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Spatial and Temporal Variations in Water Quality of the Euphrates River: A Sustainable Water Management Approach for Anbar Governorate, Iraq

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ABSTRACT

This study aims to analyze the qualitative characteristics of Euphrates River water in Anbar Governorate, identify spatial and temporal variations in water quality, evaluate the suitability of Euphrates River water for different uses, and provide recommendations for improving its management. In addition, the study seeks to provide a deep understanding of the impact of human activities on water quality, contribute to better management of water resources, reduce pollution, and provide reliable data that can be used in future research and support governmental and non-governmental efforts in formulating appropriate policies and strategies. The study sample was selected from four main sampling locations (Al-Qaim, Haditha, Ramadi, and Fallujah) and a qualitative analysis was conducted for those samples. The results of the analysis showed temporal and spatial variation in electrical conductivity values. The Al-Qaim sample recorded the lowest values due to the lack of human activities (566µS/cm in January), while the Haditha sample was higher due to the presence of Haditha Lake as well as increased human activity (708 µS/cm in August). Ramadi recorded lower values than Haditha due to increased water flow during the winter and increased water releases (621µS/cm in January). Fallujah station recorded higher values than Agricultural wastewater due to the influence of agricultural, sanitary and industrial wastewater (855 µS/cm in August). The results indicate that the Euphrates River water tends to be neutral to slightly alkaline, with pH values ranging between 6.5 and 8.5, highlighting the need to improve water resource management to reduce pollution and support different water uses. The study also showed that the highest nitrate values were recorded in Tharthar Lake during August (3.1 mg/L) and the lowest values were recorded in January (2.5 mg/L).

1. INTRODUCTION

The water quality in Iraq, like that of developing countries, suffers from poor and underdeveloped scientific and technical staff as well as poor management, which negatively reflects on its qualitative assessment [1, 2]. The impact of this was not limited to water mismanagement, but also on the equitable distribution and development of water resources. With the accumulation of these negative effects due to mismanagement and neglect of water development projects for many years, a new problem has emerged, which is funding to reform the necessary administrative and development relations. The financial estimates have become substantial that the general budgets of the Iraqi Ministry of Water Resources cannot cover, prompting specialists to search for new alternatives by involving the private sector in assuming part of the responsibility for the state, especially with regard to management and development [3]. Water quality refers to the acceptability of water for human consumption, depending on the composition of water that is affected by natural processes and human activities. Water quality is determined by a set of different standards (physical and chemical). Human health is related to those standards and affected by them if they exceed acceptable values. Therefore, various agencies such as the World Health Organization (WHO) and others have set safe limits for chemical pollutants in drinking water [4, 5]. The water quality index (WQI) is the most effective way to measure water quality. To assess water, data on its quality is included in a mathematical equation, and then its suitability for drinking is determined. Water pollution is defined as a change in the natural characteristics of water that makes it a real source of problems or makes it unsuitable for various uses [6]. This was confirmed by the World Health Organization (WHO), which defined water pollution as any change in the composition of water elements or transformation of its condition, directly or indirectly, due to human activity [7]. So that the state of the water becomes less valid for the natural uses allocated to it.

The first indicator of water quality was developed by Horton in 1965 using 10 water data that is used and studied

regularly, to be modified at a later time by different experts. These indicators used water quality standards that differ according to the number and types. The weights in each data depend on it, and the allocated weight indicates the importance of the data and its effects on the indicator.

The Euphrates River originates in Turkey and continues its course through Syrian territory until it enters Iraqi territory in Anbar Governorate at the city of Husaiba, then it completes its course through Iraqi territory to meet the Tigris River in the city of Al-Qurna in Basra Governorate, forming the Shatt al-Arab, which eventually flows into the Arabian Gulf. The Euphrates River is affected along its course from its source to its mouth by pollutants resulting from agricultural wastewater, industrial pollutants, and municipal pollutants resulting from various human activities of the cities and projects it passes nearby [8]. The study aims to conduct a qualitative analysis of the Euphrates River water in Anbar Governorate, western Iraq, and its suitability for various uses, and propose sustainable water management strategies for Anbar Governorate.

