Impact of Climatic Change and Shortage of Water Flow on the Euphrates River Water Salinity between Al-Hindyia and Al-Nasiriya, Southern Iraq

Marwa Muhammed and Moutaz Al-Dabbas

Abstract

Although the increase in water pollution, the amount of water consumption also increased in population and their activities. The effect of climatic changes are considered as the main effect on Iraqi water resources on its quality and quantity. The goal of the present research is to explain the negative effect of the decreasing of water flow and climate change on the quality of water over the years 2005 to 2010 along the Euphrates river starting from AlHindyia Barrage through Al-Samawa to Al-Nasiriya sites. Historical climatological data of rainfall and temperature for the period 1990 to 2020 and hydrological data of discharge and hydrochemical analysis for the period 2005 to 2010 were applied in this research. Three gauging stations were chosen on the stretch of the Euphrates River, Al-Hindyia Barrage, Al-Samawa and Al-Nasiriya city. The discharge of Euphrates river is correlated with the Total Dissolved Solids, the major cations (Na+, Ca²⁺, Mg²⁺ and K⁺) and anions (Cl⁻, SO₄²⁻, HCO₃⁻). It was found that the decrease of discharge due to shortage of water resources and climate change led to increase salinity, Total Dissolved Solids and major ions were became higher with time. The concentration of Total Dissolved Solids increased significantly to reach about 846 ppm in Al-Hindyia Barrage and this rate continue to rise in Samawa to about 2545 ppm and Nasiriya 2724 ppm. it was found that the ions Na⁺, So₄²⁻ dominated in Al-Hindyia Barrage water while Na⁺ and Cl⁻ dominated in Samawa and Nasiriya city water.

Keywords: Salinity; Euphrates River; Discharge; Climate change

1. Introduction

Iraq is suffering from increasing temperatures rates that affect the quality and quantity of the available surface water resources (Al-Ansari, 2013). Due to the effect of climatic changes, the absence of clear plans with unsuitable management, and old undeveloped irrigation systems, the salinity of the Euphrates River is increasing with time (Rehana and Mujumdar, 2011). Climate change has a great effect on water flow, availability, and quality in the future because of the rising evaporation and temperature rates (IPCC et al., 2013; Al-Ansari et al., 2018; Yang et al., 2017). The problem of salinity in the Euphrates River is evident after the Al Hindiya Barrage, and it tends to reduce the river’s discharge, which reaches low rates, as it contributed to the rising of the pollutants concentration and salts (Huntington, 2006; Milliman et al., 2008; Shi et al., 2011). The sources of pollution of the water system are represented by several factors such as rock weathering, rainfall, the interaction between water and soil, and the wastewater of human activities, consequently are leading to deteriorate the economic

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and agricultural practices in the Euphrates basin, (Al-Ansari, 2016; Al-Najim et al., 2005). This problem caused suffering of more than four millions of people in the Al-Muthanna, Diwaniyah and Dhi Qar governorates (Evan and kasm, 2012; Ministry of Water Resources of Iraq, 2021; Durack, 2015; Rahi and Halihan, 2010). Geological setting of the river flow area is covered by the quaternary deposits of loos sands and sabkha of mud. It is located physiologically as a part of the Mesopotamian Plain, and the area is characterized by the sediments of the flood plain of the Euphrates River, as well as depression fill deposits and wind deposits. These sediments accumulate as a result of floods and generally consist of thin layers of fine sediments sand, clay, and silt clay, all of which belong to the Holocene. The Dibdiba (Miocene clastic rocks), Dammam (Miocene carbonate rocks) and Euphrates (Lower Miocene carbonate rocks) formations out croup to the west and south of river flow area (Jassim and Goff, 2006).

Actually, the Euphrates river system is a dynamic system changes with time and it is vital to evaluate the changes with time. Therefore, the impact of decreasing the river discharge, the dissolution of ions from the geological outcrops, the entry of the transported dissolved load, the city’s sewages and the water of the agricultural lands, whose effect increases as the transportation distance increases from Al-Hindiyah to Al-Nasirya which is considered as the problem of this research. The impact of climatic change and the decreasing discharge on the Euphrates River chemical constituents for the years 2005 to 2010 is investigated and considered as novelty of the present work. Several researches have dealt with river discharges at global or regional scale (Jha et al., 2004; Mahageg, 2019; Nakaegawa et al., 2013; Shi et al., 2011; Zhang and Schilling, 2006). But few deals with the climatic data analysis and their relationship with the Euphrates flow in its southern reaches (Al-Obaidi, 1983; Salman, 1986; Ryad, 2004; Bomola, 2012; Hamad, 2015; Al-Ansari, 2019). This research shed light on the most important negative effects of decreasing discharge and increasing the Total Dissolved Solids (TDS) concentration on the water quality for three gauging stations; Al-Hindiyah barrage, Al-Samawa and Al-Nasirya gauging stations which are located on the Euphrates River course within the coordinates of the study area are 32° 43.66’N 44° 16.16’E, 31° 18.82’N 45° 17.85’E and 31° 02.73’N 46° 14.38’E respectively. The area covered about 7000 Km² of the river flow area (Fig.1).

