after [23]).

MWQI-Range	Statement	Classification	MWQI-Range	Statement	Classification
90 -100	Excellent	C-I	40 - 60	Very poor	C-IV
80 - 90	Good	C-II	20 - 40	Polluted	C-V
60 - 80	Poor	C-III	0 - 20	Very polluted	C-VI

2.4 Prediction Maps

To output, the prediction maps of the MWQI of the Euphrates River, the inverse-distance-weighting model (IDWM) in the GIS software was used to generate the interpolation for the MWQI values at sixteen locations along the river. The prediction maps consisted of the average values of the MWQI for the years 2009, 2010, and 2011 for the whole length of the river and they output based on the values at the chosen locations. The IDWM model is applied for finding the unknown values of set points at definite locations based on the average neighboring and surrounding points that have known value and locations [26]. For calculating the predicted values by this method, the nearest points to the prediction locations have a high effect compared with points that are situated further than the prediction locations [27, 28].

3. Results and Discussion

3.1 Physic-Chemical Concentrations for Parameters

Calcium (Ca) is the first parameter among eleven physic-chemical parameters selected in this study, where its concentrations were ranged between (73 – 203), (79 – 168), and

(59 – 217) ppm respectively for the years 2009, 2010, and 2011. The average values of Ca concentration (ppm) were 114 (2009), 110 (2010), and 107 (2011).

The mean values of Mg were 99, 82, and 81 (ppm) respectively in the years 2009, 2010, and 2011. The range of Mg concentration readings in the years 2009, 2010, and 2011 were (respectively) (44 – 214) ppm, (43 – 176) ppm, and (46 - 183) ppm. The measured values of the Ca and Mg at all selected locations on the river were over the permissible value of Iraqi standards (50 ppm) [24] (Figs. 4a and 4b).

The sodium concentration (Na) ranged between 128 - 853 ppm in 2009, 98 to 673 ppm in 2010, and 93 - 714 ppm in 2011. The mean values of the Na were 340 ppm (2009), 255 ppm (2010), and 247 ppm (2011). This study displayed concentrations of sodium (Na) at locations from (L.1) to (L.10) were within the Iraqi standards of 200 ppm [24], while the values at the locations from (L.11) to (L.16) over the maximum values according to the Iraqi standards (Fig. 4c).

The maximum and minimum values of Potassium (K) concentration in 2009, 2010, and 2011 were respectively (17.77, 12.23, and 15.68) ppm and (5.29, 4.24, and 5.39) ppm, while the average values of the potassium were 9.44 ppm (2009), 7.44 ppm (2010), and 8.91 ppm (2011). The results show that the readings of the measured potassium at the locations (L.1 – L.10) were within the allowable Iraqi standards (10 ppm) [24], while the measured K concentrations at some locations from (L.11) to (L.16) were over the standard limit (Fig. 4d).

The maximum concentrations readings of chloride (Cl) in 2009, 2010, and 2011 were 1290, 933, and 1055 ppm respectively at the location (L.12), with mean values of 482, 353, and 338 ppm in the three years. During the years 2009, 2010, and 2016, the lowest concentration values of chloride were 145 (L.1), 123 (L.2), and 104 (L.2) ppm. The measured concentrations of chloride of the Euphrates River were within the Iraqi standards (250 ppm), accepted the values at the locations (L.11 to L.16) [24] (Fig. 4e).

Sulphate (SO_4) concentrations and varied between (306 - 1234) ppm at the locations (L.1 and L.13) in 2009, and between (291 - 1091) ppm at the locations (L.3 and L.13) in 2010 with average values of 510 and 545 ppm respectively. SO_4 concentrations in 2011 have fluctuated between 296 ppm (at the location L.1) until 1156 ppm (at the location L.13), and in this year, the mean recorded readings of SO_4 was 510 ppm. The concentrations of SO_4 in sixteen locations on Euphrates River were over the Iraqi standards (250 ppm) during these years [24] (Fig. 3f).