2. METHODOLOGY

The study began by collecting data first through four monitoring stations on the Euphrates River in Anbar Governorate and taking samples, then analyzing that minute in the laboratory based on the required response during the months of January and August during the results that are determined by the analysis. The reason for selecting samples at these times is that these months are the coldest and hottest months of the year, based on the analysis of climate data. It is important to delve into the integration characterized by water shortages and compare the results with unexpected results.

The study area boundaries are within Anbar Governorate, starting from the city of Al-Qaim in the west to the city of Fallujah in the east. The study includes four main stations on the Euphrates River: Al-Qaim, Haditha, Ramadi, and Fallujah. The study focuses on assessing water quality in these areas and analyzing the spatial and temporal variations in the physical and chemical characteristics of the water, as shown in Figure 1.

Figure 1. Locations of sample collection for measuring the qualitative characteristics of the Euphrates River water in Anbar Governorate

To find out and study the qualitative characteristics of the river, physical and chemical analyzes of the Euphrates water in Anbar were conducted for August and January to compare and indicate the difference between them.

3. RESULTS AND DISCUSSION

Four stations were identified to measure those characteristics.

3.1 Physical properties

3.1.1 Temperature

Temperature has an important and influential role in the quality of water and its physical and chemical properties, as the relationship between temperature and water is a direct, as well as the number of impurities and plankton in the water and the speed of water runoff. All these affect water uses, as the permissible temperature is (6.5-21°C). The temperature values recorded in Al-Qaim district in August was (30°C), while the temperature recorded in January was (16°C). The reason is due

to the temperature difference between summer and winter. As for the Haditha district, it recorded the highest temperature values in August which reached 31°C. The lowest values were recorded in January with 16°C. Here, it is clear that the temperature values were higher in Haditha district than they were in Al-Qaim station, due to the presence of Haditha Lake. In Ramadi district, they reached the highest temperature values in August with 30°C while the lowest values were recorded in January with 15°C. Thus, the temperature values decreased for the Haditha district. This is due to the increase in water intake through the valleys that flow into the river, which reduces temperatures. Al-Fallujah district recorded the highest value in August with 31°C, whereas in January, the temperature was 17°C. The reason why the temperature values in winter in Fallujah district is higher than in Ramadi is due to the increase in human activities resulting from the increase in the number of residents in those areas, in addition to the water received from Al-Tharthar and Habbaniyah Lakes. Through data analysis, it is clear that the temperature difference is not significant for the temperature values within the sector. However, it went beyond the permissible limit in the study area, especially in the summer.

3.1.2 Turbidity

Both the concentration and the size of the granules of plankton substances affect the amount of the degree of turbidity. It is reflected on the optical property of water. The permissible range of turbidity is (30-180) and its value varies spatially and temporally within Anbar. Through qualitative analysis, it turns out that in August Al-Qaim district recorded the highest turbidity values of (113) NTU, while in January, the district recorded (83) NTU. The high percentage of turbidity in the summer months is due to the increase in water intakes, in contrast to the winter months, in which the percentage of water intakes decreased due to the water management policy of the countries. As for Haditha district, it recorded the highest values of turbidity in August with (155) NTU, while the lowest values of turbidity were recorded in January, and they are amounted to about (109) NTU, due to the flow of water from Haditha Dam, which increases the percentage of turbidity in the river, as well as river valleys that increase turbidity, even by very small percentages [9]. As for Ramadi district, it recorded in August turbidity values of (179) NTU, while its lowest values were recorded in January and amounted to (122) NTU. Thus, Ramadi district recorded higher values than those recorded in Haditha district. The reason for the difference in the turbidity values over time is due to the increase in human activity, especially agriculture, as well as an increase in the quantities of sewage water, and industrial activities on both sides of the river, such as sand factories that increase the turbidity values. The district of Fallujah had the highest turbidity values in August and reached (143) NTU, while the lowest values were recorded in January and amounted to about (168) NTU. A decrease in the percentage of reversibility is observed in Fallujah district compared to Ramadi district, as shown in Figure 2.

