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Application GIS Software to Determine the Distribution of T.D.S. Concentrations Along the Tigris River

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Application GIS Software to Determine the Distribution of T.D.S. Concentrations Along the Tigris River

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Abstract
Tigris River is a major source to supply water for a big part of Iraq. Lately, Iraq has experienced water shortage problems such as variability in climate and the building of huge dams in the upstream countries (Turkey and Iran). In this work, the total dissolved salts (T.D.S.) were measured at fourteen sites on the Tigris River in two periods of the year 2014. The first period consisted of six rainy-months (April – September) and the second period covered non-rainy-months (October - March). Interpolation technique of inverse-distance-weighting (I.D.W.) in ArcGIS was applied to create the prediction maps of the river for (T.D.S.) concentration in both periods. The findings revealed that the (T.D.S.) levels continued to the last site in Al-Qurnah-city (Basrah) from the first site in Fish-Khabur-city (S-1). In the first period, the (T.D.S.) levels at fourteen selected sites were over the levels in the second period. According to World-Health-Organization (2003), the (T.D.S.) concentration on the Tigris River in both periods in 2014 was graded into five classes, then, the prediction maps of the (T.D.S.) classifications were created.

Keywords: T.D.S., GIS, I.D.W., Classification Water River, Tigris River-Iraq.

1. Introduction
Iraq was considered an exception to the Middle East in terms of available water resources because of the existence of the two rivers (Euphrates and Tigris). The water quality of the rives in Iraq effects by many influences (external and internal), and they give a negative impact on water quality and quantity, where approximately 80% of the Tigris River's water originate from Turkey and Syria [1,2]. These influences divided into the under-controlled (e.g. building dams and irrigation projects) or difficult for controlling related to climate change (for instance, decrease precipitation and increasing temperature) [3-8].
Iraq covered an area of 438,317 km^2 and its population is about 40 million in 2018. The total water consumption of Iraq reaches 42.3 billion cubic meters per year. This is used for agriculture (90%), Industry (6%), and human use (4%). Recently, the discharge of the two main rivers in Iraq ongoing to reduce, and Iraq facing water shortage problems now [7, 8, 9, 10, 11]. These problems are related to the establishment of many projects of irrigation and huge dams in the neighboring countries (Turkey and Iran), as well as the great effects of fluctuating climate on the discharge of the rivers.
Tigris River originates from Turkey (in the southeastern parts) with a length of about 1700 km. It drains an area of 472,606 km^2 and its proportion is distributed within 4 countries that share in the river catchment (18%-Turkey, 3%-Syria, 28%-Iran, and 51%-Iraq). The average flow of the River Tigris until 1973 was about 21 billion cubic meters. After this year, a series of dams were built. At that period, the water release of the river at the capital of Iraq (Baghdad) reached 1208 m^3/sec, while, the discharge now is 522 m^3/sec [12, 13]. It has been noticed that with the decrease of the flow in the Tigris River the quality of its water is deteriorating [12,14]. In this research, the total soluble salt (T.D.S.) along the Tigris River was studied in 14 sites during the year 2014 to see the variations in the dry and wet periods.
A geographic-information-system (GIS) was used as a base for collecting, management, and analyzing the information. GIS combines different and many types of data with mathematical models to produce the necessary maps. To manage and develop the water resource as well as determine the properties of parameters in water bodies, the GIS and remote sensing were

employed for this purpose. The quality and characteristics of water bodies were determined by many researchers and were compared with the collected field data and the satellite images that were analyzed in GIS such as [15- 18].
The technique (I.D.W.) has been applied in ArcGIS to produce the output maps for different properties of water bodies because this method has high accuracy to determine the interpolation for unknown points based on the available known points existing along long the routes such as a river [19].
Integrating GIS and (I.D.W.) technique were adopted by several researchers in their studies to generate the maps for rivers parameters such as [20-27]. This research aims to evaluate the (T.D.S.) concentrations in 2014 at fourteen sites covering 1375 km of Tigris River within the Iraqi boundary. Moreover, producing the (T.D.S.) maps after interpolating in ArcGIS for Tigris River in the first period (rainy-months), and the second period (non-rainy-months) using the I.D.W. technique. For drinking uses, the concentration of the (T.D.S.) was estimated at 14 sites along the river. In the two periods, the I.D.W. technique and the GIS tools are used for the development of the (T.D.S.) interpolation maps along the River Tigris.

