



## **Hydrochemical Evaluation of the Tigris River from Mosul to South of Baghdad Cities, Iraq**

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### **Authors' contributions**

This work was carried out in collaboration between both authors. Author MAD designed the study and managed the analyses of the study. Author ASO performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

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### **ABSTRACT**

**Aims of this Study:** To investigate the climate change effects in Iraq on the quality and quantity of the water of the Tigris River from {Mosul} city to South of Baghdad city. This paper provides a review of the observed and the predicted impacts of climate change on the water quality in the Tigris River in Iraq.

**Study Design:** Cross-Sectional study.

**Place and Duration of Study:** The study area is starting {from Mosul city which is located in {the north part of Iraq to the Al-Azziziyah city located in the south of Baghdad (2005-2012) .

**Methodology:** The current study was include the available historical data which are the discharge and hydrochemical analysis includes (Ca, Mg, Na, K, Cl, SO<sub>4</sub>, HCO<sub>3</sub>, TDS, NO<sub>3</sub>, and EC) were taken from 6 stations along the Tigris' River from Mosul to the south of Baghdad' cities for the years 2005 to 2012. The available historical climate data' includes (Rainfall and Temperature) for the period 1990-2012. In this paper also, used some of pervious studies and compared them with the current results.

**Results:** The average annual flow of the Tigris River in Mosul station for the period (1990-2012)

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ranged between' (193.8-906) m<sup>3</sup>/sec and for Sammarra station ranged between' (366-977) m<sup>3</sup>/sec. Then, between south of Sammarra'city and north of Baghdad city, Canal of Dijla'joins the Tigris River has a discharge ranges between' (9-217) m<sup>3</sup>/sec. After that, the 'Tigris River inter to Baghdad city, the discharge value range between' (392-1173) m<sup>3</sup>/sec'and continue his flow to the south of Baghdad city and Diyala River joins it with discharge'range between (55-193) m<sup>3</sup>/sec. Finally, the Tigris River reaches to'Al-Aziziyah city station with'discharge ranges between (134-769) m<sup>3</sup>/sec.

**Conclusion:** In general the water quality of the Tigris River are sulfates, calcium, and magnesium. But in Canal of Dijla the most dominant ion is sodium due to agricultural activities and geology of the area consist of gypsum rocks and this can be effects on water quality of Tigris River in the next station (Baghdad). In Al-Aziziyah city the sulfates, calcium, and Sodium is high level due to drainage from irrigation, industrial"and domestic activities.

*Keywords: Tigris river; water quality; discharge; climate change; Iraq.*

## 1 INTRODUCTION

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 originates from Turkey and Syria [1].

The Tigris river represents one of the main sources of water with the Euphrates river in Iraq. Which is plagued by a water shortage as well as water resource management issues. Iraq is at particular risk for being unable to provide clean drinking water and adequate sanitation systems for citizens, ensure sustainable irrigation, use hydropower to produce electricity, and maintain diverse ecosystems. Iraq is therefore in a situation where it must plan for several different future scenarios, mostly negative if climate change results in increased temperatures and decreased precipitation levels [2]. even in the absence of any negative effects of climate change dealing with steady growth in population, increased urbanization, and neighbor's countries which they built a dams on the main rivers of Iraq. The flow of the River Tigris started to decrease with time due to the increase of agricultural activities, building of dams in Turkey as well as climate change [3,4]. The decrease of flow is accompanied by deterioration of the water quality due to the increase in salinity and other pollutants. Moreover, the main goal of this study is to investigate the dimension of climate change effects in Iraq on the quality and quantity of the water of the Tigris River from Mosul city to South of Baghdad city.

In 2011, 507.4mm of water fell on the northeastern part of Iraq while only 65.3mm fell

on the southern part. Lakes, reservoirs, and minor rivers are also experiencing diminished levels of water [1]. Moreover, the main aims of this study is to investigate the climate change effects in Iraq on the quality and quantity of the water of the Tigris River from Mosul city to South of Baghdad city. This paper provides a review of the observed and the predicted impacts of climate change on the water quality in the Tigris River in Iraq. First, a brief review of the climatic historical data and change of discharge of the Tigris River through time and their effect on the water quality is introduced.

### 1.1 Study Area

The study area is starting from Mosul city which is located in the north part of Iraq. The Tigris River flows in this city and the Greater Zab tributary joins the Tigris in the south of Mosul (Fig. 1). This tributary has mean annual flow is 418 m<sup>3</sup>/s. Further south, the Lesser Zab tributary joins the Tigris at Fatha. This tributary have a mean annual flow of 227 m<sup>3</sup>/s while the mean annual flow of downstream of this confluence [1,3]. South of Fatha, the Adhaim tributary joins the Tigris. The mean annual flow of this river reaches 25.5 m<sup>3</sup>/s. The Diyala River joins the Tigris south of Baghdad and the mean daily flow of this tributary is 182 m<sup>3</sup>/s [5,6,7].

### 1.2 Geology of the Area Study

The geology of the Tigris River are different from one place to another. When the Tigris river entre to the Iraqi land , its practice cutting off the Mosul sediments which represented by Muqdadiya, Injana, Fatha Formations, and continues as well until meeting the upper-Zab river in the south of Mosul [8].