Therefore, the main aims of the present research is to discuss the climate change negative effects of temperature rising and rainfall sacristy with river low flow on quality of the river water for the years 2005 to 2010 along Euphrates River from Al-Hindiyah barrage through Al-Samawa to Al-Nasirya gauging stations.

2. Materials and Methods

Three gauging stations were chosen on the stretch of the Euphrates River; Al-Hindiyah Barrage, Al-Samawa and Al-Nasirya sites.

- Historical climatological data (rainfall and temperature) for the period 1990 to 2020 were taken from Iraqi Meteorological Organization for the Najaf, Samawa and Nasyria Meteorological Stations (Iraqi Meteorological Organization, 2021).
- Discharge, TDS and major ions of the Euphrates river data for the years 2005 to 2010 for the selected sites as available data as well as to high light on the effect of climate change on the Euphrates River quality as vital part of the environmental changes in the study reach (NCWRM, 2021).
- To get a full idea about the effect of the discharge on the water quality of the Euphrates River for the period 2005 to 2010 are investigated and correlated with the discharge value and TDS and investigated correlated major cations (Na⁺,Ca²⁺,Mg²⁺, and K⁺) and anions (Cl⁻, SO₄²⁻, HCO₃⁻) with TDS in Al-Hindiyah Barrage, Samawa and Al - Nasirya station for the period (2005-2010). The total number of analysed water samples are 60 monthly average samples (NCWRM, 2021). All these water samples analyzed in the National Center of Water Resources Management laboratories.
using the standard international methods (APHA, 1999; NCWRM, 2021). The results have been already checked for their accuracy and precision by the staff of the National Center of Water Resources Management (NCWRM, 2021).

Fig. 1. Map of the Euphrates River between Hindiyia Barrage, Samawa and Nasiriya city (Ministry of water resources of Iraq, 2021).

3. Results

3.1. Climate Parameters

Annual average means are calculated from monthly values (12 months within each year) of all used climate parameters (Iraqi Meteorological Organization, 2021). The relationships of these climate parameters with time and discharge are shown as follow:

3.1.1. Temperature

Maximum and minimum temperature (°C) for Al-Hindiya Barrage, Samawa and Al-Nasiriya sites for the years 1990 to 2020 were plotted against time (Fig. 2 a, b and c). There is direct relation between temperature and years with the noticeable increase in temperature from the general trend line. The range between maximum temperature in Al-Hindiya Barrage 29-33 °C with mean value 31.5 °C while in Samawa city 29-41 °C with mean 32 °C and in Al-Nasiriya city the range 30-35 °C with mean 33 °C,
in Al-Hindyia Barrage The minimum Temperature range between 16-19 °C with mean value 18 °C while in Al-Samawa city 12-23 °C with mean 17 °C and in Al-Nasiriya city the range 16-20 °C with mean 19 °C (Fig. 2 a, b and c).

Fig. 2. Annual average values of maximum and minimum temperature for the period (1990-2020) in (a) Al-Hindyia Barrage station; (b) Al-Samawa station and (c) Al-Nasiriya station.

3.1.2. Rainfall

The relationship of mean annual rainfall (mm) with time shows a reverse relation reflecting the rainfall decreasing with years as shown by the general trend line (Fig. 3 a, b and c). The results show that the values of Al-Hindyia Barrage station are range between 31.1-185.5 mm with mean value 93.4 mm while in Al-Samawa city are range between 11.2-247.9 mm with mean value 108.2 mm and in Al-Nasiriya station are range 103-245.8 mm with mean 124.5 mm (Fig. 3 a,b and c).

Fig. 3. Annual average values of rainfall for the period 1990 to 2020 in (a) Al-Hindyia Barrage station; (b) Al-Samawa station and (c) Al-Nasiriya station.
3.2. Discharge Rainfall Correlations

The value of discharge in Al-Hindiyia Barrage range between 85-505 m³/sec, the mean 221 m³/sec, while in Al-Samawa city the range value 35-212 m³/sec with mean value 98.8 m³/sec and in Al-Nasiriya city the range 24-190 m³/sec with mean 86.9 m³/sec. A direct relation is demonstrated between rainfall with discharge for the years 1990 to 2010 (Fig. 4 a, b and c).