3.1.3 Electrical conductivity

It is a numerical value indicating the ability of water to carry electric current and is directly proportional to the concentration and equivalence of dissolved ions present in water and to the temperature of water [10]. It is the ability of 1 cm^3 of water to conduct electric current at a temperature of 25°C. Electrical conductivity is measured by micro-Siemens/cm (µS/cm). From the analysis of water, it turned out that Al-Qaim city recorded the highest values of electrical conductivity in August at (709 µS/cm), while the lowest values of electrical conductivity were recorded in January at (571 µS/cm). This is due to the high temperatures in Summer, which in turn increase the evaporation values and the high percentage of salts in the water. As for Haditha district, it recorded in January the highest values of electrical conductivity which amounted to (728 µS/cm), whereas in January Haditha recorded the lowest values which amounted to about (713 µS/cm) [11]. Through the data, we notice an increase in the electrical conductivity values for Al-Qaim district in the summer and winter months, due to the presence of Haditha Lake in which the salinity values increase, while in the Ramadi district, the highest electrical conductivity was recorded in August and reached (730 µS/cm), While the lowest values of the electrical conductivity were recorded in January, which amounted to about (627 µS/cm). The reasons why the electrical conductivity values in Ramadi district are higher than those in Haditha district, specifically in Summer, is due to agricultural wastewater and factory waste [12]. The concentration of the population increased sewage towards the river. Al-Fallujah District recorded the highest electrical conductivity in August and amounted to (851 µS/cm), while the lowest values of electrical conductivity were recorded in January, and amounted to about (774 µS/cm). The reason for the significantly higher electrical conductivity in the Fallujah district than the Ramadi district is the large number of canals and the increase in their lengths, as their discharges exceed 7 m^3/s^3, and the high percentage of agricultural drainage water, in addition to the water coming from Habbaniyah and Al-Tharthar lakes, which are characterized by a large concentration of salts, as shown in Figure 3.

3.2 Chemical characteristics of the Euphrates in Anbar

3.2.1 Acid and Alkaline (pH)

It's the capacity of water to balance the standard acid and pH. It is a measure of how acidic or alkaline the water is. Its values range between (0-14), where the value is equal to (7), the acidity and alkalinity are equal and the water is considered very fresh, but if it is less than (7), it tends to acidic, and if it is more than (7), the water become alkaline, which is suitable for many uses. The permissible ratio is between (6.8-8.4). The PH values increase with low temperatures and decrease when the temperatures are high. Therefore, we notice high values in winter. Al-Qaim district recorded the highest PH values in January at (8.2 mg/m^3), while lower PH values in August amounted to about (7.7 mg/m^3). It is clear from the analysis that there is a difference in pH values. This is due to the difference in temperature values between the Summer and Winter seasons. In January, the higher PH values of (8.5 mg $/m^3$) were recorded in Haditha district, while in August, lower values of (7.9 mg/m^3) were recorded. The reason is also related to temperature values. Thus, in the winter months, the PH values recorded in Haditha District are higher than those recorded in Al-Qaim district [13]. As for Ramadi district, it recorded the highest values in January which amounted to (7.5 mg/m^3), while the lowest values recorded in August were (7.9 mg/m^3). Fallujah District recorded the highest PH values in January (8 mg/m^3), while its lowest values were recorded in August (7.8 mg/m^3). This means that the waters in most of the sections of Euphrates tend to be alkaline. This is due to reasons including temperature differences, canal water and sewage

water, as well as water returning to Euphrates through Al-Tharthar and Habbaniyah Lakes. The water is within the permissible percentage whose values range between (6.5, 8.5 mg/m^3), as shown in Figure 4.