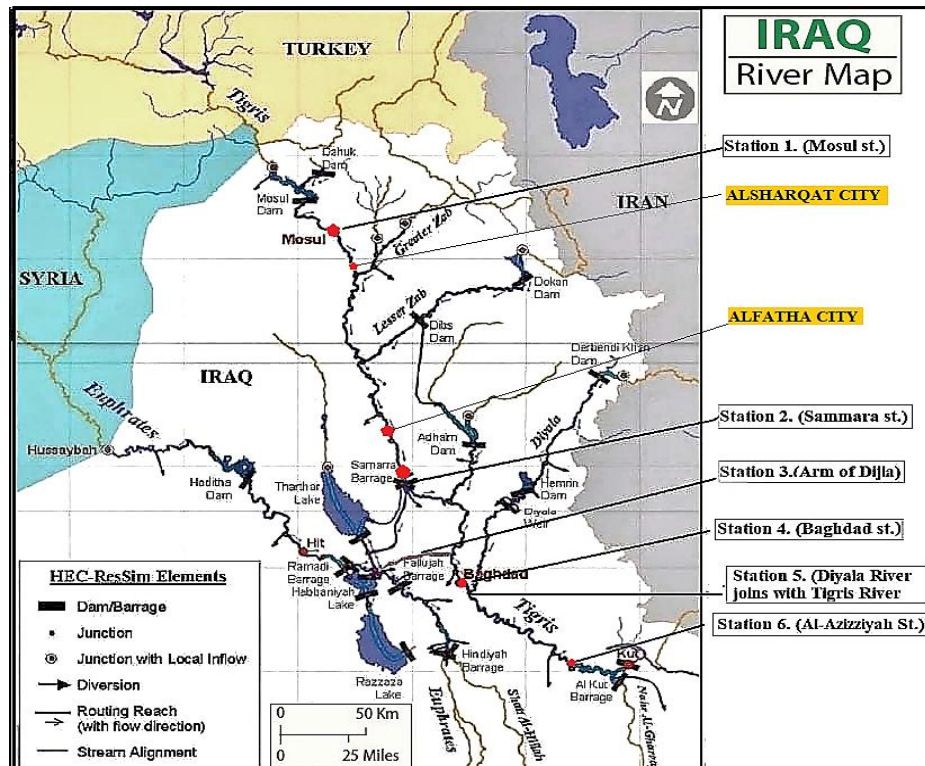


Fig. 1. Location map of Iraq the study area

## 2 MATERIALS AND METHODS

A: Historical Climatological data (Rainfall and Temperature) were taken from 'Iraqi Meteorological Organization' for Mosul, Samarra, Baghdad and, Al-Aziziyah Meteorological Stations, for the period (1990-2012), [9].

B: Six gauging stations were chosen on the stretch of Tigris River; Mosul, Samarra, Baghdad, Canal of Dijla, Diyala River and, Al-Aziziyah (Fig. 1). Discharge of the Tigris River data was collected from a historical data Hydrochemical analysis for the years (2005-2012), [10].

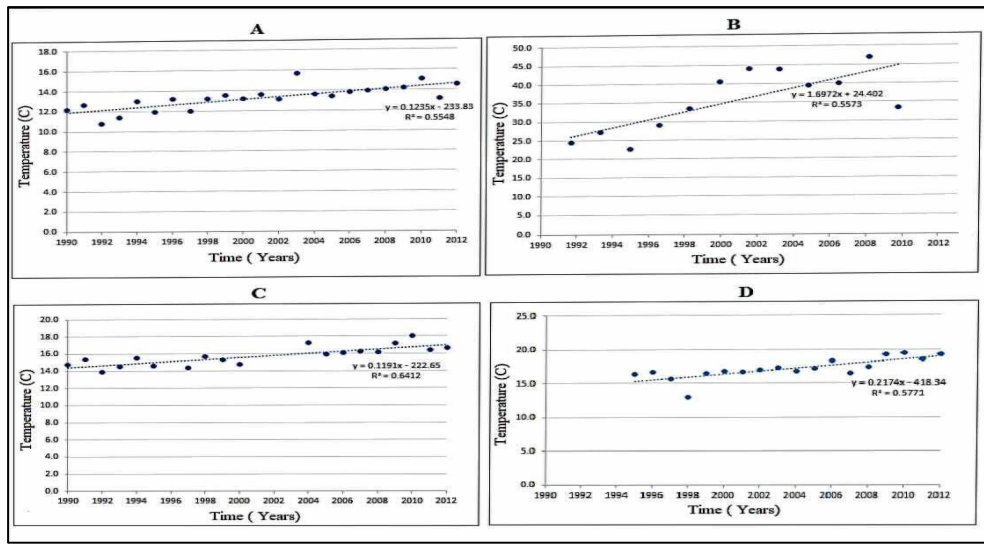
C: To get a full idea about the discharge effect on the water quality, Water Quality of the Tigris River for the period (2005-2012) are investigated and correlated with the discharge values and the Physio-chemical parameters such; total dissolved solids (TDS), major cations ( $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ , and  $\text{K}^+$ ) and anions ( $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{HCO}_3^-$ ) in Mosul, Samarra, Baghdad, Canal of Dijla, Diyala River and, Al-Aziziyah stations for the years (2005- 2012). The water quality of the present study was compared with

the other studies (pre and after the year 2004) to show the differences in water type during the years and notice climate change effects on salinity [11].

## 3. RESULTS AND DISCUSSION

### 3.1 Climate Parameters: Temperature and Rainfall

Mean annual temperature ( $^{\circ}\text{C}$ ), for Mosul, Samarra, Baghdad and, Al-Aziziyah stations during the years (1990–2012) were plotted against years for available data (Fig. 2: A, B, C and D). There is a positive correlation between temperature and years with the remarkable increase in temperature values demonstrating from the general trend line. The results show that the Mean Minimum Temperature values of the Mosul 'station were range between ( $10.8-15.6\text{ }^{\circ}\text{C}$ ) (Fig. 2A), While in Samarra station were range between ( $24.4-47.0\text{ }^{\circ}\text{C}$ ) (Fig. 2B). In Baghdad station were range between ( $13.9-18\text{ }^{\circ}\text{C}$ ) (Fig. 2C), While in Al-Aziziyah station were range between ( $13-19.6\text{ }^{\circ}\text{C}$ ), (Fig. 2D).



**Fig. 2. Annual average values of Minimum Temperature (C°) for the period (1990-2012) in (A): Mosul station,(B): Samarra Station, (C): Baghdad station and, (D): Al-Aziziyah Station [9]**

Fig. (2) shown that The Temperature was increasing through time and that agrees with [2] which proved that during the last years, the temperature changes dramatically due to climate change and global canaling.

The mean annual rainfall was plotted against time for the years (1990– 2012) to show a negative correlation indicating the decrease of rainfall with years (Fig. 3 A,B,C ,and D). There is an indirect correlation between rainfall and years with a remarkable decrease in rainfall values demonstrating from the general trend line. The results show that the values of Mosul station are range between (301-577) mm (Fig. 3A). In Samarra Station, values are range between (69-200) mm (Fig. 2B). While, in Baghdad and Al-Aziziyah cities values range between (59-192) and (85-177) mm respectively (Fig. 3C & D).

Fig. (3) shown that rainfall reverse relationship with time and that [12] proved that where the rainfall in Mosul station was 600 mm but during last year it reached 300 mm.

### 3.2 Discharge of the Tigris River

The average annual flow of the Tigris River in Mosul station for the period (1990-2012) ranged between (193.8-906) m<sup>3</sup>/sec and for Samarra station ranged between (366-977) m<sup>3</sup>/sec (Fig. 4 A & B). Then, between south of Samarra city and north of Baghdad city, Canal of Dijla joins

the Tigris River which has a discharge ranges between (9-217) m<sup>3</sup>/sec (Fig. 4C). After that, the Tigris River inter to Baghdad city, value range between (392-1173) m<sup>3</sup>/sec and continue his flow to the south of Baghdad city and Diyala River joins it with discharge range between (55-193) m<sup>3</sup>/sec (Fig. 4 D & E). Finally, the Tigris River reach to Al-Aziziyah city station with discharge ranges between (134-769) m<sup>3</sup>/sec (Fig. 4F).