The T.D.S. concentration recorded in 2009, 2010, and 2011 were varied (respectively) between 823 - 4188 ppm, 755 – 3354 ppm, and 675 - 3685 ppm. The mean readings of the T.D.S. concentrations were (respectively) 1841 ppm, 1470, and 1439 ppm in the years 2009, 2010, and 2011 respectively. For the EC concentration, the highest and lowest readings were ranged (μmhos/cm) between 1304 – 6292 (2009), 1111 – 4718 (2010), and 1018 – 5273 (2011). For E.C. concentration, the average values in 2009, 2010, and 2011 were 2783, 2135, and 2116 μmhos/cm respectively. The readings of T.D.S. and E.C. were over the acceptable Iraqi standards (1000) ppm, and (2000) μmhos/cm [24], accepted the values at the locations (L.11 - L.16) (Figs. 5a and 5b).

The peak readings of the total hardness (T.H.) concentrations were (ppm) 1421 (2009), 1152 (2010), and 1183 (2011). The readings of 370, 374, and 349 ppm have represented the minimum values of (T.H.). For the years 2009, 2010, and 2011, the mean concentrations were 694, 614, and 577 ppm separately. The (T.H.) concentrations recorded in this study were over Iraqi standards of 500 ppm [24] at locations from (L.1) to (L.9) in the years of 2009 and 2010, and locations (L.1 - L.10) in 2011 (Fig. 5c).

