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The Effect of Variance Discharge on the Dissolved Salts Concentration in the Euphrates River upper reach, Iraq

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Abstract

The Euphrates River Basin in Iraq suffers from climate changes represented by the scarcity of precipitation and the increase in temperatures, which is directly reflected in the discharge rates and the increase in total dissolved solids, and consequently, the increase in the dissolved loads in the river. Four measurement stations (Haditha, Ramadi, Fallujah, and Al-Hindiya) in the upper reach of the Euphrates River were investigated. Available data were analyzed from 1970 to 2020 related to precipitation (mm) and temperatures (°C). The results showed a clear decrease in precipitation rates over the years, while a clear increase in air temperature rates was observed. The discharge rates decreased temporally and spatially downstream as follows: 502, 383.7, 382.1, and 211.8 m^3/s in Haditha, Ramadi, Fallujah, and Al-Hindiya, respectively. The average total dissolved solids (ppm) from 2005 to 2020 shows a gradual increase downstream, 698.8, 764.8, 833, and 922.3 ppm. The dissolution load classification curves for 2005 to 2020 show an increase in the downstream dissolved loads of 0.781, 0.786, 0.927, and 0.944 million tons/month in Haditha, Ramadi, Fallujah, and Al-Hindiya, respectively. It reflects the increase in the dissolution process of basin materials cumulatively downstream. It is recommended that careful management of the transmission of pollutants of agricultural and anthropogenic activities outputs into the river without any treatments for the downstream reaches will be required.

Keywords: Dissolved loads, Climate parameters, Haditha, Al-Hindiya, Euphrates River.

تاثير تباين التصريف على تركيز الاملاح الذائبة في المجرى العلوي من نهر الفرات / العراق

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الخلاصة

يعاني حوض نهر الفرات في العراق من التغيرات المناخ المتمثلة بندرة هطول الأمطار وزيادة درجات الحرارة مما ينعكس بشكل مباشر على معدلات التصريف وزيادة إجمالي المواد الصلبة الذائبة وبالتالي زيادة الأحمال الذائبة في النهر. شملت منطقة الدراسة 4 محطات قياس في المجرى العلوي لنهر الفرات في العراق وهي حديثة الرمادي والفلوجة والهندية. تم تحليل التسجيلات التاريخية المتوفرة لهطول الأمطار (مم) ودرجة الحرارة (درجة مئوية) للمدة من 1970 ولغاية 2020. أظهرت النتائج انخفاضًا واضحًا في معدلات هطول الأمطار على مر السنين ، بينما لوحظت زيادة واضحة في معدلات درجة حرارة الهواء. ونتيجة لذلك ، انخفضت

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معدلات التصريف زمانيا و مكانيًا في اتجاه المصب وكما يلي 502 و 383.7 و 382.1 و 211.8 متر مكعب / ثانية في كل من حديثة والرمادي والفلوجة والهندية على التوالي. يُظهر متوسط إجمالي المواد الصلبة الذائبة (جزء في المليون) للفترة من 2005 إلى 2020 زيادة تدريجية في اتجاه مجرى النهروكما يلي 698.8 و 764.8 و 833 و 922.3 جزء في المليون. توضح منحنيات تصنيف الأحمال الذائبة للأعوام 2005 إلى 2020 زيادة الأحمال المذابة عند المصب 0.781 و 0.786 و 0.927 و 0.944 مليون طن / شهر في حديثة والرمادي والفلوجة والهندية على التوالي. هذا ما يعكس الزيادة في عمليات الاذابة لمواد الحوض بشكل تراكمي باتجاه اسفل النهر.

التوصية بان هناك حاجة إلى إدارة جيدة ودقيقة لمعالجة انتقال الملوثات من مخرجات الأنشطة الزراعية والبشرية إلى النهر في اجزاءة الجنوبية.

1. Introduction

In recent years, the entire world is suffering from global climatic changes which are affecting the native hydrological system over the world with highly influencing the water resources and discharge [1, 2]

There is evidence that the discharge and sediment transport in rivers are highly affected by the conditions of global climate changes. It directly reflects on the water quality that may be attributed to the variation in the discharge rates [3, 4, and 5].

The upper reach of the Euphrates River in Iraq from Haditha to Hindiya Barrage was chosen to evaluate the climatic change effect on the river discharge and water quality. The Euphrates River locates along the western limb of the Mesopotamian between the coordination (31°48'2.65”) -(32°43'28.34") N and (44°15'58.70”) -(44°29'10.09") E. Al- Tharthar diversion project involves water transfer structures from Al- Tharthar Lake and the Tigris River to the Euphrates [6] (Figure 1).