This result agrees with [3,5] which approves that discharge of the Tigris River is decreasing through time. Discharge of the Tigris River at (Baghdad) reached 1208 m<sup>3</sup>/sec, while, the discharge now is 522 m<sup>3</sup>/sec [3,13]. It has been noticed that with the decrease of the flow in the Tigris River the quality of its water is deteriorating [1,12].

### 3.3 Water Quality of the Tigris River

The hydrochemical studies of Surface water can provide a better understanding of potential water quality variations due to geology and land-use practices. It is important to assess surface water quality by correlating it with the annual flow of the Tigris River to evaluate the effects of climate change. The Hydrochemical parameters of the Tigris River stations which they are includes mean annual values of: TDS, EC, Ca, Mg, Na, K, Cl, SO<sub>4</sub>, HCO<sub>3</sub>, NO<sub>3</sub> for the period (2005-2012) as shown in Table (1).

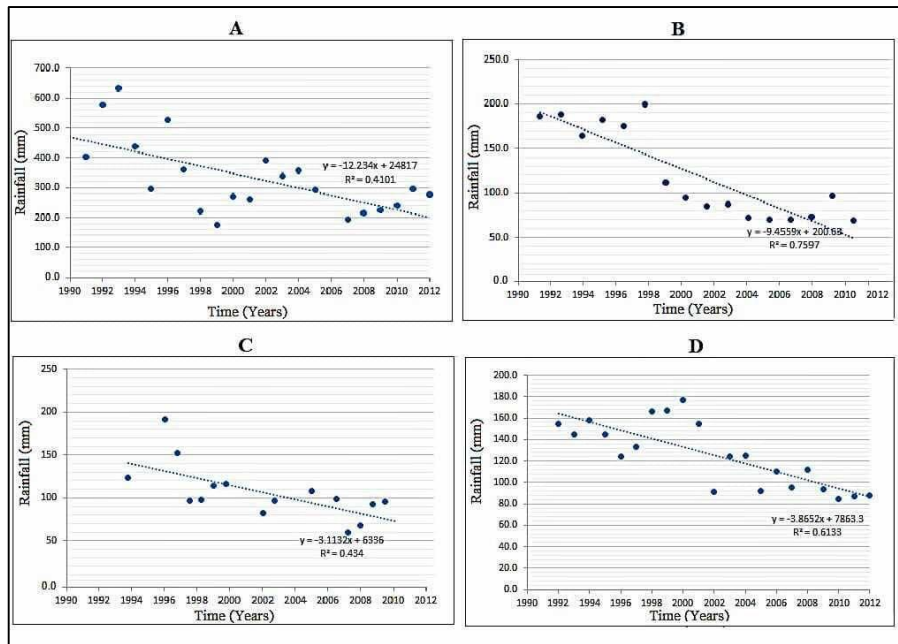


Fig. 3. Annual average values of Rainfall for the period (1990-2012) in (A): Mosul station, (B): Samarra Station, (C): Baghdad station and, (D): Al-Aziziyah Station, [9]

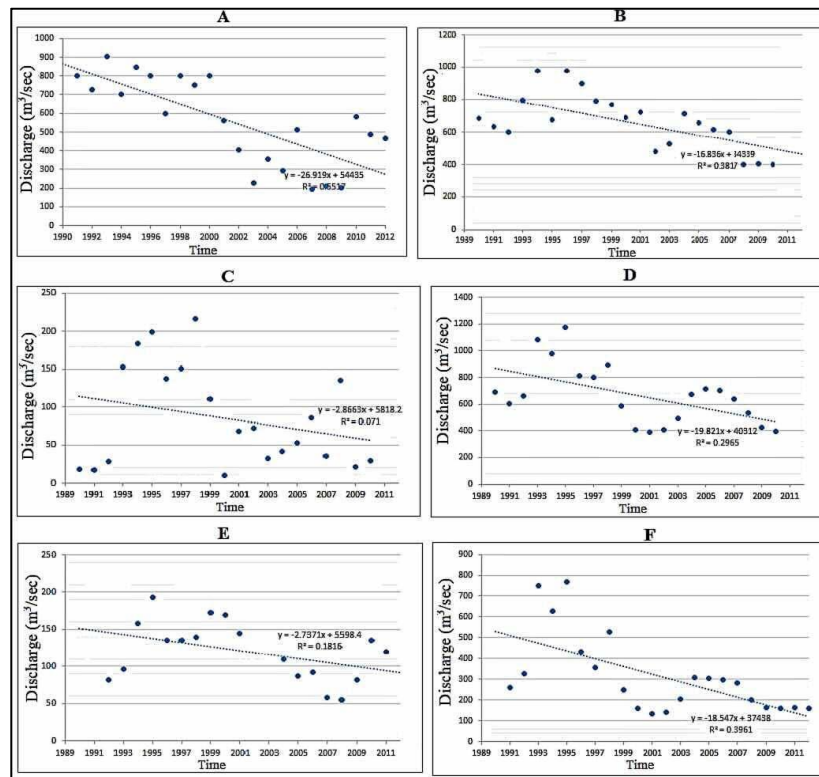


Fig. 4. Discharge (m<sup>3</sup>/sec) of the Tigris River for the period (1990-2012), (A): Mosul station, (B): Samarra station, (C): Canal of Dijla station (D): Baghdad station, (E): Diyala River, and (F): Al-Aziziyah Station [10]