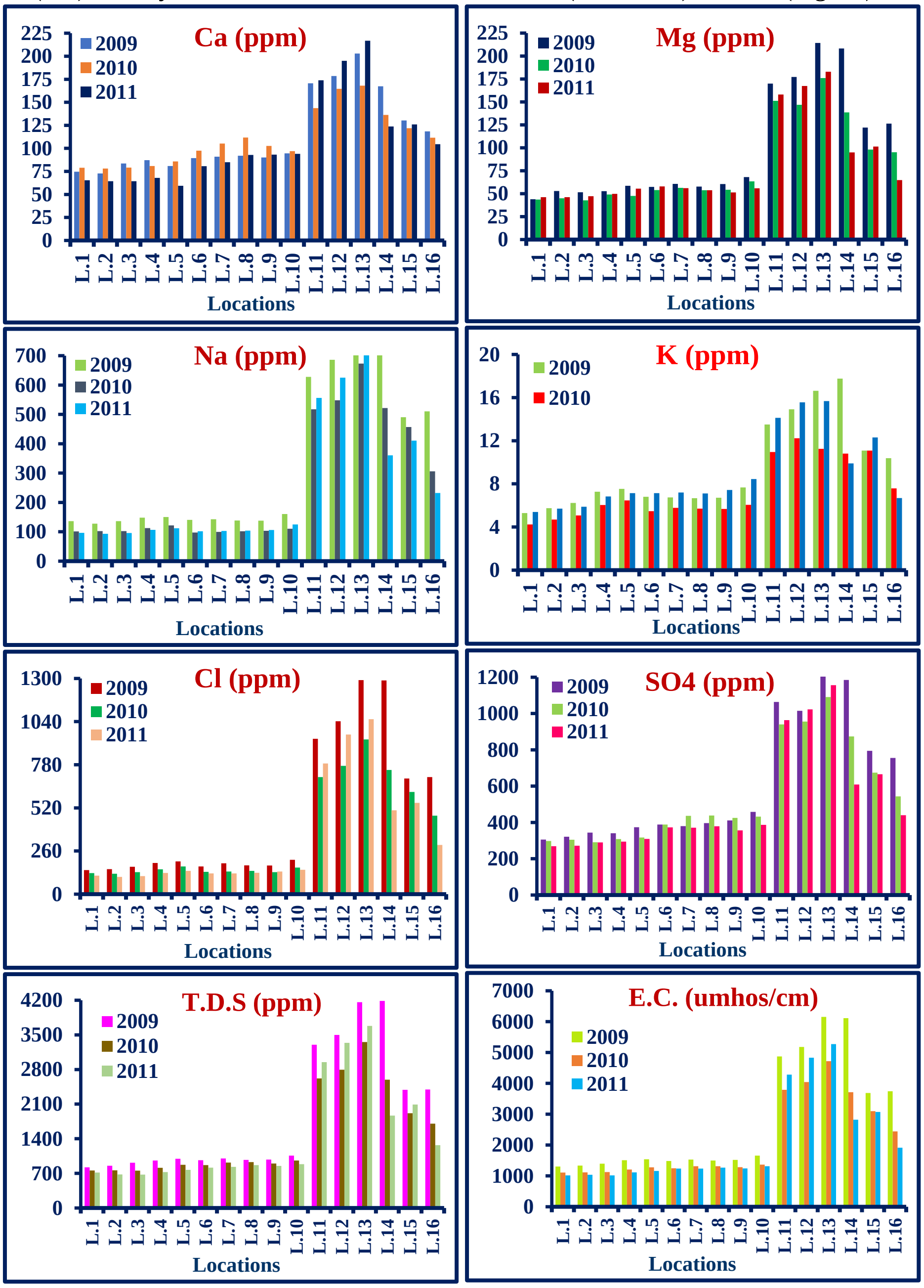

Figure 4. Concentrations along Euphrates River in (2009, 2010 and 2011) for parameters of (a): Ca; (b): Mg; (c): Na; (d): K; (e): Cl; (f): SO_4.

The maximum values of bicarbonate (HCO_3) were 171, 151, and 168 ppm (respectively) in 2009, 2010, and 2011. The minimum values of HCO_3 were (ppm) 129 (2009), 112 (2010), also 96 (2011). Average values in the years 2009, 2010, and 2011 were (respectively) 149, 132, and 139 ppm. Compared with the Iraqi standards, all readings of HCO_3 concentrations recorded in this study have exceeded the upper limit (200 ppm) [24] (Fig. 5d).
The average values of Nitrate (NO_3) were 8.56 ppm (2009), 5.01 ppm (2010), and 2.16 ppm (2011). The highest and lowest values were 24.3 and 1.78 ppm in 2009, 11.47, and 1.43 (ppm) in 2010, then in 2010 4.29 and 1.13 ppm. All readings of NO_3 in this study were within the Iraqi standards limit (50 ppm) [24] (Fig. 5e).

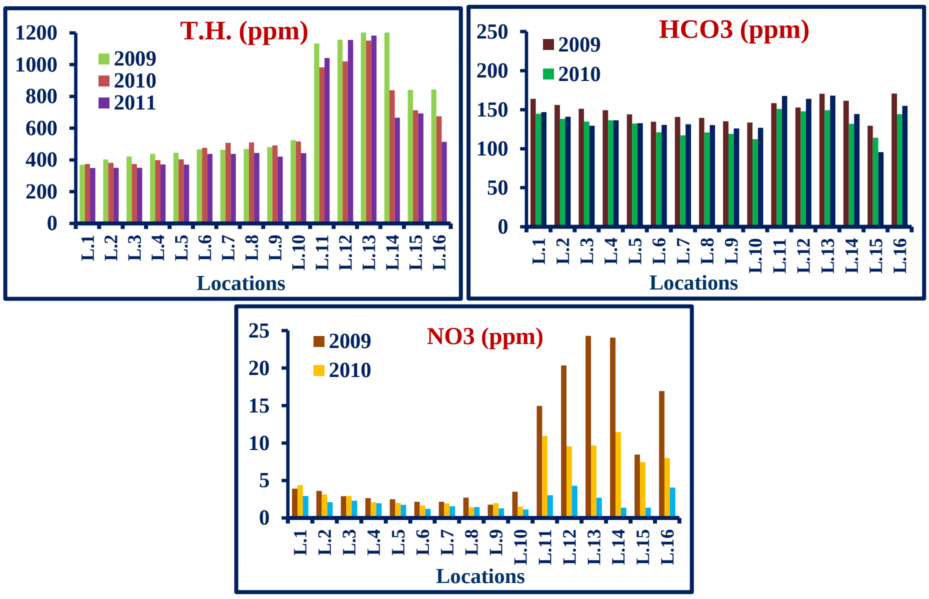

Fig. 5. Concentrations along Euphrates River in three years of (2009 - 2011) for parameters of (a): T.D.S.; (b): E.C.; (c): T.H.; (d): HCO_3; (e): NO_3.