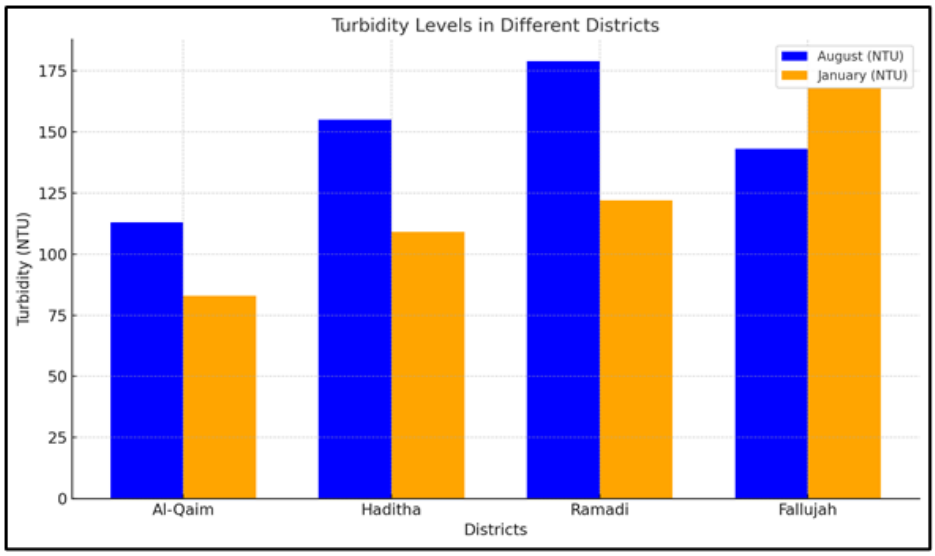

Figure 2. Rate of temperature and turbidity in the study area

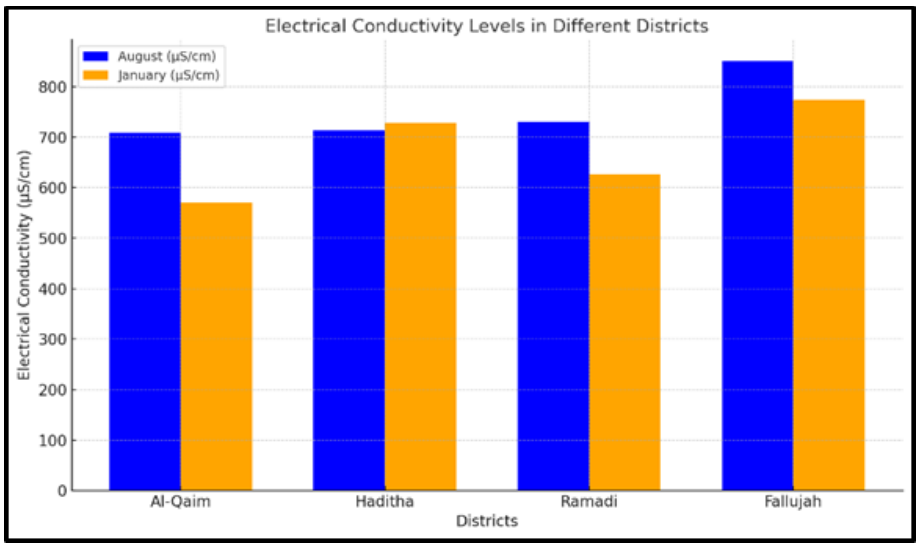

Figure 3. The rate of electrical conductivity in the study area

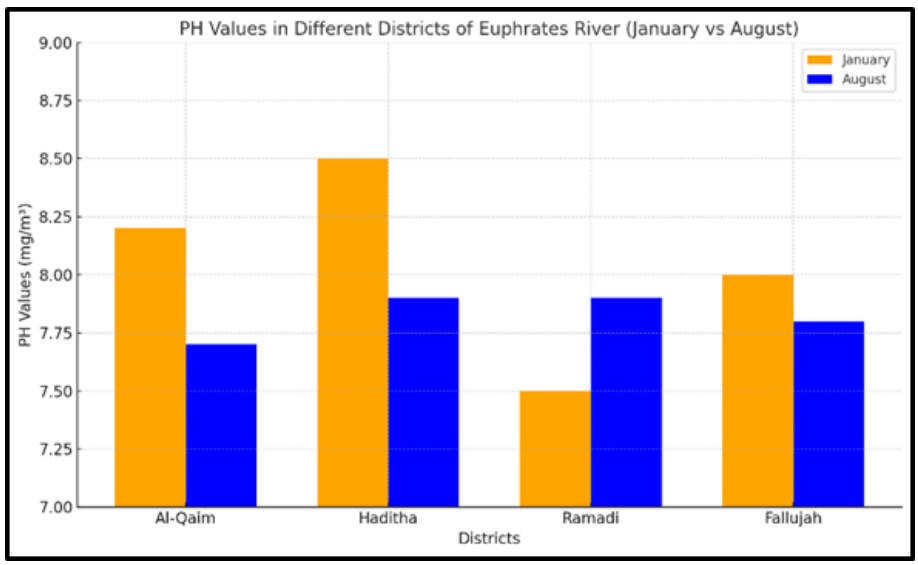

Figure 4. The rate of acidity in water

3.2.2 Total dissolved solids (TDS)

They are all solids dissolved in water, whether they are ionized or non-ionized. In other words, they are a group of dissolved salts that are actually soluble in water and move with it through the rocky pores. They do not include suspended substances and colloids. Salts have their effect on the general characteristics of water. This affects plants and soil. The proportions of dissolved substances increase according to agricultural activities and soil washing operations as well as industrial activities. Within Anbar, the salt values vary temporally and spatially, where the in August, values reached (353 mg/L) while lower values of (287 mg/L) were recorded in January. The reason is due to the high temperature in the month of August, in addition to the presence of limestone and gypsum rocks within the region and within the course of the river, noting that the permissible limits are 510-1568 mg/L, while Haditha District recorded values in the month of (August) that amounted to (428 mg/L), while recorded Lower values in the month of (January) (330 mg/L). The reason for the high values in the summer season is due to the high-water releases from the Haditha Dam, whose salinity was previously mentioned [14]. As for Ramadi district, it recorded the highest values in August of (425 mg/L) and lower values of (313 mg/L) were recorded in January. Fallujah district recorded values of (457 mg/L) in August, while lower values of (395 mg/L) were recorded in January. This is due to the water intake of the Habbaniyah and Al-Tharthar lakes, as well as the sewage and agricultural water of Fallujah due to the large number of canals.

3.2.3 Total hardness (TH)