**Table 1. Parameters concentrations along Tigris River{ for the period (2005-2012), [11].**

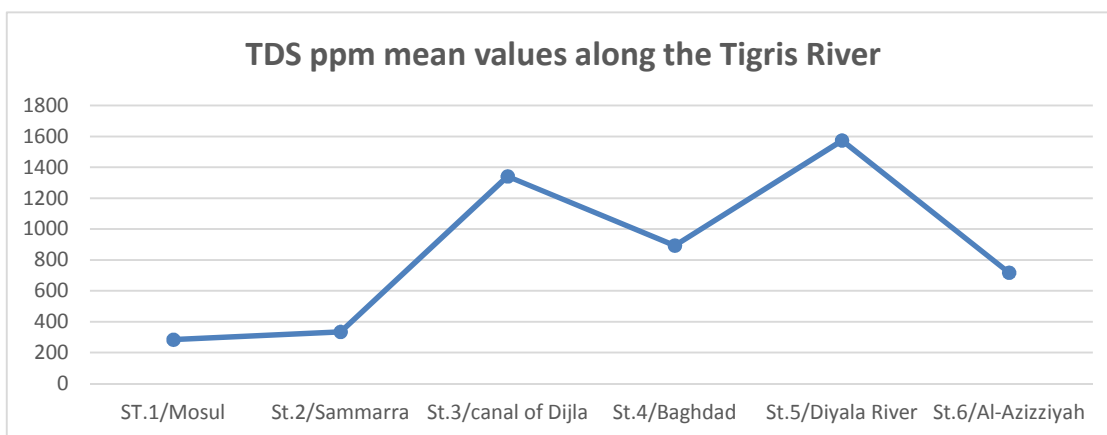
<b>Stations</b>		<b>Ec ds/m</b>	<b>TDS</b>	<b>TH</b>	<b>Ca</b>	<b>Mg</b>	<b>Na</b>	<b>K</b>	<b>Cl</b>	<b>SO4</b>	<b>HCO3</b>	<b>NO3</b>
ST.1/Mosul	Range	0.36-0.77	226-333	188-254	24.9-72.2	24-43.8	16.91-25.13	0.9-3.2	14.95-33.63	88.11-271.83	126.5-161.7	2.3-10.9
	Mean	0.49	283.78	223.1	44.6	29.6	21.87	2.6	21.73	135.89	148.4	4.8
St.2/Sammarra	Range	0.20-0.51	279-383	234-239	26-58.1	22.6-42.1	19.40-28.3	0.8-3.2	16.28-22.54	101.83-137.2	143.5-161.8	1.6-8.9
	Mean	0.39	334.83	237.8	45.7	29.6	23.54	2.5	21.7	117.75	154.7	3.7
St.3/Arm of Dijla	Range	0.74-2.27	970-2170	500-686.81	72.9-163.3	47.2-71.6	116-290	4.4-5.7	172.18-256.05	157-463.36	87.4-109.4	1.5-6.5
	Mean	1.4	1341.18	602.45	135.6	61.7	164.23	5.5	205.41	261.08	107.5	4.4
St.4/Baghdad	Range	0.65-2.24	428-1601	230-680	34-73.8	33.2-50.9	66.12-238.54	1.1-4.2	68.75-260	168.18-564.9	148-171.7	2-5.5
	Mean	1.31	893.51	402.93	54.4	42.4	115.89	3.1	177.62	293.39	156.8	3.4
St.5/Diyala River	Range	1.67-3.11	506-2217	660-848	137-144	106-140	95-393.91	5-22.3	60-388.29	230-805.70	256-342.2	2-12.5
	Mean	2.61	1574.05	766.29	129.1	118.8	292.35	10.6	294.36	663.69	279.1	7.6
St.6/Al-Aziziyah	Range	0.91-1.11	602-956.4	360-497	53.1-133.5	37-120.8	77-422.33	2.4-22.3	74-422.33	246.65-422.33	150-293.8	2.1-47
	Mean	1.08	717.8	402.79	84.7	57.6	197.37	6.1	200.87	308.42	174.7	10.1

The discharge decreases downstream the river affecting the Tigris River's salinity as (TDS) to increase due the river dissolved load and the conventional irrigation methods in addition to the high rates of evaporation. The Annual average TDS values of the Tigris River at Mosul and Samarra stations are ranging between (226-333) ppm and (279-383) ppm respectively. While, in the canal of Dijla are ranging between (970-2170) ppm. For Baghdad, Diyala River and, Al-Azizziyah stations the values are ranging between (428-1601) ppm, (506-2217) and, (602-956.4) ppm respectively (Fig. 5).

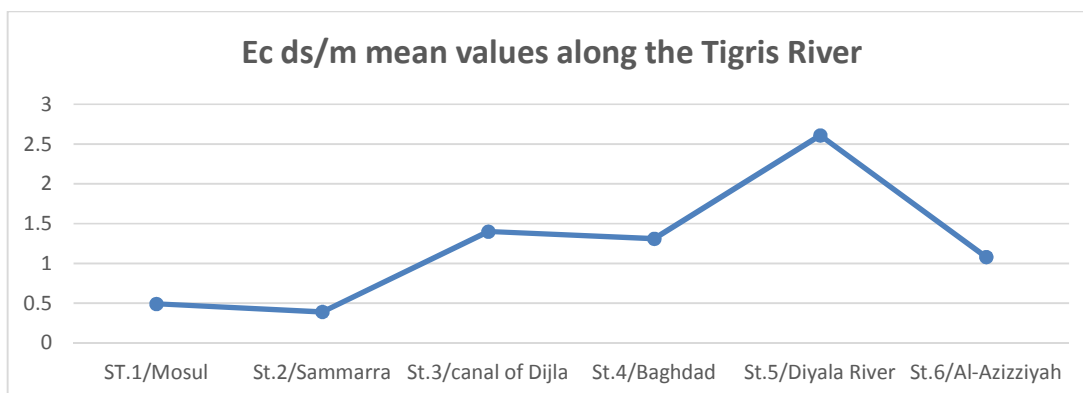
The TDS value in Mosul station before 2000 was (135)ppm and became (293) ppm, in Sammarra station was 210 and became 330 ppm, for Baghdad was 182 and became 850 ppm and, in Al-Azziziyah station became more than 1000 these increasing due to various uses of the Tigris River [1].

Electrical conductivity as important water quality parameter shows the ability of electrical current in the water. This parameter is a function of the presence of ions and has a direct relationship to the total dissolved solids (TDS). By increasing the amount of sulfate, chloride, sodium, potassium, calcium, and magnesium in water, the EC is increased; therefore deteriorating water quality.

The Annual average EC ds/m values of the Tigris River are ranging between (0.36-0.77) ds/m and (0.20-0.51) ds/m for Mosul and Samarra stations respectively. While, the canal of Dijla the EC Annual average values are ranging between (0.74-2.27) ds/m. For Baghdad, Diyala River and, Al-Azizziyah stations the EC Annual average values are ranging between (0.65-2.24) ds/m, (1.67-3.11) ds/m and, (0.91-1.11) ds/m respectively (Fig. 6).



**Fig. 5. TDS Annual average values ppm along the Tigris River from Mosul station to Al-Azizziyah station for the period (2005-2012), [11]**



**Fig. 6. EC Annual average values along the Tigris River from Mosul station to Al-Azizziyah station for the period (2005-2012), [11]**

Baghdad and Al-Azizziyah station has high dissolved salinity and suffered significantly of high levels of TDS than other stations because of the Canal of Dijla and Al Rustamia wastewater treatment plant that located in the south of Baghdad city within Diyala River (It's throwing the overloaded wastewater directly into the Tigris River without any treatment).

Calcium Annual average values of the Tigris River ranges between (24.9-72.2) ppm and (26-58.1) ppm for Mosul and Sammarra stations respectively. Canal of Dijla ranges between (72.9-163.3) ppm. For Baghdad, Diyala River and, Al-Azizziyah stations values ranges (34-

73.8) ppm, (137-144) and, (53.1-133.5) ppm respectively (Fig. 7).