3.2 Modified Water Quality Index (MWQI)

For estimating the quality of the Euphrates River water at the chosen locations in three years of 2009 – 2011, the weighted-arithmetic-method employed after modifying.
The average values of MWQI in the two seasons (dry and wet) as well as average readings for three years of the Euphrates River were, respectively, as follows: 88.4, 86.9, 85.7 (L.1), 87.9, 85.9, 86.9 (L.2), 87.1, 85.7, 86.4 (L.3), 85.7, 84.2, 84.9 (L.4), 85.1, 83.9, 84.5 (L.5), 84.9, 83.9, 84.4 (L.6), 84.3, 83.7, 84.0 (L.7), 84.2, 83.8, 83.9 (L.8), 84.5, 83.6, 84.0 (L.9) and 83.1, 82.3, 82.7 (L.10). The values of all parameters at the locations (1 - 3) were within Iraqi standards of rivers accepted Ca and SO4, and at locations (L.4 – L.10) eight parameters within Iraqi standards of rivers accepted three parameters are Ca, SO_4, Cl. The average values of MWQI for the years (2009 - 2011)

at locations (L.1 – L.10) were within the range of (80 - 90) and the water at these locations was classified as good water quality (class, C-II).

The calculated values of the MWQI were within the range of (80 – 90) and classified as good water quality (class, C-II) for the locations from (L.1) until (L.10) of the Euphrates River. At these locations, there were low concentrations of contaminants that give positive influences assisted to improve the river water quality index. Furthermore, increase the discharge of Euphrates River contributed to reducing Physic-Chemical parameters concentrations, where most rivers have the property of itself-purify, consequently, these leading to reduce MWQI values.

Along Euphrates River at the locations of Al-Shinafiyah (L.11), Al-Samawah (L.12), Al-Nasiriyah (L.13), Al-Madina (L.14), Al-Izz (L.15), and Al-Qurnah (L.16), the MWQI values for the wet season and dry season and average values for the selected three years (respectively) were (65.6, 64.6, 65.1), (64.0, 60.4, 62.2), (61.6, 56.5, 58.8), (69.9, 63.4, 66.7), (76.8, 67.7, 72.2) and (78.3, 76.9, 77.6). Most parameters were higher than allowable Iraqi standards of rivers at the locations (L.11 – L.16), excepted two parameters (HCO_3 and NO_3) at locations (L.11 – L.15), and three parameters (K, HCO_3, and NO_3) at the location (L.16) which were within Iraqi standards. Table 4 shows the MWQI classes for sixteen locations on Euphrates River in two seasons (dry and wet) and the average values of the MWQI for the seasons also for these three years.

Table 4. Classification of MWQI and average values of Euphrates River, for three years (wet, dry, total).

Location	2009		2010		2011		Average MWQI for two seasons				Average MWQI for three years	
	Class wet	Class dry	Class wet	Class dry	Class wet	Class dry	Wet	Class	Dry	Class	Total	Class
L.1	C-II	C-II	C-II	C-II	C-II	C-II	88.4	C-II	86.9	C-II	87.7	C-II
L.2	C-II	C-II	C-II	C-II	C-II	C-II	87.9	C-II	85.9	C-II	86.9	C-II
L.3	C-II	C-II	C-II	C-II	C-II	C-II	87.1	C-II	85.7	C-II	86.4	C-II
L.4	C-II	C-II	C-II	C-II	C-II	C-II	85.7	C-II	84.2	C-II	84.9	C-II
L.5	C-II	C-II	C-II	C-II	C-II	C-II	85.1	C-II	83.9	C-II	84.5	C-II
L.6	C-II	C-II	C-II	C-II	C-II	C-II	84.9	C-II	83.9	C-II	84.4	C-II
L.7	C-II	C-II	C-II	C-II	C-II	C-II	84.3	C-II	83.7	C-II	84.0	C-II
L.8	C-II	C-II	C-II	C-II	C-II	C-II	84.2	C-II	83.8	C-II	83.9	C-II
L.9	C-II	C-II	C-II	C-II	C-II	C-II	84.5	C-II	83.6	C-II	84.0	C-II
L.10	C-II	C-II	C-II	C-II	C-II	C-II	83.1	C-II	82.3	C-II	82.7	C-II
L.11	C-III	C-III	C-III	C-III	C-III	C-III	65.6	C-III	64.6	C-III	65.1	C-III
L.12	C-III	C-IV	C-III	C-III	C-III	C-IV	64.0	C-III	60.4	C-III	62.2	C-III
L.13	C-IV	C-IV	C-III	C-III	C-III	C-IV	61.1	C-III	56.5	C-IV	58.8	C-IV
L.14	C-III	C-IV	C-III	C-III	C-III	C-III	69.9	C-III	63.4	C-III	66.7	C-III
L.15	C-III	C-III	C-III	C-III	C-III	C-III	76.8	C-III	67.7	C-III	72.2	C-III
L.16	C-III	C-III	C-II	C-III	C-II	C-II	78.3	C-III	76.9	C-III	77.6	C-III