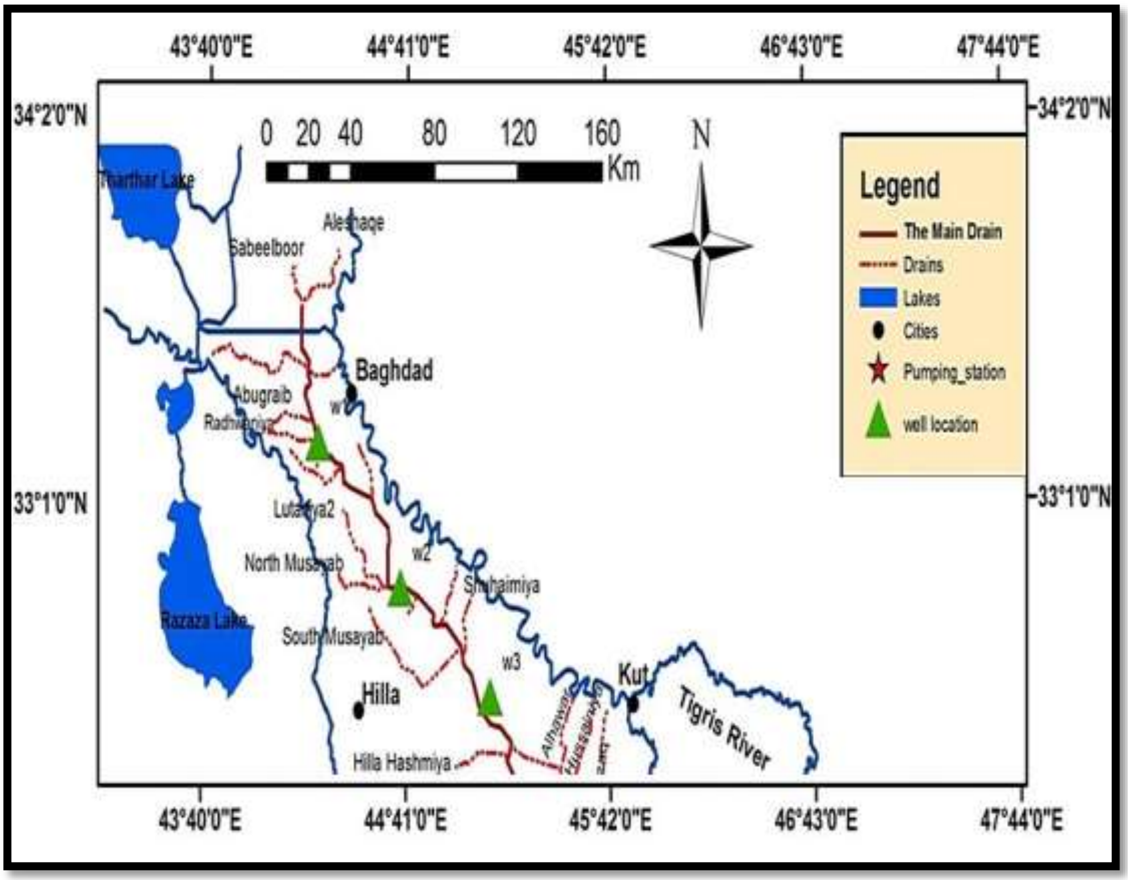

Figure 1-Al- Tharthar diversion project, after (CEB, 2011) [6].

Four gauging stations were chosen within the upper reach of the Euphrates River in Iraq these are Haditha Al- Ramadi, Al- Falluja, and Al- Hindiya (Figure 2).
The high rates of salts dissolution from the agricultural and anthropogenic activities outputs contributed to the water deterioration and increase the river water salinity and affecting its suitability for different uses [7, 8].