High concentrations of calcium may indicate the land's geological composition in the Canal of Dijla station have a gypsum.

Magnesium Annual average values of the Tigris River range between (24-43.8) ppm and (22.6-42.1) ppm for Mosul and Sammarra stations respectively. While, values of an canal of Dijla station ranged between (47.2-71.6) ppm. For Baghdad, Diyala River and, Al-Azizziyah stations values ranged (33.2-50.9) ppm, (106-140) and, (37-120.8) ppm respectively (Fig. 8).

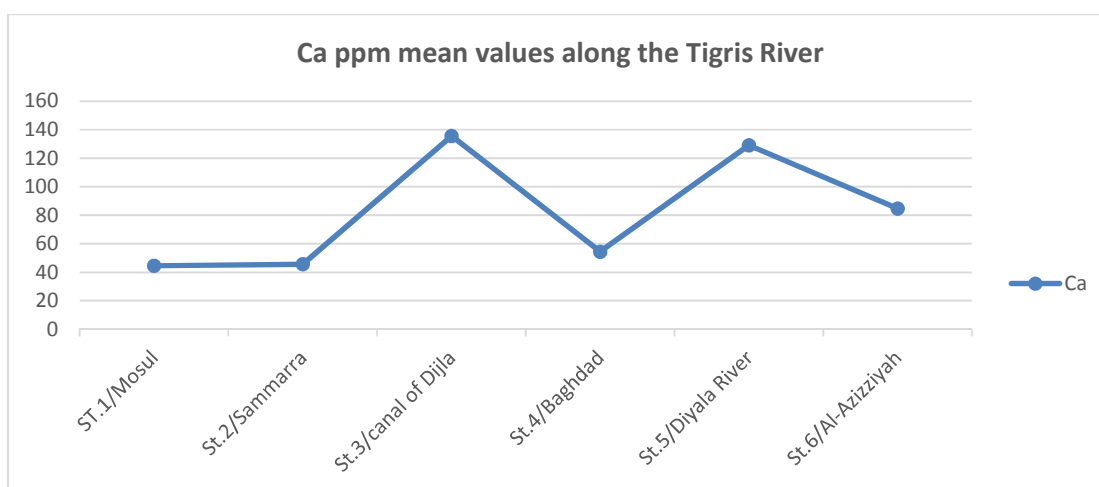


Fig. 7. Ca Annual average values ppm along the Tigris River from Mosul station to Al-Azizziyah station for the period (2005-2012), [11]

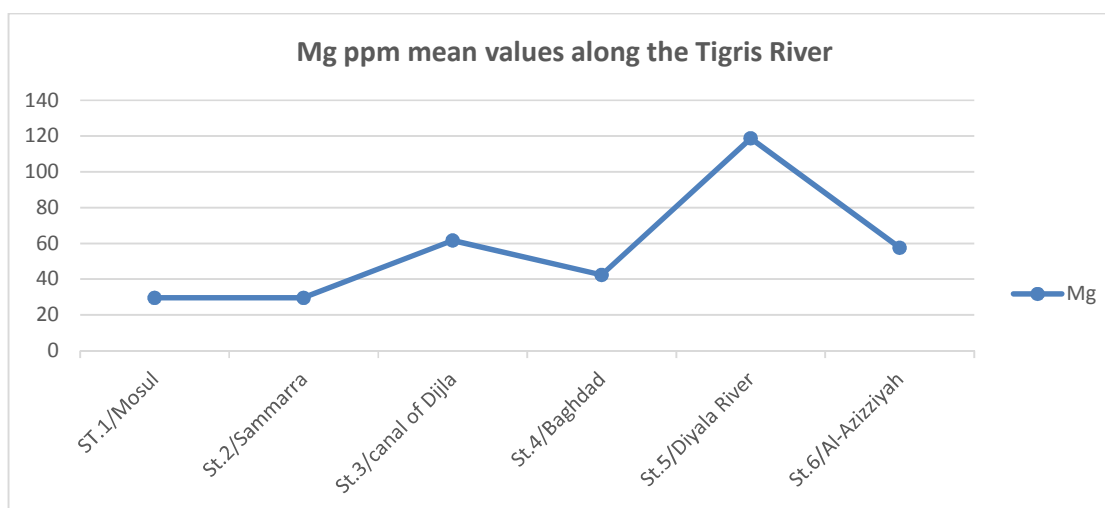


Fig. 8. Mg Annual average values ppm along the Tigris River from Mosul station to Al-Azizziyah station for the period (2005-2012), [11]



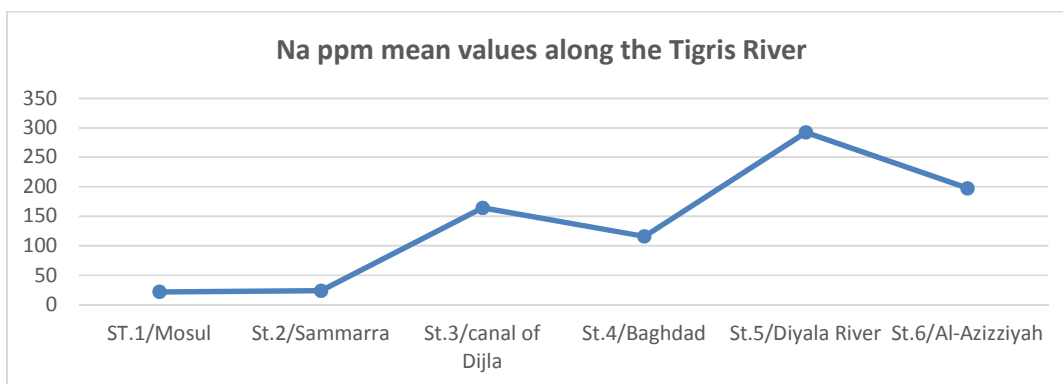
The Sodium (Na) Annual average values of the Tigris River are range between (16.91-25.13) ppm and (19.40-28.3) ppm for Mosul and Sammarra stations respectively. While, canal of Dijla values ranges between (116-290) ppm. For Baghdad Diyala River and, Al-Azizziyah stations values ranges (66.12-238.54) ppm, (95-393.91) and, (77-422.33) ppm respectively (Fig. 9).