The calculated values of the MWQI at the locations (L.11, L.12, L.14, L.15, and L.16) were within the category of (60 – 80). Consequently, the MWQI at these locations was defined as poor water quality (class, C-III). For other locations, most concentrations of the physic-chemical parameters for the location (L.11) in Shinafiyah passing to the location (L.16) at Al-Qurnah (excepted L.13 at Al-Nasiriyah) were over the permissible Iraqi standards. Therefore, the resulted MWQI values were classified as poor water quality (class, P-III). In location (L.13), the MWQI value was within the category of (40 – 60), and this location was classified as very poor water quality (class, C-III) due to the increased all concentrations of parameters in this location

For the sixteen locations, along Euphrates River, the average MWQI in the seasons of dry and wet also average MWQI for three years (2009 - 2011) can be seen in Fig. 6.

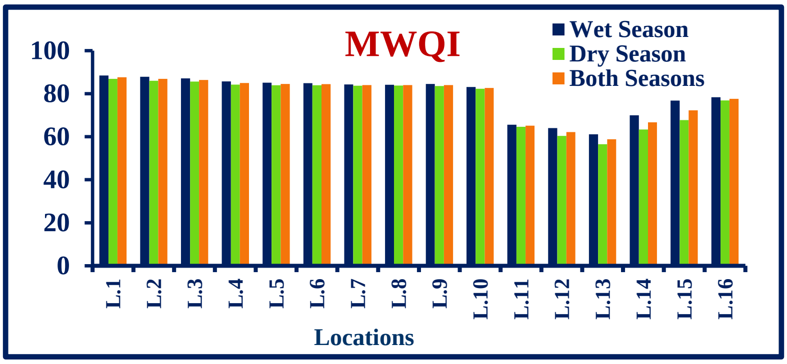

Fig. 6. Average values of the MWQI for sixteen locations along the Euphrates River.

The maps of the distribution average values of the MWQI along the Euphrates River via utilizing the IDWM for each season (dry and wet), as well as the average values of the MWQI for the years (2009, 2010, and 2011), can be seen in Figs. 7, 8 and 9.