Fig. 4. The relationship between discharge- rainfall (1990 to 2010) in (a) Al-Hindiyia Barrage station, (b) Al-Samawa station and (c) Al-Nasiriya station

3.3. Discharge TDS Correlation

The TDS is becoming higher the Euphrates river southern reaches, in Al-Hindiyia Barrage TDS ranged between 600-1156 ppm, with average value 846.3 ppm, while in Al-Samawa city ranged between 1495- 5500 ppm, with average value 2545 ppm and in Al-Nasiriya city ranged between 295- 6750 ppm, with average value 2724.534 ppm. The water flow has indirectly related with TDS for the years 2005 to 2010 (Fig. 5 a, b and c).

Fig. 5. Discharge- TDS relationship 2005- 2010 (a) Al-Hindiyia Barrage station, (b) Al-Simwa station and (c) Al-Nasiriya station
3.4. Major Ions TDS Correlation

3.4.1. TDS- Ca$^{2+}$ correlation

Ca$^{2+}$ in Al-Hindiya Barrage ranged between 8-144 ppm with mean value 76.3 ppm, while it increased in Al-Samawa city to range between 20-274 ppm, with mean value 134.5 ppm. And it continues to increase towards Al-Nasiriya city to range between 16-360 ppm, with mean value 139.36 ppm. There is direct relationship between TDS and Ca$^{2+}$ for the years 2005 to 2010 for the three locations (Fig. 6 a, b and c).

Fig. 6. TDS- Ca$^{2+}$ relationship 2005-2010 (a) Al-Hindiya Barrage station; (b) Al-Samawa station and (c) Al-Nasiriya station.

3.4.2. TDS- Mg$^{2+}$ correlation

In Al-Hindiya Barrage, Mg$^{2+}$ ranged between 23-139 ppm, mean value 59.5 ppm, while in Al-Samawa city ranged between 62.4-284 ppm, mean value 151.1 ppm and ranged between 48-456 ppm in Al-Nasiriya city with mean value 152.08 ppm for the years 2005-2010. Direct relationship is noticed between TDS and Mg$^{2+}$ for the studied sites (Fig. 7 a, b and c).

3.4.3. TDS- Na$^+$ correlation

Direct relationship resulting from plotting Na$^+$ ppm with TDS ppm in Al-Hindiya Barrage, Al-Samawa and Al-Nasiriya sites for the years 2005-2010. Na$^+$ ranged between 62-160 ppm in Al-Hindiya Barrage with mean value 113.4 ppm, while it ranged between 182-1065 ppm with mean value 522.2 ppm in Samawa city and ranged between 178-1329 ppm with mean value 545.44 ppm (Fig. 8a, b and c).
3.4.4. TDS- $K^+$ correlation

Direct relationship resulting from plotting $K^+$ ppm with TDS ppm in Al-Hindiya Barrage, Al-Samawa and Al-Nasiriya station for the years 2005-2010. $K^+$ ranged between 3.2-8 ppm in Al-Hindiya Barrage with mean value 5.79 ppm, while it ranged between 6-21 ppm with mean value 11.75 ppm in Samawa city and ranged between 1.5-21 ppm with mean value 11.13 ppm in Al-Nasiriya station (Fig. 9 a, b and c).
3.4.5. TDS- $SO_4^{2-}$

Direct relationship resulted from plotting $SO_4^{2-}$ ppm and TDS ppm in Al-Hindiya Barrage, Al-Samawa and Al-Nasiriya sites for the period 2005-2010. $SO_4^{2-}$ ranged between 250-850 ppm, mean value is 392 ppm in Al-Hindiya Barrage, while it ranged between 114-1560 ppm with mean value 892.2 ppm in Al-Samawa station and ranged between 576-1709 ppm with mean value 924.24 ppm in Al-Nasiriya station (Fig. 10 a, b and c).

**Fig. 9.** Relationship between TDS- K$^+$ (2005-2010), (a) Al-Hindiya Barrage station (b) Al-Samawa station and (c) Al-Nasiriya station.