It is a numerical expression of the concentration of calcium and magnesium ions contained in water, as well as other alkaline salts. Calcium and magnesium are one of the most important causes of hardness. Their natural sources include limestone which dissolves in water during contact with it. In addition, their concentration increases depending on the geological formations through which water passes, especially in winter, due to the rain factor and what it transports to the river and the agricultural wastewater received to the river through canals and untreated sewage. Hardness is important in identifying the suitability of water for human consumption. The increase in the hardness of the water changes the water properties such as color, taste and smell. The maximum limit of hardness is (500) mg/L. Through analysis, the value of hardness varies temporally and spatially in the Euphrates in Anbar, where Al-Qaim district recorded the highest values at the rate of (301 mg/L) in August, while lower values were recorded in (January) and amounted to (23 mg/L). The reason for this is that the riverbed is within calcareous formations. In August, Haditha district recorded an average of (372 mg/L), and lower values of (279 mg/L) were recorded in January. The reason for its rise is due to the melting of lime rocks in Haditha Lake. As for Ramadi district, it also recorded an average of (355 mg/L) in August, then decreased in January to (309 mg/L). The reasons why the hardness values recorded in Ramadi are higher than those recorded in Haditha are due to the high intakes of dry valleys after the Haditha Dam, as well as the increase in drains and untreated sewage water [15]. In August, Al-Fallujah district recorded an average of (349 mg/L) and lower values in January at a rate of (300 mg/L). The reason is the increase in the canals and the rise of the intake from Habbaniyah and Tharthar lakes, where Tharthar Lake is distinguished because it is built on a distinct geological formation due to the abundance of lime rocks. All values are less than (500 mg/L) except for the values of Tharthar Lake, which were recorded higher than the permissible values, as shown in Figure 5.