2. Methodology

2.1. Collection Data

The values of the (T.D.S.) on the Tigris River in fourteen sites in 2014 were measured by the NCWoRM (2015), [28] (Table 1). These sites are Fish-Khabur-city, Mosul-Dam-district, Al-Mosul-city, Shraqat-city, Tikrit-city, Samarrah-city, Al-Tarmiyah-city, Al-Muthanna-Bridge (Baghdad), Shuhada-Bridge (Baghdad), Al-Aziziyah-city, Al-Kut-city, Ali Garbi-city, Al-Amarah-city, and Al-Qurnah-city (Figure 1). Total dissolved solids (T.D.S.) at all sites were divided into two periods in 2014, the first period consisted of six rainy-months from October to March, and the second period included six non-rainy-months from April to September.

Table 1. Concentrations of the T.D.S. on the Tigris River for rainy and non-rainy months in 2014 [28].

Sites	Sites-Distance (km)	X-direction	Y-direction	T.D.S. (ppm)	
				First-Period	Second-Period
Fish-Khabur-city (S-1)	0	266102	4104412	447	442
Mosul-Dam-district (S-2)	82	316791	4061850	505	495
Al-Mosul-city (S-3)	168	332982	4023924	580	567
Shraqat-city (S-4)	296	342773	3929097	656	640
Tikrit-city (S-5)	431	380372	3829949	746	717
Samarrah-city (S-6)	474	391570	3794163	757	727
Al-Tarmiyah-city (S-7)	651	438111	3700862	772	763
Al-Muthanna-Bridge (S-8)	663	439145	3699016	808	798
Shuhada-Bridge (S-9)	702	453880	3675739	858	852
Al-Aziziyah-city (S-10)	828	506020	3640265	909	900
Al-Kut-city (S-11)	977	573481	3599129	970	962
Ali Garbi-city (S-12)	1105	658264	3593945	1172	1164
Al-Amarah-city (S-13)	1236	702802	3526406	1370	1361
Al-Qurnah-city (S-14)	1375	732823	3433509	1408	1399
Average				854	842
S.D.				283	285
Max.				1408	1399
Min.				447	442

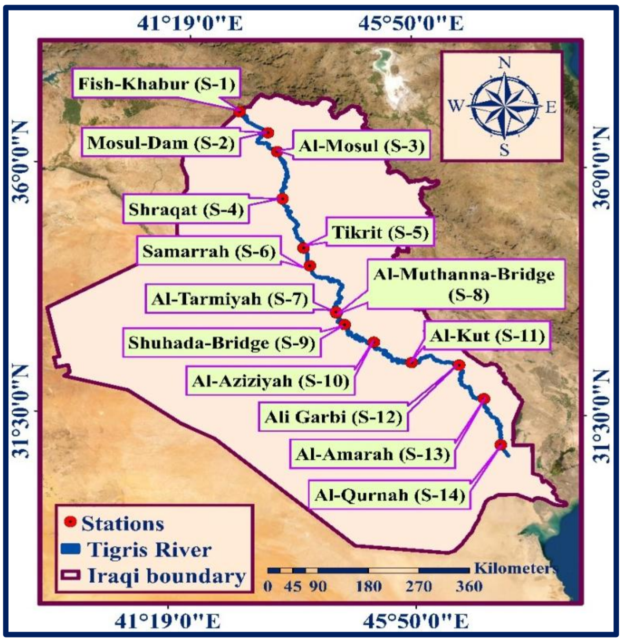

Figure 1. Sampling sites of Tigris River, Iraq.