Results showed significantly high sodium during the study period, which is responsible for the deterioration of water quality in general, the result of the increase in the presence of sodium salts in the feeding areas through agricultural areas , primary gypsum which is occurs in the geology's of the Mosul and Sammarra stations and secondary gypsum which is occurs on the bank of the Tigris River, evaporation process, and man-made activities. The K Annual average values of the Tigris River ranges between (0.9-3.2) ppm and (0.8-3.2) ppm for Mosul and

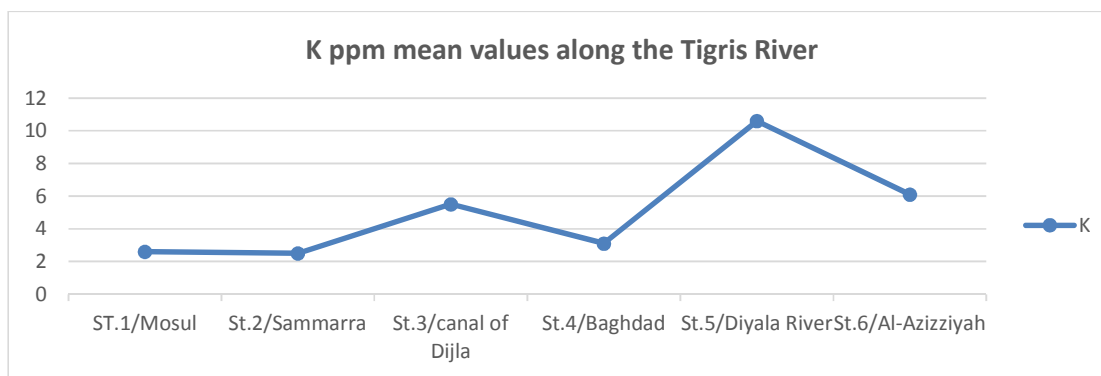
Sammarra stations respectively. While, canal of Dijla values ranges between (4.4-5.7) ppm. For Baghdad Diyala River and, Al-Azizziyah stations values ranges (1.1-4.2) ppm, (5-22.3) and, (2.4-22.3) ppm respectively (Fig. 10).

The Cl Annual average values of the Tigris River ranges between (14.95-33.63) ppm and (16.28-22.45) ppm for Mosul and Sammarra stations respectively. While, canal of Dijla values range between (172.18-256.05) ppm. For Baghdad Diyala River and, Al-Azizziyah stations values ranges (68.75-260) ppm, (60-388.29) and, (74-422.33) ppm respectively (Fig. 11).

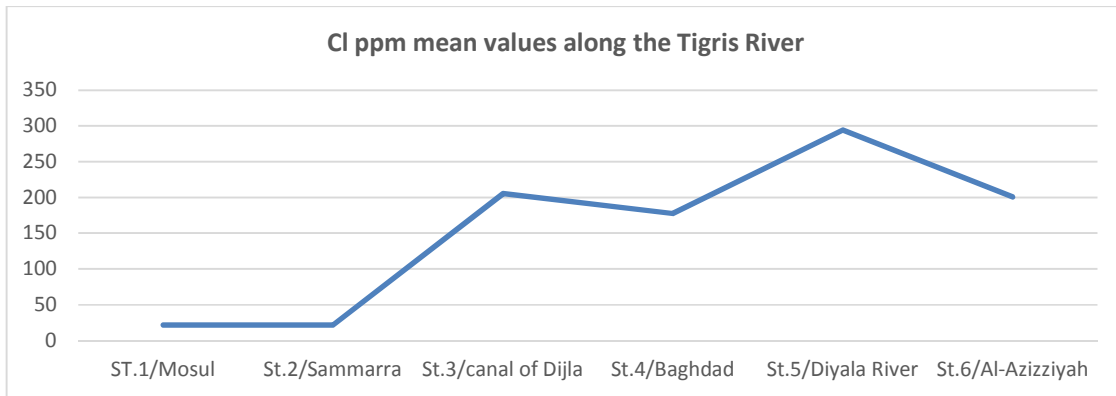
Through the data, it is clear that Diyala River and Al-Azizziyah stations have a high value of the Cl have this greatly affects the deterioration of the quality of Tigris River is various uses of the river . It can be noted through the salty taste of Diyala River station, which indicates an increase in chloride salts in it.



**Fig. 9. Na Annual average values ppm along the Tigris River from Mosul station to Al-Azizziyah station for the period (2005-2012), [11]**



**Fig. 10. K Annual average values ppm along the Tigris River from Mosul station to Al-Azizziyah station for the period (2005-2012), [11]**



**Fig. 11. Cl Annual average values ppm along the Tigris River from Mosul station to Al-Azizziyah station for the period (2005-2012), [11]**

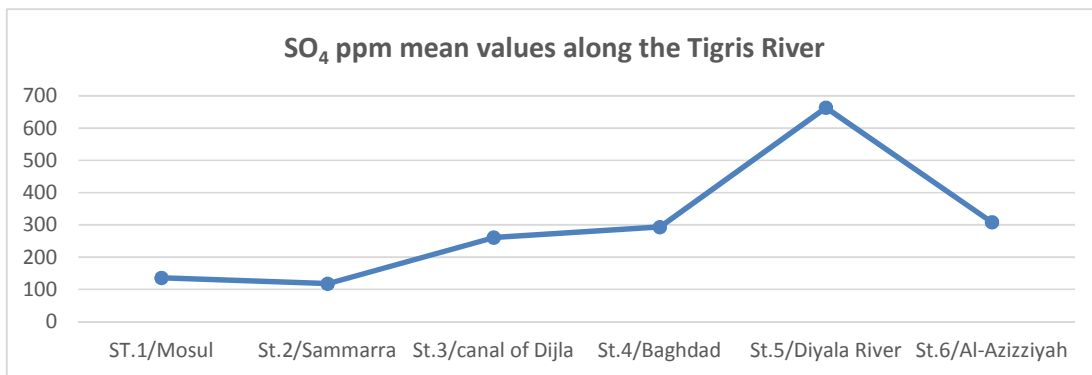
The  $SO_4$  Annual average values of the Tigris River range between (88.11-271.83) ppm and (101.83-137.2) ppm for Mosul and Sammarra stations respectively. While, canal of Dijla values range between (157-463.36) ppm. For Baghdad Diyala River and, Al-Azizziyah stations values ranges (168.18-564.9) ppm, (230-805.70) and, (246.65-422.33) ppm respectively (Fig. 12).

The large values of  $SO_4$  in the (Canal of Dijla, Baghdad, Diyala River, and Al-Azizziyah) stations may be due to man-made activities and natural resources as lithology in the basin can add large quantities of sulfates. The  $HCO_3$  Annual average values of the Tigris River range between (126.5-161.7) ppm and (143.5-161.8) ppm for Mosul and Sammarra stations respectively. While, canal of Dijla values range between (87.4-109.4) ppm. For Baghdad Diyala River and, Al-Azizziyah stations values ranges (148-171.7) ppm, (256-342.2) and, (150-293.8) ppm respectively (Fig. 13).