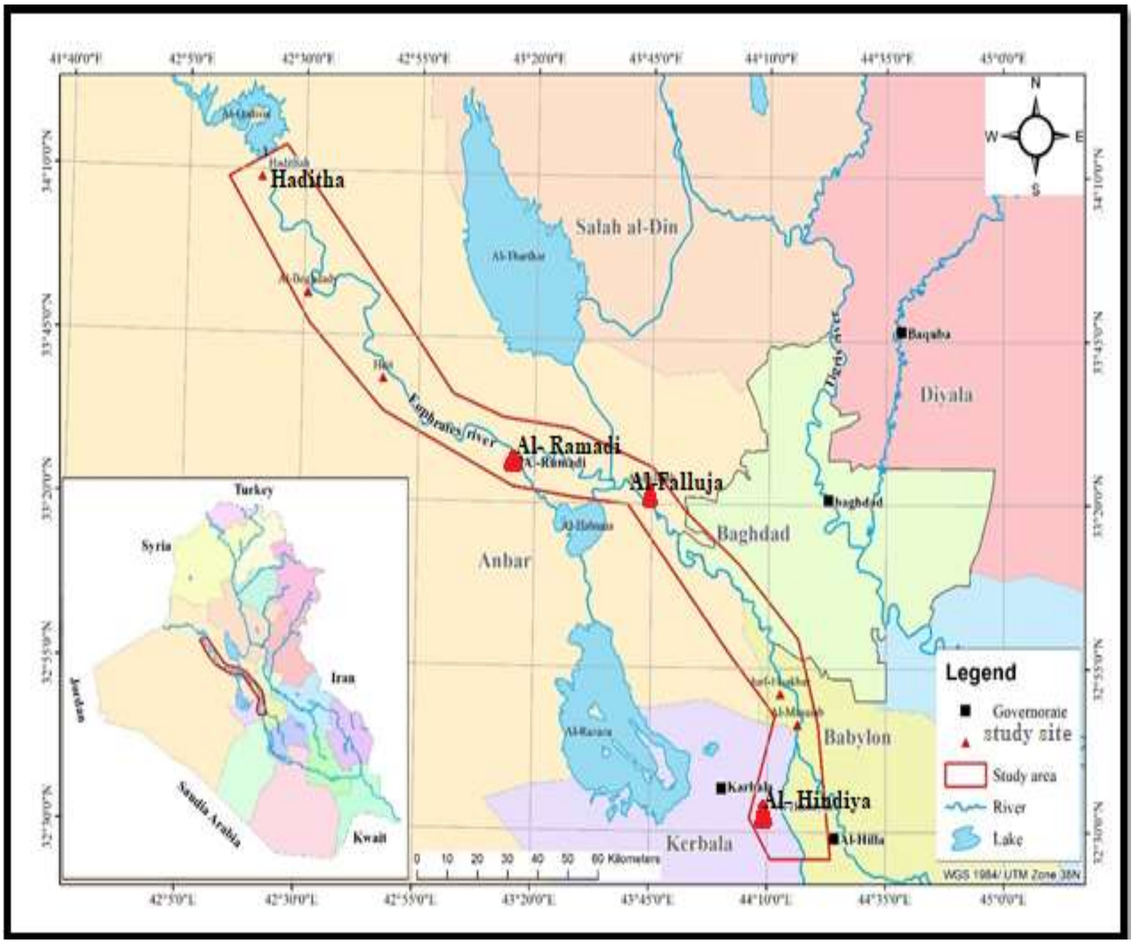

Figure 2-Location map of the study sites.

The geology of the Euphrates River in the studied sites started from the Haditha site and consists of the Baba Formation (Upper Oligocene), which is comprised of dolomitic limestone. The Anah Formation is composed of chalky limestone, coral reef, and breccia, and then the Euphrates Formation (Lower Miocene) is mainly of conglomerate, dolomitic, and chalky limestone. The Fatha Formation (Middle Miocene) is composed of marl, limestone, gypsum, bituminous gypsum, and claystone; it is overlain by Quaternary deposits [9] (Figure 3).

The continuous variation in dissolved sediment concentration in the river can cause many environmental, social, and economic implications [10, 11]. Climate change will also prompt a more prominent reliance on water and an incremented unreliability in surface water accessibility [12]. Pollutants can move from soil to water in many forms; soluble in sediment solution, exchangeable in organic and inorganic components, as structural components of the lattices of sediment minerals, or as insoluble precipitates with other sediment components as complexes [13]. The dissolved sediment concentration in the river affects the aquatic habitats, which may be caused by an enormous problem and water quality degradation [14]. Dissolved sediment concentration may act as a source of nutrients for the aquatic biota and wetlands [15, 16, 17, and18].

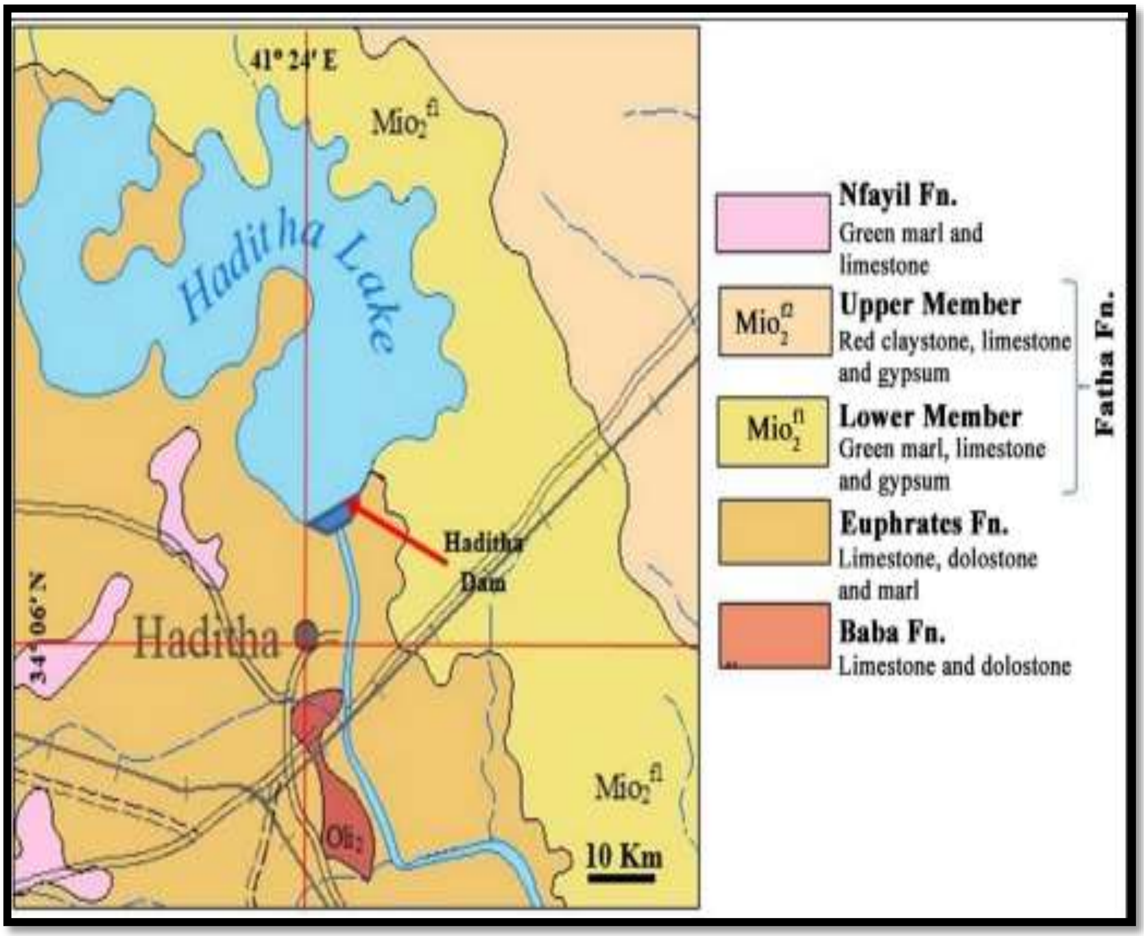

Figure 3-Geological map of the study area [9]