2.2. Predicting of T.D.S. Concentration Maps Using I.D.W. Technique

The Inverse-Distance-Weighted (I.D.W.) technique was employed to create maps of (T.D.S.) after interpolating in the rainy and non-rainy months in the Tigris River. The (I.D.W.) technique is reflected principally in the first law in geography-layout [29], where this I.D.W. technique is depending on estimating accurate local deterministic interpolation [30]. According to, the (I.D.W.) technique is considered more suitable than other techniques for interpolating purposes [24]. According to [24], the mathematical equation (1) of the I.D.W. technique was applied for interpolation purpose as follows:

$$V_0 = \frac{\sum_{i=1}^{n} V_i \frac{1}{D_i^p}}{\sum_{i=1}^{n} \frac{1}{D_i^p}} \qquad (1)$$

Where: V_o: The estimated point zero value; V_i: The V known point value i; D_i: Distance between the point zero, and point i; D: The known points number used in estimation; *p*: the specified power > 1.

2.3. Classification of the Tigris River for Drinking Uses

According to the W.H.O. [31], the (T.D.S.) concentration in raw water was classified into five classes for drinking uses. In class-I it is less than 300 ppm was considered as excellent palatability for drinking and other uses, while the ranges of class-II (300-600), class III (600-900), class-IV (900 – 1200), class-V (> 1200) were classified respectively as good, fair, poor and unacceptable for drinking and different uses of household (Table 2).

Table 2. Classification of the (T.D.S.) of raw water for drinking uses [31].

Class	Range ppm	Statement
I	< 300	Excellent
II	300 - 600	Good
III	600 - 900	Fair
IV	900 - 1200	Poor
V	> 1200	Unacceptable

3. Results and Discussion

The values of (T.D.S.) concentration along the Tigris River during the first period (rainy-months) ranged from 447 ppm at the site (S-1) to 1408 ppm at the site (S-14). In the second period (non-rainy-months), the readings of the (T.D.S.) ranged between 442 to 1399 ppm. The mean levels of (T.D.S.) during the first and second periods were 854 ppm and 841 ppm respectively. Except for the values recorded at sites (S-11 to S-14), the (T.D.S.) readings were higher than the Iraqi standards limit of 1000 ppm, while according to [31], the (T.D.S.) concentrations at all sites showed they have been over the allowable limit of 500 ppm excluding the values at the site (S-1). T.D.S. levels have increased from Fish-Khabur-city in the northern part of Iraq (site S-1) toward the Al-Qurnah-city in the southern part of Iraq (site S-14).

In all selected sites, the values of (T.D.S.) concentrations along the river in the first period were over the values of the second period. In the current study, the peak value of the (T.D.S.) was recorded at the site (S-14) at the Al-Qurnah-city, which is due to the accumulation of salts from upstream sites. Additionally, the Tigris River receives different pollutants discharging into the river such as industrial wastes, runoff of agricultural waste and domestic wastewater, etc. These factors caused an increase of the (T.D.S.) values at all sites, particularly in the site (S-14). The lowest value of (T.D.S.) recorded at the site (S-1) is due to the fact that this stretch of the river upstream that site is not heavily populated and there are very low agricultural activities upstream this site.

Figure 2 shows the predicted maps for (T.D.S.) concentrations along the Tigris River for the first and seconds periods through measuring (T.D.S.) at fourteen sites from the north toward the south. It is evident from the results that the (T.D.S.) concentration values were increasing toward the south (Figure 3).