3.2.4 Nitrate (NO_3)

One of the most important sources of nitrate NO_3 is agricultural fertilizers. Nitrate NO_3 increases with the increase of water canals and their lengths, which transfer nitrates added to agricultural land to the river due to the thawing resulting from the irrigation used in most of Anbar, especially in the lands near the river, as well as some rocks containing nitrogen that has water solubility and the permissible nitrate ratio is (50) mg/L [8]. Through data analysis, it turns out that there is a spatial and temporal difference of their values, where Al-Qaim recorded in the August values of (21 mg/L) while the values in January were at a lower rate of (19 mg/L). The reason for the rise in nitrates values in summer compared to winter is due to the increase in the amount of agricultural drainage resulting from increased irrigation. As for Haditha district, it recorded its highest values in the study period in August to reach (27 mg/L), while lower values were recorded in January (19 mg/L). Here the values began to be relatively higher than what they were in Al-Qaim. Studies indicate that Haditha Lake has a role in increasing its percentage. Ramadi district in August recorded values of (38 mg/L), while in January it recorded values of about (20 mg/L). It is clear that there is an increase in the values of nitrates in Ramadi district and they are higher than in Haditha district [16]. Here the role of water canals is evident whose number increases when entering the river in the sedimentary plain area south of the city of Hit. Fallujah District also recorded the highest Nitrate values in August which amounted to (19 mg/L), while the lowest values were recorded in January (11 mg/L). It is noted that there is a decrease in nitrate values in Fallujah District compared to Ramadi district, due to weak agricultural activity in Fallujah compared to Ramadi, as shown in Figure 6.

3.2.5 Sulfate (SO_4^{-2})

In the study area, sulfate concentrations recorded varying values, where the percentage of permissible values is (380-884). Gypsum rocks are the most important sources of this element due to its solubility in water, as well as groundwater, which increases the percentage of sulfates in river water. The analysis shows that there is a spatial and temporal variation of the percentage of sulfates in the Euphrates in Anbar [17]. In August, Al-Qaim district recorded a percentage of (172 mg/L) which is the highest value, while the lowest value was recorded in January and amounted to (128 mg/L). The reason is due to the high-water temperatures in summer, which increase the ability to melt the rocks in contact with it. In August, Haditha district recorded values which amounted to (192 mg/L), while lower values were recorded in January at a rate of (137 mg/L). From the analysis, it is noted that the sulfates rates are higher in Haditha than they were in Al-Qaim, resulting from an increase in the water patch provided by Haditha Dam and thus increased the melting processes [18]. In August, Ramadi district recorded the highest values of sulfates which amounted to (266 mg/L) and the lowest value in January (109 mg/L). The values rise as a result of an increase in agricultural drainage and sewage water intake. In August, Fallujah recorded the highest values which reached to (271 mg/L) and while January recorded the lowest value which amounted to (191 mg/L). It is clear that there is an increase in

values which higher than the previous stations due to the water intake from Habbaniyah and Tharthar lakes, as well as the role of Al-Fallujah dam by raising the water level by more than 2.5 m and for a distance of more than 12 km.