**Fig. 10.** Relationship between TDS- $SO_4^{2-}$, (2005-2010), (a) Al-Hindiya Barrage station; (b) Al-Samawa station and (c) Al-Nasiriya station.
3.4.6. TDS – Cl⁻ correlation

Direct relationship is noticed between Cl⁻ with TDS. In Al-Hindiya Barrage station, Cl⁻ ranged between 57-202 ppm with mean value 137.7 ppm. While Cl⁻ in Al-Samawa city ranged between 238-1832 ppm with mean value 734.3 ppm and ranged between 208-1853 ppm with mean value 739.99 ppm in Al-Nasiriya station (Fig. 11a, b and c).

![Graphs showing TDS-Cl⁻ correlation](image)

**Fig. 11.** Relationship between TDS- Cl⁻, (2005- 2010); (a) Al-Hindiya Barrage station, (b) Al-Samawa station and (c) Al-Nasiriya station.

3.4.7. TDS - CO₃ correlation

Direct relationship between TDS and CO₃. In Al-Hindiya Barrage; CO₃ ranged between 1.1-12 ppm, mean value 6.71 ppm; while it ranged between 3-30 ppm, mean value is 11.86 ppm in Al-Samawa city site and ranged between 0.37-24 ppm with mean value 12.6 ppm in Al-Nasiriya station (Fig.12 a, b and c).

![Graphs showing TDS-CO₃ correlation](image)

**Fig. 12.** Relationship between TDS- CO₃; (a) Al-Hindiya Barrage station, (b) Al-Samawa station and (c) Al-Nasiriya station.
3.4.8 TDS- HCO₃⁻ Correlation

Direct relationship is noticed between TDS and HCO₃⁻. In Al-Hindiya Barrage; HCO₃⁻ ranged between 95-330 ppm, mean value 140.4 ppm; while it ranged between 122-201 ppm, mean value is 159.1 ppm in Al-Samawa city site and ranged between 116-195 ppm with mean value 161.13 ppm in Al-Nasiriya station (Fig. 13 a, b and c).

![Fig.13. Relationship between TDS- HCO₃⁻. (a) Al-Hindiya Barrage station, (b) Al-Samawa station and (c) Al-Nasiriya station.](image)

3.5. Hydrochemical Formula of the Euphrates River

The type of water varies from time to time along the study period. The formula of water classification depends on the ratio of the main ions expressed by epm % units which has more than 15% availability (Ivanov, et al., 1968.). The cations are at the base of equation, while anions are above with pH and TDS values, as shown in eq (1).

$$
TDS \ (g/l) = \frac{(SO_4^{2-} .Cl^- .HCO_3^-)_{eppm} \%}{(Na^+.Ca^{++}.Mg^{++}.k)_{eppm} \%} pH
$$

(1)

According to Kurlolov’s formula determined the hydrochemical formula of the Euphrates River (Al-Ansari et al., 2019; Partow, 2001; Ivanov et al., 1968). The decreasing order of ions in the formula is applying to indicate the basic water type. The type of water varies from time to time along the study period and by applying Kurlolov’s formula on the hydrochemical parameters for each year, the water type of the Euphrates River for the period (2005-2010) is (Na⁺,Mg²⁺,Ca²⁺,SO₄⁻ and Cl⁻) at Al-Hindiya Barrage and classified as: NaSO₄ water type, While, have (Na⁺, Mg²⁺, Ca²⁺,Cl⁻ and SO₄⁻) at Samawa and Al-Nasiriya station and classified as NaCl water type.

In general, the high percentages of SO₄ at Hindiya indicate that the Euphrates river water was effected by dissolution of the evaporates rock that exposed within the Euphrates river course where the average concentration of SO₄ at Hindiya was 392 ppm and deteriorated near Samawa 892 ppm and Nasiriya 924 ppm sites with nearly double and half increase that may reflect the dissolution and leaching of such ion from the geological outcrops by the action of natural waters that increases as the
transportation distance increases from Hindiya to Samawa and Nasiriya. While, the Cl\(^-\) individual load is relatively reflect the pollution of sewage water and the irrigation water of the agricultural lands that flow into the Euphrates river south Hindiya. Where the average concentration of Cl\(^-\) at Hindiya was 137 ppm and deteriorated near Samawa and Nasiriya sites to be 734 ppm and 740 ppm respectively, with nearly fivefold increase.