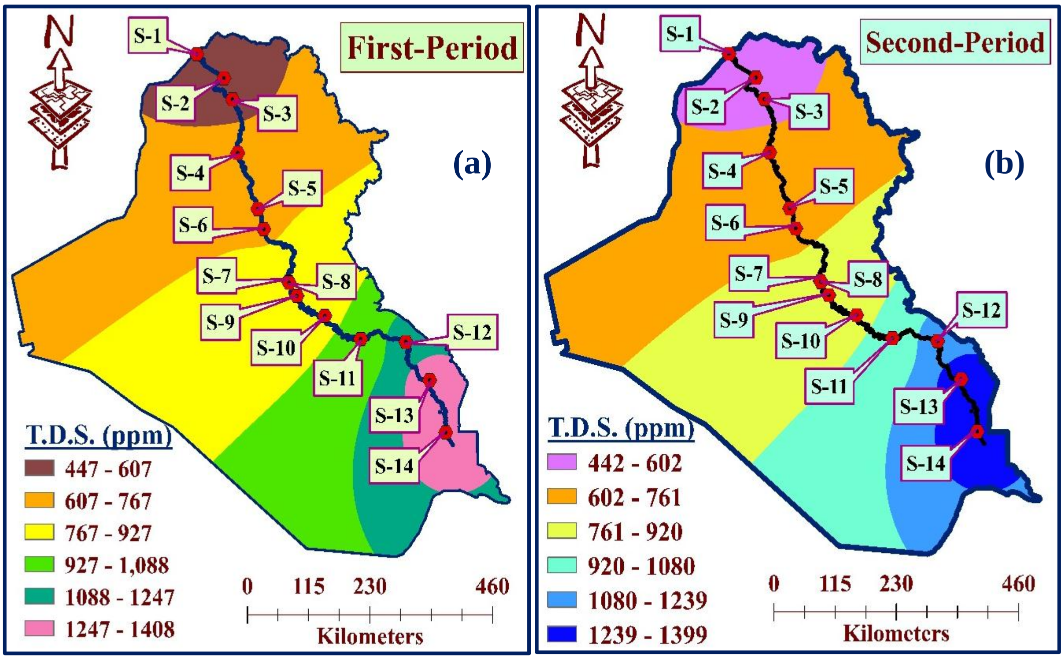

Figure 2. Prediction maps of the (T.D.S.) concentration on Tigris River for the two periods of (a): rainy-months; (b): non-rainy-months.

This increase is related to several reasons. These are:

a. Construction of dams and related irrigation projects: This is where evaporation is increased to reach about 8 billion cubic meters [10, 32, 33]. Additionally, backwater to the river from irrigation projects is another factor to increase the salinity of the water.
b. Wastewater and waste of war: Approximately 84% of the wastewater is directly discharged into the rivers [34]. Waste from the two Gulf wars is another source of contamination.
c. Population growth rates: This rate is considered very high, particularly in Iraq and most of the population in riparian countries resides on the bank of the rivers [35].

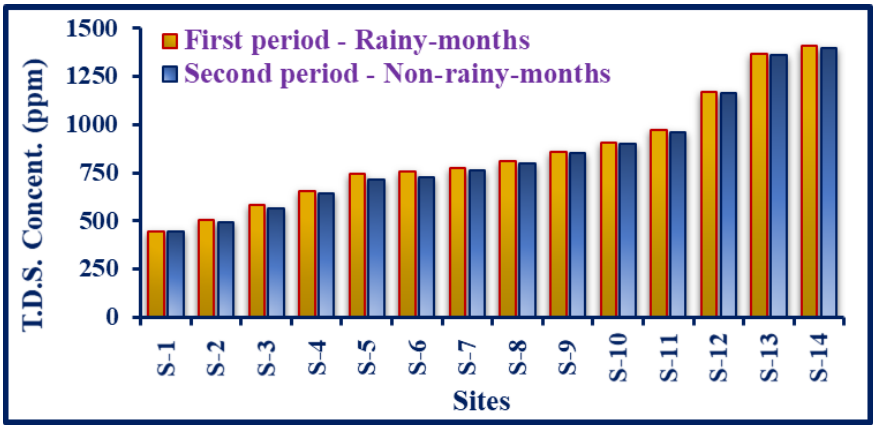

Figure 3. T.D.S. Variation of at fourteen sites on the Tigris River for two periods.