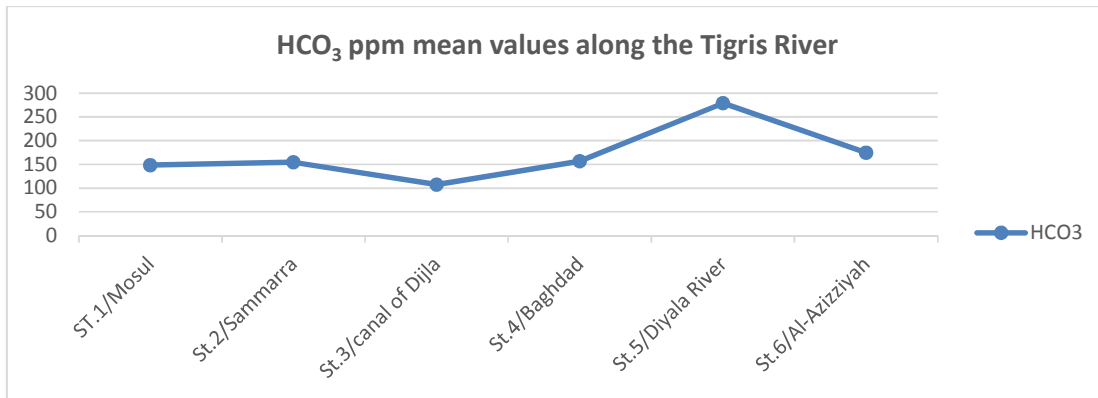
The  $NO_3$  Annual average values of the Tigris River range between (2.3-10.9) ppm and (1.6-8.9) ppm for Mosul and Sammarra stations respectively. While, canal of Dijla values ranges between (1.5-6.5) ppm. For Baghdad Diyala River and, Al-Azizziyah stations values ranges (2-5.5) ppm, (2-12.5) and, (2.1-47.0) ppm respectively (Fig. 14).

The  $NO_3$  in Al-Azizziyah station was high more than in other stations due to the intensive use of pesticides and chemicals in canaling that contains N that will be returned to irrigation flow into the river.

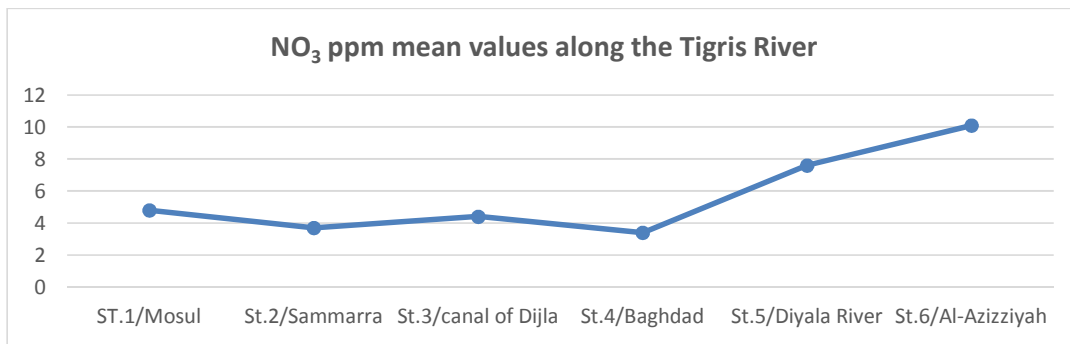
Rivers have a wide domain of differences in their chemical content. This is not limited to different rivers only, but even in one river. It is noticed that there is a variation in the concentrations of elements in the water of the same river from one site to another, as well as in the same site from time to time because the river is a dynamic system in a state of continuous change.



**Fig. 12.  $SO_4$  Annual average values ppm along the Tigris River from Mosul station to Al-Azizziyah station for the period (2005-2012), [11]**



**Fig. 13. HCO<sub>3</sub> Annual average values ppm along the Tigris River from Mosul station to Al-Aziziyah station for the period (2005-2012), [11]**



**Fig. 14. NO<sub>3</sub> Annual average values ppm along the Tigris River from Mosul station to Al-Aziziyah station for the period (2005-2012), [11]**

The work of literatures indicated that the water quality of the Tigris River is affected by climate change and that its headwaters have average salinity of 226-333 ppm at the Iraqi-Turkey border, and the salinity rise along the Tigris river course southward. The deterioration of water quality and the high concentrations of heavy metals caused pollution from many sources are becoming serious threats to the river course [12]. TDS analysis showed an inverse correlation with discharge from Mosul to Al- Aziziyah stations for years (2005- 2012).

The hydrochemical parameters of this research for the period (2005-2012) were compared with many previous studies Table (1). At Mosul station, previous studies before 2003 showed that all hydrochemical concentrations are less than or close to the current study values [14,15]. It was found that average TDS in the present study was relatively higher than the previous studies; it was (193) ppm in [15] (Table 1). Actually, the water quality of the Tigris River

before 2003 reveals that the water quality rich in bicarbonates ions (HCO<sub>3</sub>) which indicates the clear effect of rainfall in the past decades that decreased the concentration of the salinity by a dilution process. When comparing the results of the research with the studies after the year 2003, show that there is an increase in TDS and that water quality was changed to Ca-SO<sub>4</sub> and Mg-SO<sub>4</sub> which indicates the irrigation processes, agricultural activities and the effect of water storage in the Mosul reservoir, meaning that the results of previous studies agree with the current research idea that water quality changes during the time [16,17,18,19].

It was found that average TDS in the present study was relatively higher than the previous studies; it was (193) ppm in [15] (Table 2). While It was found that the average TDS value in the researches after the year 2003 were ranging from (470 to 900) ppm in Mosul and al-Aziziyah respectively as analyzed by [18,19,20,21], (Table 1).