The climate of the Euphrates River basin in Iraq is classified under the indication of a dry climate characterized by high-temperature degrees during summer and low rates of rainfall during winter [19]. Numerous studies have inspected the river discharges at regional and global scales using a variety of approaches, including hydrological modeling, gauge stations data analysis, and regression analysis [20 and 21]. Previous studies have revealed the effects of anthropogenic activities on the dissolved sediment transported in the river [22, 23, 24, and 25]. The research originality is to verify the effect of climate change on the hydrochemistry of the Euphrates River from 2005 to 2021.

The main goal of this research is to evaluate the climate parameters (mean annual rainfall and Temperature) that influence the dissolved sediment concentrations variation and river dissolved loads, in addition to highlighting the deterioration of water quality within the upper reach of Euphrates River from Haditha to Al- Hindiya (Figure 2).

2. Material and Methods

2.1 Climate parameter effect

The available historical data of climate parameters (Rainfall and Temperature) for the years from 1970 to 2020 were collected from four meteorological stations: Haditha (from 1970 to 2020); Ramadi (from 1982 to 2018); Falluja (from 1982 to 2018) and Al- Hindiya (from 1980 to 2018) respectively [26]. The climatic parameters over time have shown a decrease in precipitation rates and apparent increases in Temperature

.2.2 TDS versus discharge correlation

The historical data of monthly hydrochemical analysis, as well as the river discharge records of the Euphrates river water, is collected for the years 2005 to 2020 for Haditha, Ramadi, Falluja, and Al-Hindiya [27]. The collected data was evaluated and tested for independency, stationary, and homogeneity. TDS (ppm) was plotted versus discharge rates

(m^3/sec) to determine the effect of decreasing water flow on the river water salinity. The plots reveal an inverse correlation between water salinity and discharge decrease. The equation results from the potting of the relationship between discharge versus TDS concentration were used to calculate the monthly dissolved loads (ton/ month) in the studied stations.

3. Results and Discussion

3.1 Climate Parameters Correlations

a. Rainfall

One of the most important factors affecting the discharge rate is the climatic parameters. The climatic regime in the Euphrates River basin shows a significant deviation in the distribution of interval series over the most recent 50 years [19]. Plotting the annual rainfall versus the time (years) for the four meteorological stations indicates an inverse correlation. It shows a relative decrease in average mean annual rainfall toward the south of the river, such as 15.33, 88.66, 100.12, and 89.66 mm, in Haditha, Ramadi, Falluja, and Al-Hindiya, respectively (Figures 4 A, B, C, and D).