4. Discussion

The results in this study indicate the impact of climatic changes significantly on the rate of discharge over the year (2005 to 2010) due to the increase in temperatures and the scarcity of rainfall that greatly affected in raising the level of salinity of the Euphrates River and deteriorate the water quality of this River, this noticed through the relationship between discharge and total dissolved solids (TDS). The study area along the Euphrates River is an agricultural and residential area, where sewage and effluents from homes, as well as pesticides and chemicals used in agriculture flow towards the river without treatments, cause significant pollution. Actually, it is believed that the effect of climate change is much higher than the effect of the amount of increase in water consumption, and the increase in water pollution as a result of the increase in population and projects on the banks of river during this period. Moreover, the amount of annual rainfall on southern Iraq decreased to the half of their amounts than that during the seventies (Adam, et al., 2020; Ali and Dabbas, 2021). The previous researches results are in agreement with the concept of the present study of increasing the water salinity with time and this is due to the effect of climate warming and the scarcity of the Euphrates River water flow (Al-Ansari et al., 2019; Al-Obaidi, 1983; Salman, 1986; Bomola, 2012; Ryadh, 2004; Hamad, 2015). The salinity is increased temporally with time, therefore the average TDS and the hydrochemical parameters were compared with others studies, Table 1.

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<td>Al-Hindya</td>
<td>Al-Samawa</td>
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<tr>
<td>TDS</td>
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<tr>
<td>Ca(^{2+})</td>
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<td>Mg(^{2+})</td>
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<td>HCO(_3^-)</td>
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<td>Water type</td>
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Table 1. Physio-chemical parameter correlation of the Euphrates River of present study with others results (Al-Ansari et al., 2019; Al-Obaidi, 1983; Salman, 1986; Bomola, 2012; Ryadh, 2004; Hamad, 2015).

The results of previous researches showed that all the same or lower than the present research output of the water chemical constituents (Al-Ansari et al., 2019; Al-Obaidi, 1983; Salman, 1986; Bomola, 2012; Ryadh, 2004; Hamad, 2015). The existence of relatively high bicarbonates ions before 2003 indicate the noticeable rainfall contribution in the last ten years that diluted the total dissolved salts and lowers their values within the Euphrates River. But the situation becomes even worse as the TDS concentrations along the Euphrates River increases dramatically (Table .1). According to the prior studies, the Euphrates River has good to moderate salinity concentration, while the studies after year
2005 have emphasized the increase in water salinity of the river more than before year 2005 due to the relatively low flow in the river that caused by the global climate change that consequently affect the salinity of the river. It is believed that the average mean annual water type deteriorated due to the climate change that caused in rainfall rareness and high rates of temperature degrees.

5. Conclusions

- The temperature increased over the years 1990 to 2020 in the studied meteorological stations respectively, with decreasing in rainfall over the years. Climate change has a direct effect on the discharge rates, accordingly, the discharge rates in the Euphrates River decreased which is clear from the direct correlation between discharge rainfall. Consequently, such a situation affects to increase the water salinity and deteriorates the water quality of the Euphrates River.

- The averages mean annual flow of the Euphrates River for the period 2005 to 2010 are 221, 98.8 and 86.9 m³/sec for Al-Hindiya Barrage, Al-Samawa and Al-Nasiriya gauging stations, respectively.

- The averages mean annual TDS of the Euphrates River for the period 2005 to 2020 are 846.3, 2545 and 2724.5 ppm for Al-Hindiya Barrage, Al-Samawa and Al-Nasiriya gauging stations, respectively. Such results reflect the current research idea that water quality changes during the time and this is due to the impact of climate changes and the nature of the exposed rocks within the Euphrates River course, As well as the entry of the sewage water and the drainage water of the agricultural lands that flow into the river.

- The water type of the Euphrates River for the period 2005 to 2010 is NaSO₄ at Al-Hindiya Barrage, While, it is NaCl water type at Samawa and Al-Nasiriya station. The high percentages of SO₄ at Al-Hindiya indicate that the Euphrates river water was effected by dissolution of the evaporates rock that exposed within the Euphrates river course where the average concentration of SO₄ at Hindiya was 392 ppm and deteriorated near Samawa 892 ppm and Nasiriya 924 ppm sites with nearly double and half increase that may reflect the dissolution and leaching of such ion from the geological outcrops by the action of natural waters that increases as the transportation distance increases from Hindiya to Samawa and Nasiriya. While, the Cl⁻ individual load is relatively reflects the pollution of sewage water and the irrigation water of the agricultural lands that flow into the Euphrates River south Hindiya. Where the average concentration of Cl at Hindiya was 137 ppm and deteriorated near Samawa and Nasiriya sites to be 734 and 740 ppm respectively, with nearly fivefold increase.

- The results indicate a lowering of salinity downstream towered southern reaches of the Euphrates River. In conclusion, it is believed that the higher salinity values within the southern parts of the Euphrates River are because of the effect input of untreated of the irrigation drains flow and saline groundwater.

Acknowledgements

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