Generally, the (T.D.S.) concentration increase from the site (S-1) to site (S-14) due to the existence of big cities that have a dense population, and the existence of many irrigation projects, which affect the quality of the river system, as well as discharge contaminants irregularly into the river from various sources.

Prediction maps of the (T.D.S.) concentration of the Tigris River in 2014 during the first and second periods were created applying the Inverse-Distance-Weighted technique in the environment of GIS. The created maps give a clear idea about the concentration of the (T.D.S.) along the Tigris River and permit the researchers the chance in the future to check their results with the results in this study.

According to the classification of [31] for (T.D.S.) in the raw water, the measured (T.D.S.) concentration was classified into five classes for the fourteen sites on the river (**Table 3**). For both sections of 2014, the (T.D.S.) concertation levels at sites (S-1, S-2, and S-3) were ranged from 300 to 600 ppm and classified as class II (good for drinking uses), while the concentrations of (T.D.S.) from S-4 until S-9 were within the range of 600 – 900 ppm (Class III) and the water at these classified as fair for drinking uses. The (T.D.S.) concentrations at the sites (10, 11, 12) and (13, 14) were classified as class IV and class V respectively. The (T.D.S.) concentrations at sites (S-10, S-11, S-12) were ranged between 900 – 1200 ppm, and its concentrations at the sites (S-13, S-14) were higher than 1200 ppm. Therefore, the water for drinking uses of the Tigris river was considered poor at sites (S-10, S-11, S-12) and unacceptable at sites (S-13, S-14). **Figures 4a and 4b** show the prediction maps of classification of the (T.D.S.) concentration in the first period and second period in 2014 for the Tigris River according to World-Health-Organization [31].

Table 3. Classification of the (T.D.S.) at the fourteen sites on Tigris River in 2014 according to [31].

Site	Distance (km)	T.D.S. (ppm)			
		Rainy	Statement	Non-Rainy	Statement
Fish-Khabur-city (S-1)	0	447	Good (II)	442	Good (II)
Mosul-Dam-district (S-2)	82	505	Good (II)	495	Good (II)
Al-Mosul-city (S-3)	168	580	Good (II)	567	Good (II)
Shraqat-city (S-4)	296	656	Fair (III)	640	Fair (III)
Tikrit-city (S-5)	431	746	Fair (III)	717	Fair (III)
Samarrah-city (S-6)	474	757	Fair (III)	727	Fair (III)
Al-Tarmiyah-city (S-7)	651	772	Fair (III)	763	Fair (III)
Al-Muthanna-Bridge (S-8)	663	808	Fair (III)	798	Fair (III)
Shuhada-Bridge (S-9)	702	858	Fair (III)	852	Fair (III)
Al-Aziziyah-city (S-10)	828	909	Poor (IV)	900	Poor (IV)
Al-Kut-city (S-11)	977	970	Poor (IV)	962	Poor (IV)
Ali Garbi-city (S-12)	1105	1172	Poor (IV)	1164	Poor (IV)
Al-Amarah-city (S-13)	1236	1370	Unacceptable (V)	1361	Unacceptable (V)
Al-Qurnah-city (S-14)	1375	1408	Unacceptable (V)	1399	Unacceptable (V)