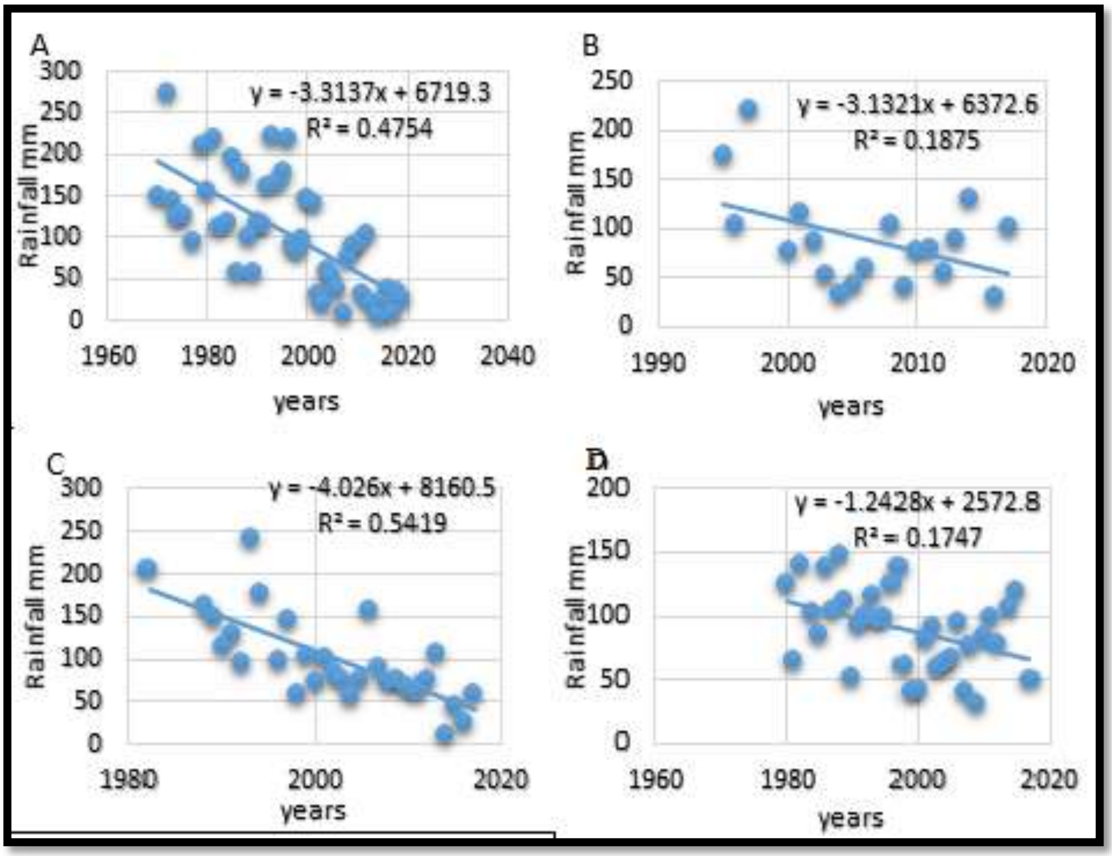

Figure 4-Average Rainfall (mm) correlation: (A) Haditha, (B) Ramadi, (C) Falluja, (D) Al-Hindiya

b. Temperature

An increase in air temperature leads to an increase the evaporation and thus the decrease in water levels and concentrated pollutants [10]. Plotting the annual air temperature versus the time (years) for the four meteorological stations indicates a direct correlation and shows a relative increase in average mean annual air temperature toward the south of the river, such as: in Haditha ranging between 16 to 27.4 ºC, the average is 21.8 ºC; in Ramadi ranged between 25 to 39 ºC, the average 30.3ºC; in Falluja ranged between 15.2 to 39 ºC, the average 32.4 ºC; in Al- Hindiya ranged between 29 to 38.8 ºC, the average value 33.2 ºC (Figures 5 A, B, C, and D).

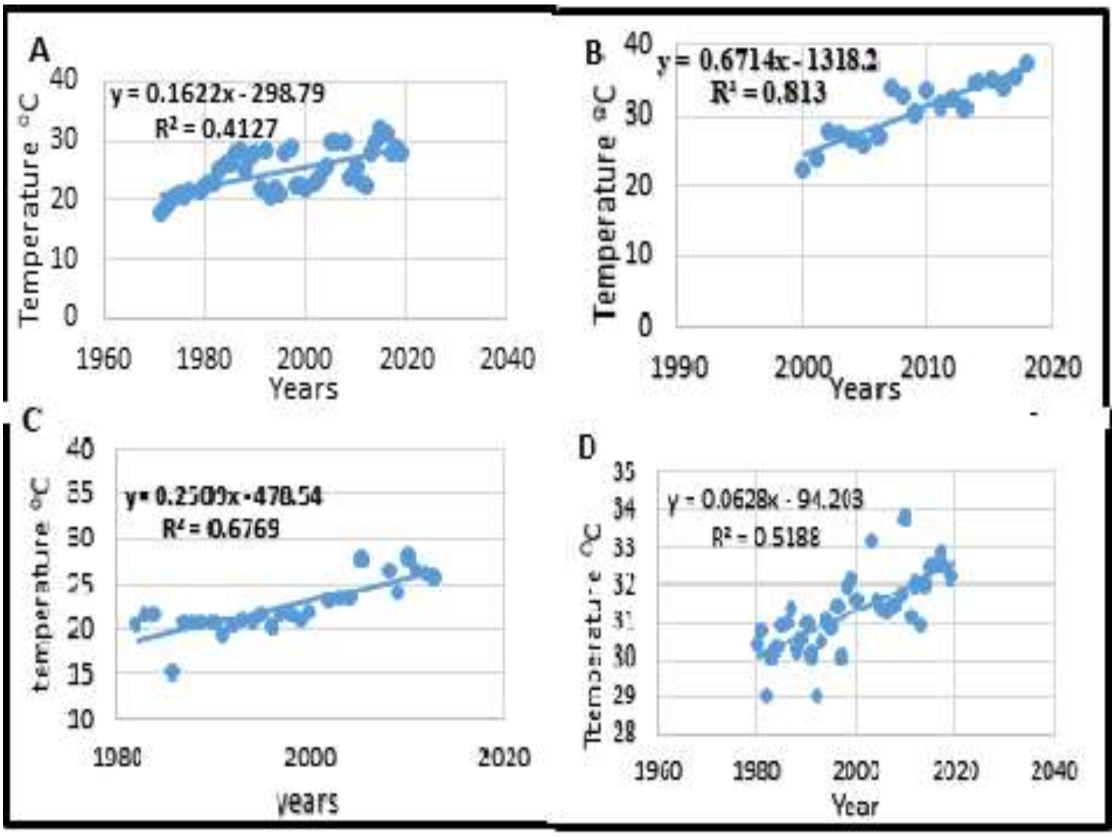

Figure 5-Average Temperature (°C) correlation (A) Haditha (B) Ramadi, (C) Falluja, (D) Al-Hindiya

3.*2 TDS versus Discharge Correlation*

The correlation between water salinity as TDS concentrations and their variation with discharge rates is very useful for preparing a quantitative study, such as whether water quality is improving or getting worse over the years, and also it is essential for planning water pollution control programs [28]. TDS concentration is correlated inversely with discharge, the high rates of discharge act as a dilution agent, therefore; the strength of the solute becomes less when the discharge increase [29, 30, 31, 32, 33, and 34].