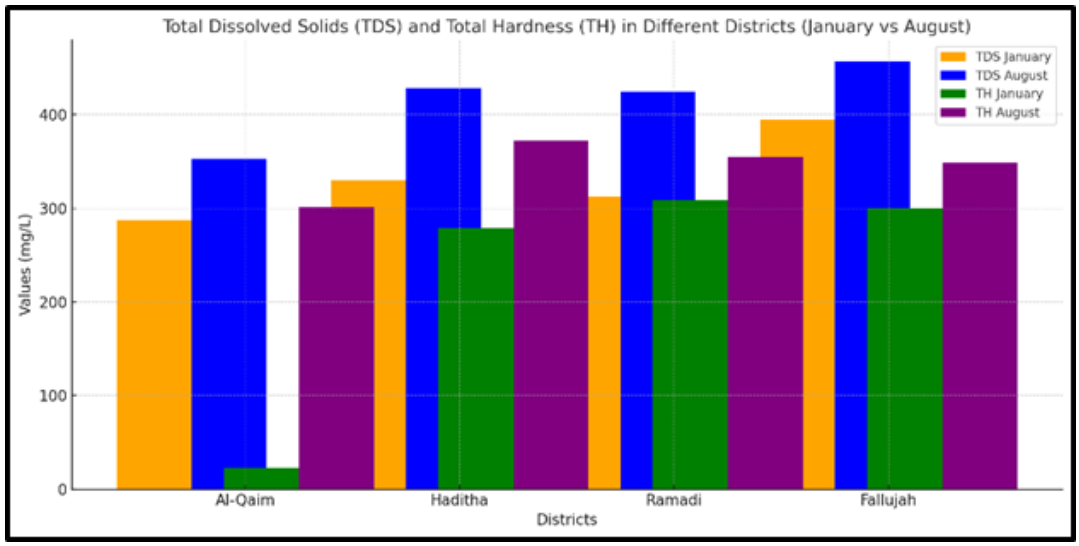

Figure 5. Average TDS – TH values in the study area

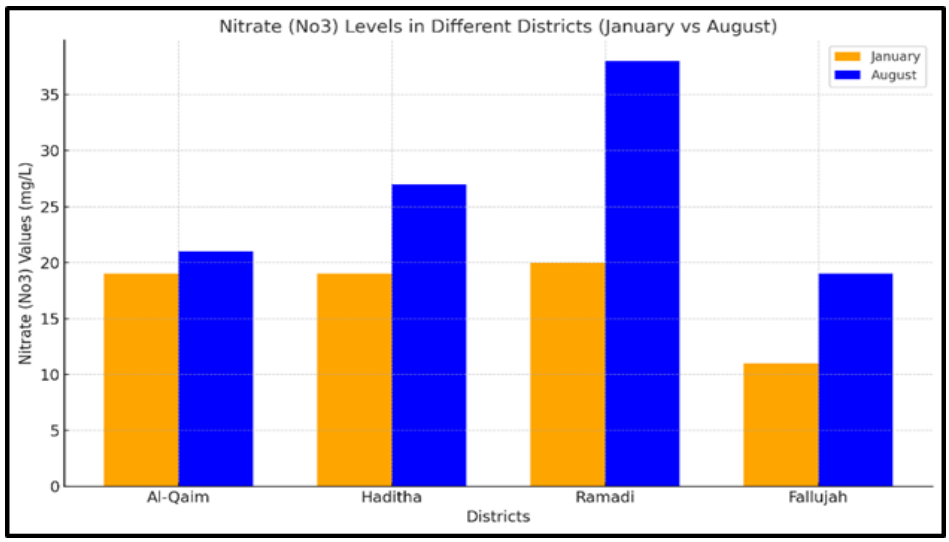

Figure 6. Rate NO_3 in the study area

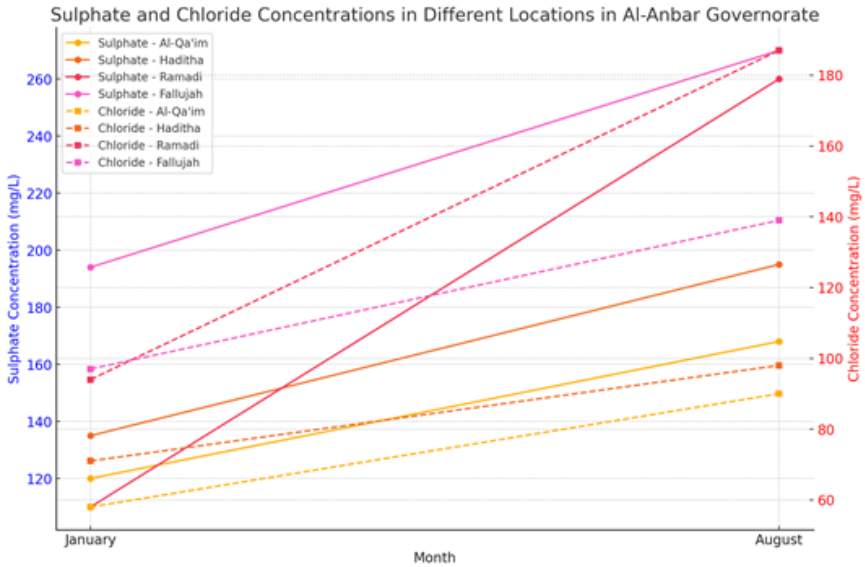

Figure 7. Rate SO_4^{-2} – Cl in the study area

3.2.6 Chlorine (Cl)

Chlorine is used as a water disinfectant. Since most of that water returns to the river, thereby chlorine contributes to an increase in the concentration of its ion in the river. Despite the variation of its proportions in the study area, it remained within the permissible limits of (250) mg/L. Chlorine is an element soluble in water and found in widely dispersed limestone and gypsum rocks. It has a significant effect on crops when it exceeds critical limits. In August, Al-Qaim district recorded its highest values of (91 mg/L), while the values decreased in January to (52 mg/L). The presence of chloride is due to the spread of gypsum and limestone rocks within the region, as well as sewage which contains this ion [19, 20]. Haditha district recorded values of (98 mg/L) in August, which is higher than January when its value reached (70 mg/L). The reason for the increase in values is due to the melting processes of gypsum and lime rocks in Haditha Lake, which are higher in the summer months due to high temperatures. Al-Ramadi district recorded values higher than the aforementioned districts in August with values that reached (189 mg/L) while the lowest value was recorded in January, where the value of gypsum and lime rocks in Haditha Lake reached (71 mg/L). The reason for the increase in values is due to the melting processes of gypsum and lime rocks in a modern lake, which are higher in the summer months due to high temperatures, and al-Ramadi district recorded values higher than the aforementioned districts in August (190 mg/L), while the lowest value was recorded in January, where the value of chloride is (94 mg/L). The values in al-Ramadi district are rising as a result of agricultural drainage, sewage and industrial drainage. The water of the valleys has its effect on the rise in Chlorine values. In August, the district of Fallujah recorded its highest values of (139 mg/L), while the lowest value was recorded in January when the value of chloride was (97 mg/L). It is noted that the Chlorine values in Fallujah are close to those in the district of Ramadi. This increase is due to the water incoming from Habbaniyah and Tharthar lakes, as shown in Figure 7.