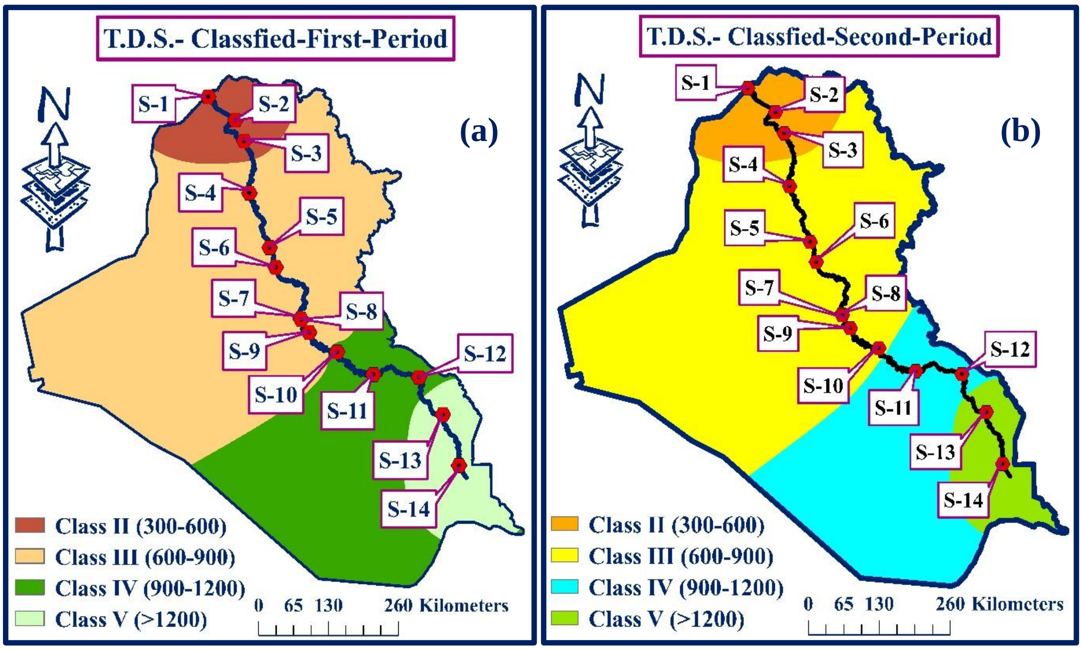

Figure 4. Prediction maps of classification of the (T.D.S.) concentrations along Tigris River in 2014 according to [31] during (a): first period (rainy-months); (b): second period (non-rainy-months).

Conclusions

The current study was conducted to measure the concentration of (T.D.S.) at fourteen sites along the Tigris River in 2014 during the first period (rainy-months) and first period (non-rainy-months).

Total-Dissolved-Solids concentration values and have ranged from 447 to 1408 ppm in the first period and from 442 ppm to 1399 ppm in the second period. The mean (T.D.S.) concentrations were 843 ppm during the first period and 833 ppm during the second period. Total-Dissolved-Solids (T.D.S.) levels at the sites (from S-1 to S-11) were within the acceptable limit of the Iraqi standards of 1000 ppm, while the (T.D.S.) levels at sites (S-12, S-13, and S-14) were more than 1000 ppm.

In this study, the inverse-distance-weighted (I.D.W.) technique in the GIS environment has been used to generate the predilection maps of the (T.D.S.) in the first and second periods of the year 2014 in both cycles of the interpolation process between fourteen river sites. This helps to identify monitoring points or locations along the river with elevated levels of disability, and in turn, will help to improve standards and track emissions. The values of (T.D.S.) concentration along the Tigris River during the first and second periods were increased from the site (S-1) in Fish-Khabur-city, Dohuk-Governorate to the site (S-14) in Al-Qurnah-city, Al-Basrah-Governorate.

For all sites, along the Tigris River, the results displayed that the readings of (T.D.S.) concentration during rainy- months were higher than the readings in the non-rainy-months. Generally, the flow of the Tigris River is decreasing with time and water, and soil salinity is increasing. The water becomes unacceptable south of Baghdad. This is due to several factors such as the extensive backwater flow from irrigation projects as well as industrial activities. The (T.D.S.) concentrations at the selected sites along the Tigris River have classified the water of the river for drinking uses into five classes according to the World Health Organization [31]. The sites (S-1, S-2, S-3), (S-4, S-5, S-6, S-7, S-8, and S-9), (S-10, S-11, and S-12), and (S-13 and S-14) were classified (respectively) Good-class II (300-600 ppm), Fair-Class III (600-900 ppm), Poor-Class IV (900-1200 ppm) and Unacceptable-Class V (more than 1200 ppm).

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