The results show that the ranges and averages of TDS for the period 2005 to 2020 indicated a gradual increase in concentrations southward as 698.8, 764.8, 833, and 922.3 ppm, and a gradual decrease in discharge rate as 502, 383.7, 382.1, and 211.8 m^3/s for Haditha, Ramadi, Falluja, and Al- Hindiya gaging stations respectively (Table 1, and Figure 6). River salinity increases downstream as a result of the accumulation of salts from upstream. In addition, both Falluja and Hindiya stations were affected by the salty water released from Al- Tharthar Lake (Table 1 and Figures 2 and 6).

Table 1- Range and average TDS, and discharge m^3/s for the study sites

Station	Range & average TDS (ppm)	Range & Average Discharge (m^3/s)
Haditha	393- 1140 (698.8)	205- 888 (502)
Al-Ramadi	341- 944 (764.8)	198- 832 (383.7)
Al-Falluja	615- 1158 (833)	203- 415 (382.1)
Al-Hindiya	422- 1100 (922.3)	85- 505 (211.8)

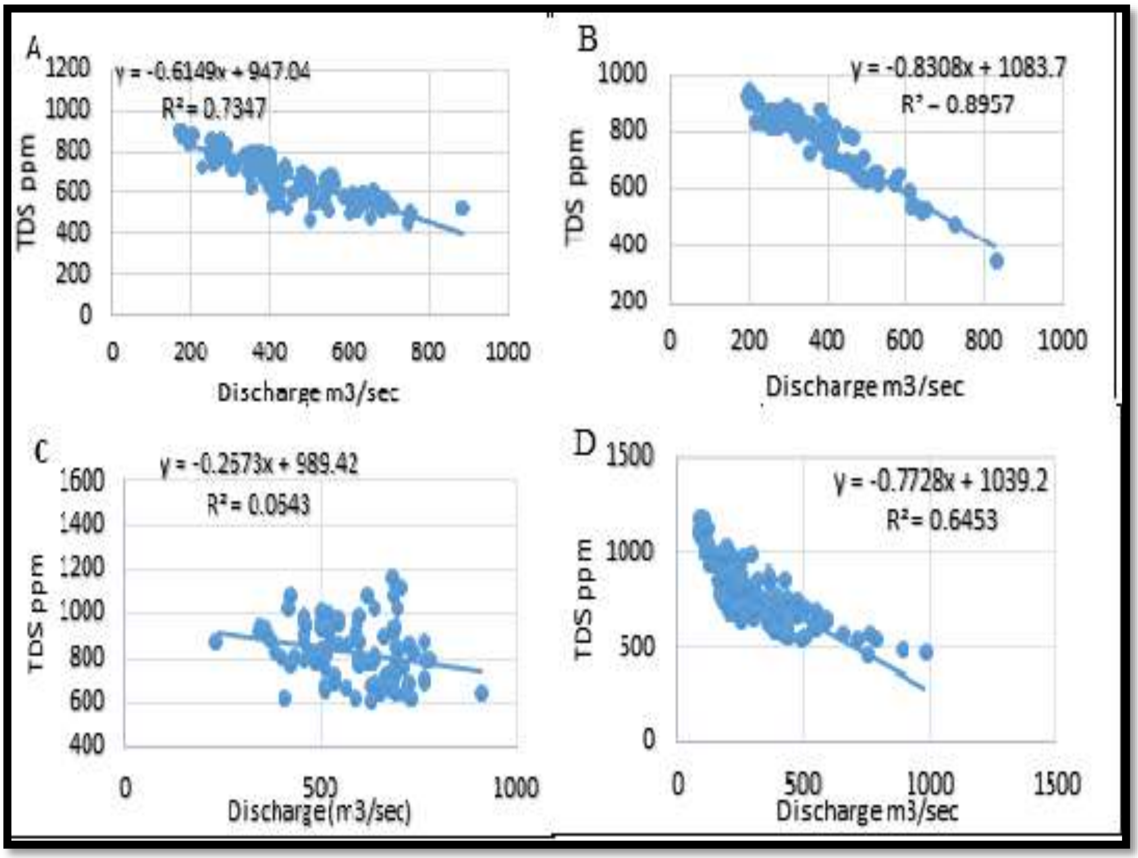

Figure 6-Correlation of TDS (ppm) versus discharge (m^3/sec) (A) Haditha, (B) Ramadi, (C) Falluja, (D): Al- Hindiya Previous studies also confirmed the increase in salinity (as TDS) downstream.

Gibbs, 1970, [34] pointed to the TDS concentrations as 590, 603, 678, and 889 ppm. While, Meyback, 1975, [35]; pointed out the TDS concentrations as 866, 882, 923, and 982 ppm. Walling, 1978, [36]; pointed the TDS concentration with high values as 1000, 1067, 1102, and 1147 ppm in Haditha, Ramadi, Falluja, and Al-Hindiya, respectively (Figure 7).