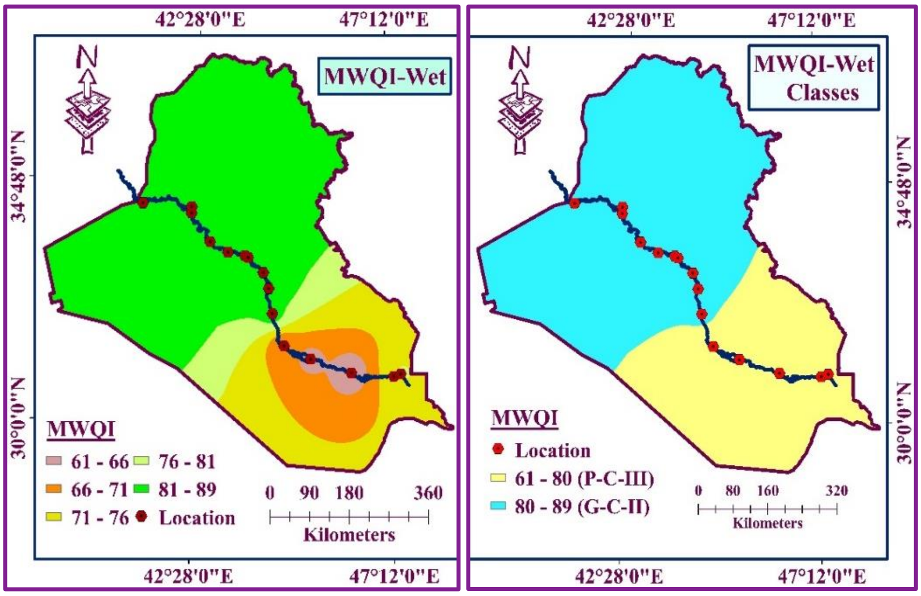

Fig. 7. Maps of ranges and classification of the MWQI for the wet season (average values), Euphrates River.

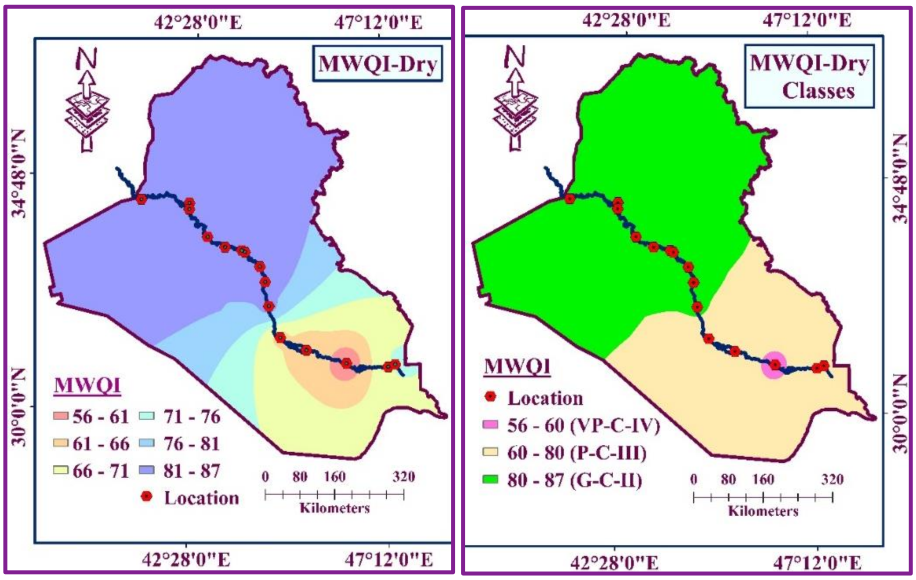

Fig. 8. Maps of ranges and classification of the MWQI for the dry season (average values), Euphrates River.