**Table 2. Comparison of the mean values of Hydrochemical analyses of the Tigris River between current, pervious and recent studies**

Stations	studies	EC	TDS	T.H	Na	Cl	SO4	Water Type
Mosul	Current study (2005-2012)	0.5	283.8	223.10	21.875	21.7	135.9	Ca-Mg-SO <sub>4</sub>
	[19]	0.9	575	804	50	52	403	Ca-SO <sub>4</sub>
	[15]	0.2	193	216	15	20	122	Ca-Mg-HCO <sub>3</sub> -SO <sub>4</sub>
Sammara	Current study (2005-2012)	0.5	328	210	16	21	97	Ca-Mg-HCO <sub>3</sub> -SO <sub>4</sub>
	[19]	0.4	334.8	237.80	23.545	21.7	117.75	Ca-Mg-SO <sub>4</sub>
	[15]	1.1	730	888	65	88	442	Ca-SO <sub>4</sub>
Baghdad	Current study (2005-2012)	1.3	893.51	240.3	115.89	177.6	293.39	Ca-Mg-HCO <sub>3</sub> -SO <sub>4</sub> Ca-Mg-SO <sub>4</sub>
	[19]		800	941	88	120	464	Ca-Na-SO <sub>4</sub>
	[18]		470	312.02	70	67.27	198.58	Ca-Na-SO <sub>4</sub>
	[17]		627.7	235.8	59.2	89.1	247.6	Ca-Na-SO <sub>4</sub>
	[16]		684.3	260	61.7	94.4	283.8	Ca-Na-SO <sub>4</sub>
	[15]	0.3	182	147.64	46	24.46	8.65	Ca-Mg-HCO <sub>3</sub> -SO <sub>4</sub>
Al-Aziziyah	Current study (2005-2012)	1.1	717.8	402.79	197.37	200.9	308.42	Ca-Na-Mg -SO <sub>4</sub> .Cl
	[19]	1.4	900	1014	100	180	474	Ca-Na-Cl-SO <sub>4</sub>
	[18]		712.3	251.8	99.8	125.6	209.2	Na- Ca -SO <sub>4</sub> -Cl
	[17]		752.6	299	97.3	122.5	225	Na- Ca -SO <sub>4</sub> -Cl
Diyala River	Current study (2005-2012)	2.6	1574.0	766.29	292.35	294.3	663.69	Ca-Na-Mg-SO <sub>4</sub> Cl
	[20]		473.8	168	26	43	158	Ca-Mg-SO <sub>4</sub>
	[21]	0.5	438	159	213.38	255.6	499.42	Na-Mg- HCO <sub>3</sub> .SO <sub>4</sub>

Such results of previous studies are in concordance with the current research idea that water quality changes during the time and this is due to the impact of climate changes and the deficiency of discharge of the Tigris River [16,17,18,19]. In general, the water quality of the Tigris River at al- Aziziyah station, the concentrations of sulfates, calcium, and magnesium are relatively higher than Mosul station water quality due to the agricultural activities.

Moreover, the same conclusion was reached for average concentrations of the cations  $\text{Ca}^{+2}$ ,  $\text{Mg}^{+2}$ ,  $\text{Na}^+$ , and the anions  $\text{SO}_4^{-2}$ ,  $\text{Cl}^-$  and  $\text{HCO}_3^-$ , that the results of the current study average concentrations of the cations and the anions are relatively higher than the studies done before the year 2003 for Mosul and al- Aziziyah respectively; and they are close or less than those studies after the year 2003 (Table 2).

Such finding considered evidence of water deterioration as the influence of discharge decrease which in turn is affected by the climate changes represented by the scarcity of rainfall and rising the temperatures and consequently the evaporation from Mosul and al- Aziziyah station throughout the years of study and the past decades (Table 2).

Between the south of Samarra and the north of Baghdad stations, the Canal of Dijla joins the Tigris River, which was greatly affecting by the quality of the Tigris river because it contains high concentrations of dissolved load, as it consists mainly Gypsum rocks, whose effect is limited to increasing the sodium components.

At the south of Baghdad city, the Diyala River joins the Tigris River, it has greatly impacted the Tigris River quality by adding a high concentration of dissolved load which it reaches to (1574) ppm (Table 2) due to human activities such as various agricultural activities and the release of wastewater directly into the river, and can note that in water quality of the Tigris River in Al-Aziziyah station. And note rapidly increasing the value of EC at the station of Diyala River due to disposing of the water sewage at the point before Diyala River joining the Tigris River.

Furthermore, the use of Al-Tharthar reservoir water to back up the Tigris river basin shortages, the intensive use of nutrients and chemicals in canalizing that follow with the return irrigation

follows into rivers, as well as discharging untreated sewage water into waterways; have led to deterioration in water quality and quantity of the Tigris River.

#### 4. CONCLUSION

The Tigris River represents one of the main sources of water with the Euphrates River in Iraq. The recent water crisis in the region has prompted the necessity of assessing the quality of the river's water. Water samples from (6) stations along the Tigris River 2005-2012 to test (10) physical and chemical parameters in the selected stations. These parameters are Ca, Mg, Na, K, Cl,  $\text{SO}_4$ ,  $\text{HCO}_3$ , TDS,  $\text{NO}_3$ , and EC and annual flow along the Tigris river. In addition to the available historical climatic data 1990-2012. The temperature was increased over the years in the studied meteorological stations respectively with decreasing the Rainfall was over the years. Climate change population increase and various uses of the Tigris River has a direct effect on the discharge rates. Consequently such a situation affects to increase the water salinity and deteriorate the water quality of Tigris River. The Climatological data for the period (1990-2012) show the Rainfall values for Mosul and Sammarra Stations were range between (301-577) and (69-200) mm respectively, While, in Baghdad and Al-Aziziyah cities range between (59-192) and (85-177) mm respectively. Mean Minimum Temperature values of the Mosul station were range between (10.8-15.6  $^{\circ}\text{C}$ ), While in Samarra station were range between (24.4-47.0  $^{\circ}\text{C}$ ). In Baghdad station were range between (13.9-18  $^{\circ}\text{C}$ ), While in Al-Aziziyah station were range between (13-19.6  $^{\circ}\text{C}$ ). It is noticed that the Rainfall values of all Stations were decreased through time and the temperature is constantly increasing due to the climate change effects over the years. The TDS and EC at Mosul station is the range between (189-556) mg/L and (0.29-4.81)  $\mu\text{hos/cm}$  respectively, while in Sammarra Station ranges between (210-492) mg/L and (0.15-7.78)  $\mu\text{hos/cm}$  respectively. While, an canal of Dijla ranges between (970-2170) mg/L and (0.74-2.27) ds/m. For Baghdad, Diyala River and, Al-Aziziyah stations values ranges between (428-1601) mg/L and (0.65-2.24) ds/m, (506-2217) mg/L and (1.67-3.11) ds/m and, (602-956.4) mg/L and (0.91-1.11) ds/m respectively. In general the water quality of the Tigris River are sulfates, calcium, and magnesium. But in Canal of Dijla the most dominant ion is sodium due to

agricultural activities and geology of the area consist of gypsum rocks and this can be effects on water quality of Tigris River in the next station( Baghdad ). In Al-aziziyah city the sulfates, calcium, and Sodium is high level due to drainage from irrigation, industrial and domestic activities. By comparing the hydrochemical analysis results of present study with the studies before year 2003 reflecting salinities relatively lower than the current study during the nineties of the last century, while the studies after year 2003 were roughly converging in its values with close or relatively higher than the current study.

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### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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