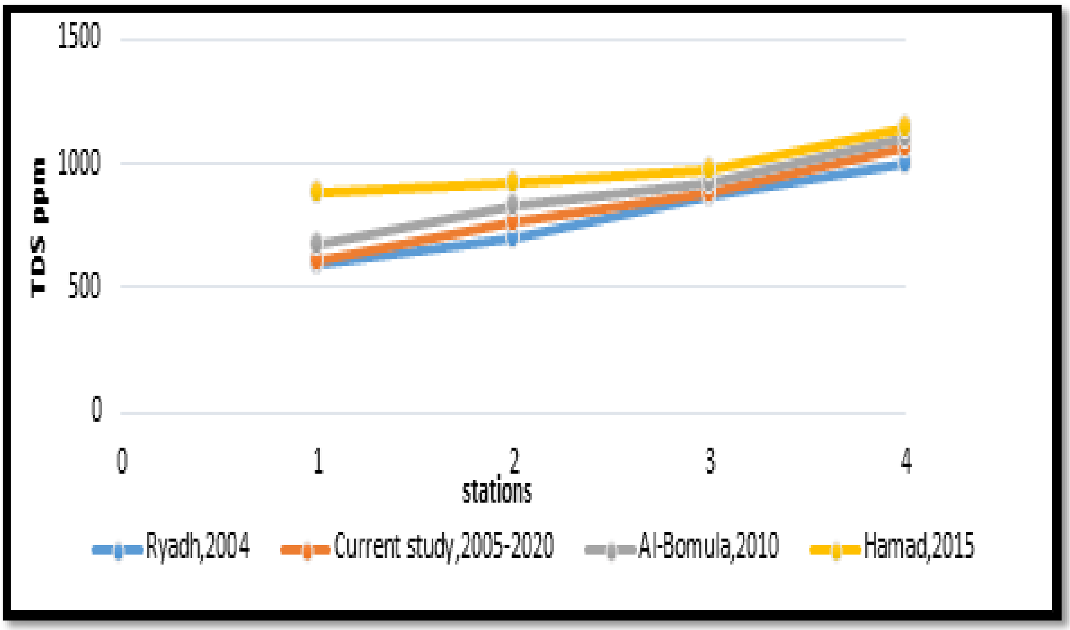

Figure 7- Increasing TDS concentration (ppm), spatially and temporarily for the Haditha, Ramadi, Falluja, and Al-Hindiya.

Additional brakish water was discharged from Al– Tharthar Lake in to the Euphrates River via Al- Tharthar- Euphrates canal [37, 38, 39]. However, the TDS concentration for Al-Tharthar Lake from 1979 to 2020 ranged between 956 to 2266 ppm, with an average value of 1402.8 ppm (Figure 8) [40].

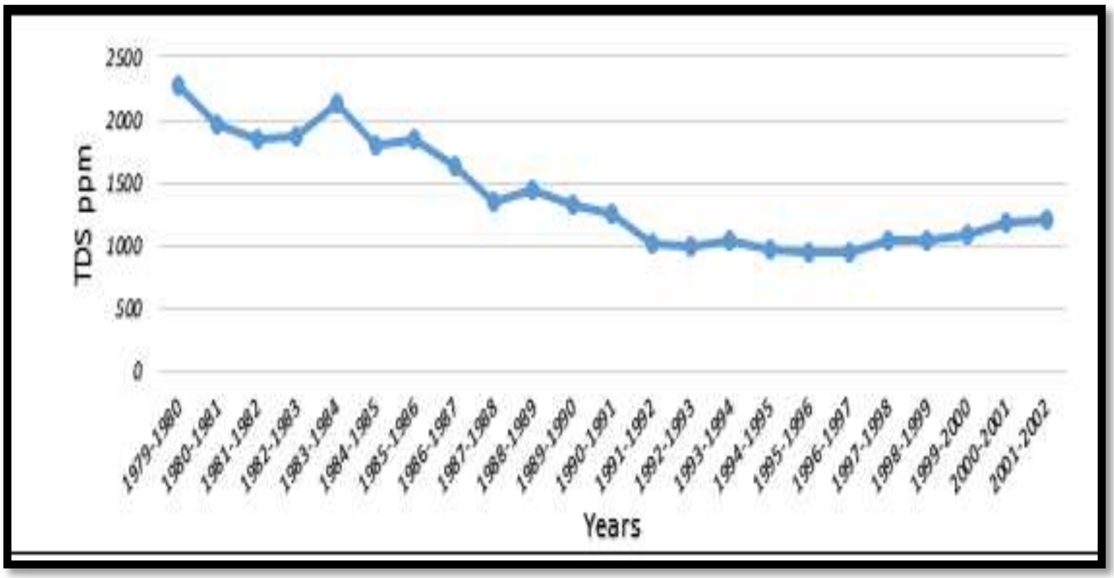

Figure 8-TDS concentration (ppm) diverted from of Al-Tharthar Lake into the Euphrates River [40].

3.3 Dissolved loads calculation

The rating curve has been used to determine the relationship between monthly discharge and the monthly dissolved loads transferred through specific gauging stations. A direct relationship between the discharge and loads due to the dissolution processes of basin materials led to an increase in the loads that the river carried [41].

The average monthly dissolved loads for the current study from 2005 to 2020 are calculated as 0.78, 0.79, 0.93, and 0.94 million tons/ month for Haditha, Ramadi, Falluja, and Al-Hindiya stations, respectively (Figures 9 A, B, C, and D). The coming input water from Al-Tharthar – Euphrates canal affected the salinity as TDS concentration and dissolved loads in Falluja and Al- Hindiya stations [42].