4. CONCLUSIONS

1- Through the analysis of the data, it becomes clear that the thermal difference is not significant for the temperature values within the river section, Ramadi district recorded the lowest thermal values.
2- From the analysis of the data, it is noted that there is a spatial variation in the recorded electrical conductivity values, as Al-Qaim station recorded the lowest values, due to the lack of activities in that area compared to the rest of the regions. Haditha district recorded higher values than Al-Qaim due to the presence of Haditha Lake that increases the percentage of salts as well as human activity. As for Ramadi district, it recorded lower values than Haditha due to the rise in the water intake in winter through the valleys as well as increased water discharges from Haditha. Fallujah district recorded values higher than Ramadi in terms of electrical conductivity.
3- The waters of the Euphrates tend to be alkaline, in most sections of the river. This is due to several reasons, including temperature differences, agricultural wastewater, sewage, as well as water returning to the river through industrial activity. The water is within the permissible percentage and its values range between 6.5, 8.5 mg /m^3.
4- When comparing the permissible total hardness values, we find that they are within the permissible limits, where all values are less than 500 mg/L.
5- Developing water resources management strategies: These strategies should include measures to reduce pollution, improve water quality, and make it suitable for various uses. By monitoring factories and farms that discharge wastewater into the river.
6- Implement Modern Water Treatment Technologies: Adopt advanced and modern technologies for water treatment to reduce pollutant levels significantly. This can greatly contribute to improving water quality and reducing the health and environmental risks associated with pollution.

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