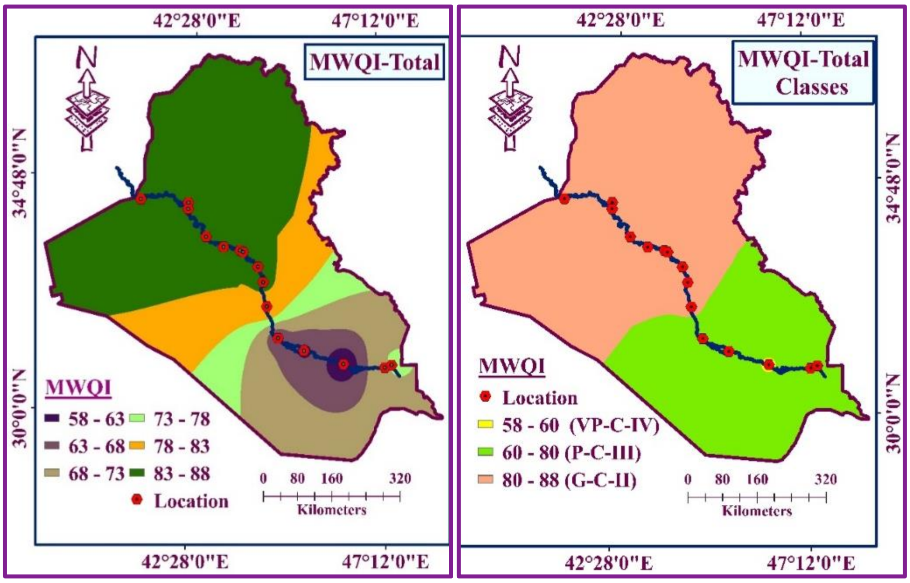

Fig. 9. Maps of ranges and classification of average values of the MWQI, for three years (2009 – 2011), Euphrates River.

4. Conclusions

The important role of the Euphrates River beside the Tigris River to utilize water in different aspects in the region that passing through it especially in Iraq, the current study aims to determine the water quality in Euphrates River. Eleven physic-chemical parameters were measured at sixteen locations on the river in three years (2009 – 2011) for two seasons. The chosen physic-chemical parameters are included Cl, SO_4, HCO_3, NO_3, Na, K, Ca, Mg, T.H., T.D.S., and E.C.

The readings of entirely physic-chemical parameters (expected HCO_3) in the years of 2009, 2010, and 2011 along the Euphrates River were noted to increase progressively from the location (L.1) in Al-Qaim to the location (L.10) in Al-Kifl. Then, the trend of increasing for all concentrations of parameters was displayed obviously after location (L.10) especially for locations (L.11 – L.14). The concentration of HCO_3 was decreased gradually from location (L.1) to location (L.10) and then increased after (L10) particularly at the locations (L.11, L.12, L.13, and L.16).

To calculate the WQI of the Euphrates River, the method of weighted arithmetic was employed after modifying under the new title of the modified-weighted-arithmetic method (MWAM). The averages values of the MWQI for three years (total, wet, and dry) were calculated for sixteen locations on the Euphrates River.

For the locations from (L.1) until (L.10) of the Euphrates River, the averages values of the MWQI (wet, dry, total) were classified as good water quality (class, C-II) within the range of (80 – 90).

The water quality of the Euphrates River at locations (L.11, L.12, L.14, L.15, and L.16) based on the calculated values of the MWQI was classified as poor water quality (class, C-III) within the category of (60 – 80). The water quality at the location (L.13) in Al-Nasiriyah governorate was classified as very poor water quality (class, C-IV) within the range of class (40 – 60), where all concentrations of physic-chemical parameters measured at this location were upper the Iraqi standards limit.

The calculated values of the MWQI at the locations (L.11, L.12, L.14, L.15, and L.16) were within the category of (60 – 80). Consequently, the MWQI for Euphrates River at these locations was classified as poor water quality (class, C-III). The MWQI of the river waterway in Shinafiyah location (L.11) until the location (L.16) at Al-Qurnah (excepted L.13 at Al-Nasiriyah) was classified as poor water quality (class, C-III) based on the calculated MWQI values. This is due to that most measured values of parameters at these locations (L.11 - L.16) were over the allowable Iraqi standard.

The MWQI value at location (L.13) was within the category of (40 – 60), and this location was classified as very poor water quality (class, C-III) due to the increased concentrations of measured parameters in this location.

The average of the total values three years and the average values in the wet and dry seasons for these years of MWQI at sixteen locations were employed to find out the prediction maps along the whole route of the Euphrates River, where the interpolation method of Inverse distance weighting in the GIS was used for this purpose.

In general, the novelty of this study included two portions. The first section studied the water quality of the Euphrates River as a total length through adopted eleven physic-chemical parameters measured at sixteen locations. The second section included applying a modified method to calculate the water quality index (MWQI) of the Euphrates River in Iraq for three years in the dry and wet seasons. Moreover, creating the distribution (prediction) maps for the MWQI values in both two seasons to evaluate the quantity of the river at each its part for drinking uses. These maps can be supported future studies for water quality of Euphrates River at any location on it.

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