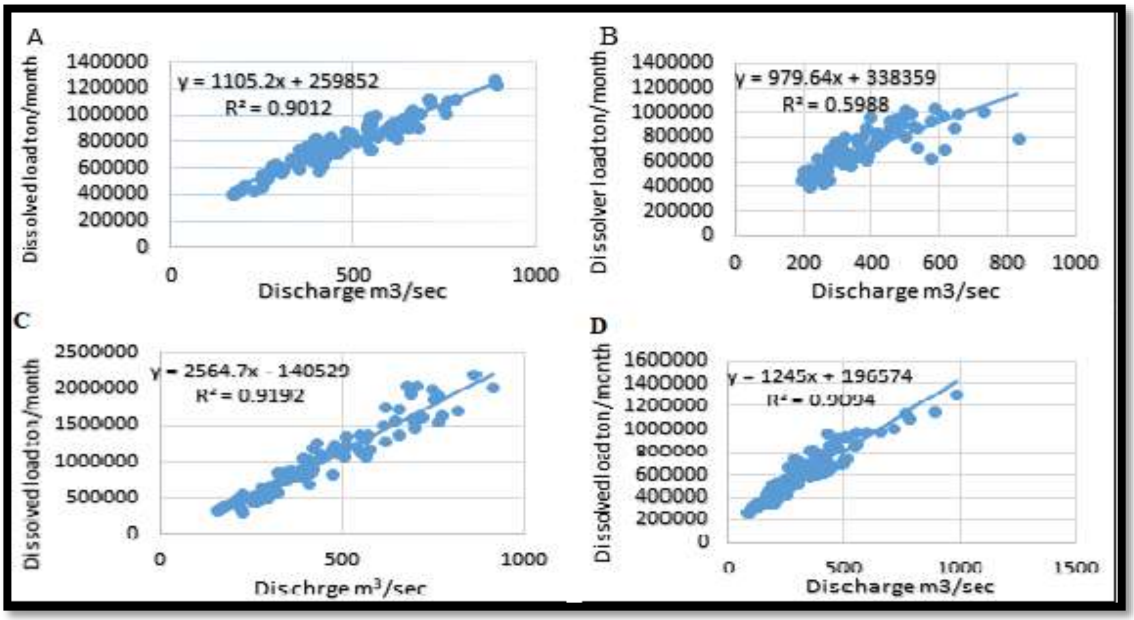

Figure 9-Rating Curve of dissolved loads (tons/month) versus discharge rate (m^3/sec) (A) Haditha, (B) Ramadi, (C) Falluja, and (D) Al- Hindiya.

conclusion that there is a seasonal variation in the concentrations, which corresponds to the high suspended and dissolved loads during dry seasons. Moreover, the current study results agree with the previous studies for the same gaging stations [41; 42]. A comparison between the current study (average and ranges) of dissolved loads with the previous studies is shown in Table 2.

The salinity concentrations as TDS values increased substantially at the Falluja site due to the high salinity impact of the water flow to the Euphrates from Tharthar Lake. Khaleefa and Kamel, 2021 [43] concluded that the minimum release discharge from Haditha dam is 153 m^3/s to maintain the salinity at an acceptable limit (i.e. less than 1000 ppm) until Falluja and must prevent irrigation water return to the river after this site. The current research results in concord with Guyot et al. 2010 [44]

The results of the current study came close to the loads calculated from the previous studies, a relative decrease showed in the current study loads, which may result from the decrease in the discharge rates.

Table 2- Range and average TDS loads (million tons/ month) of the selected station on the upper reach of the Euphrates River

Station	Range & Average dissolved load Current Study, 2005- 2020	Range & Average TDS load, [41].	Range & Average TDS load, [42].
	(million tons/ month)		
Haditha	(0.464- 1.690) 0.781	(0.77- 0.94) 0.87	(0.60- 1.70) 1.10
Al-Ramadi	(0.544- 0.891) 0.786	(0.80-0.99) 0.90	(0.46- 2.30) 1.20
Al-Falluja	(0.464- 1.690) 0.927	(1.5- 2.73) 1.88	(0.84- 2.3) 1.90
Al-Hindiya	(0. 522- 1.33) 0.944	(1.31- 1.89) 1.52	(0.86- 1.69) 1.158

4. Conclusions

Four sites (Haditha, Ramadi, Falluja, and Al-Hindiy) were chosen along the Euphrates River's upper reach to determine the effect of the decreasing flow on the water quality from 2005 to 2020 and to calculate the dissolved loads in addition to finding the rating curve equation for each site. The following conclusions were abstracted:

1- There is a relative increase in TDS concentration downstream, especially at Falluja and Al-Hindiya stations affected by Al- Tharthar Lake water outflow.

2- The river discharge was decreased downstream due to climatic change and the effect of dam construction in riparian countries. There is an indirect relation between discharge rates (m^3/sec) and TDS concentration (ppm).

3- The dissolved loads, which are correlated directly with discharge rates, change temporally and spatially, as the river loads were directly affected by TDS accumulation from Haditha to Al-Hindiya.

4- Low flow rates in the Euphrates River caused an increase in all the ionic concentrations represented by TDS, especially downstream of the river.

5- Careful management of the transmission of pollutants of agricultural and anthropogenic activities outputs into the river without any treatments for the downstream reaches will be required.

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