Assessment of Water Quality in Tigris River of AL-Kut City, Iraq by Using GIS

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Abstract. The concerns about water contaminants affect most developing countries bypassing rivers over them. The issue is challenging to introduce water quality within the allowed limits for drinking, industrial and agricultural purposes. In the present study, physical-chemical parameters measurements of water samples taken from eleven stations were collected during six months in 2020 through flow path along the whole length of Tigris River inside AL Kut city (center of Wassit government) were investigated for six parameters are total hardness TH, hydrogen ion pH, biological oxygen demand BOD_5, total dissolved solids TDS, nitrate NO_3, and sulfate SO_4. The water quality analysis results were compared with the maximum allowable limit concentration recommended by World Health Organization WHO and Iraqi limitation spastically; TH, BOD_5, TDS, and SO_4 had an average value of 421, 62, 813, and 376 mg/l, respectively. The spatial distribution of six water quality parameters within the studied area was carried out by implementing the Quantum Geography Information System QGIS technique established on the Inverse Distance Weighted IDW method to produce the interpolation predicted maps of stations along the river in Al Kut city. The results showed water quality degraded and an increase in the concentrations observed for all parameters along the river path, especially at the last two stations due to attributed to human activities, land use and industrialization, and outfall of sewerage flow to the river directly without treatment. Spatial distribution is essential to give a thorough understanding of the river's contamination reality. This makes it easier to understand, analyze and find the appropriate treatments and solutions to the problem of water quality.

Keywords: Water quality; Tigris River; GIS; spatial mapping; Al Kut city.

Introduction

Water is the world's largest natural resource. In practically all human activities for drinking, irrigation, and municipal use to satisfy industry demands, growing food, recreational activities, and power production, it is a key element for preserving all life forms [1]. Nevertheless, water quality has deteriorated considerably globally in many large rivers because of anthropogenic activity in the past two to three decades [2]. More than 20% of the world's population does not have safe potable water, and almost half of the population lacks sufficient access to clean water. This issue is especially acute in many third-world countries, where an estimated 95 percent of untreated urban waste is discharged directly into the river. Iraq is among the nine countries of the Middle East with insufficient freshwater resources [3,4]. Water pollution is a major global problem. In order to determine the condition of pollution in the river, continuous monitoring of water quality is essential. Water pollution of lakes and rivers is increasingly trendy across large parts of the world [5].

Recently, GIS had played a key role in promoting water-connected phenomena representation and analysis. It is widely used to monitor and manage wastewater, especially in economically expanding and growing developing countries [5]. It supports mapping, modeling, and management of facilities, order management, and short-term planning. GIS hydrological models for surface runoff, inundation flow, and water quality were developed [6,7]. GIS is often integrated into public water utilities, such as computerized maintenance, work order, and business assets management [5]. An assessment is essential for freshwater pollution reduction of biological, chemical, and physical water pollution. Tigris River is one of Iraq's largest rivers and a major source of potable water for Al Kut city, Wassit

Province. [7]. Wastewater treatment plants in the city of Kut are incomplete, especially in the southern part of the city. Therefore, a large amount of wastewater is discharged directly into the river or streams that flow into the river. In addition to the problems related to the dumping of household waste in the area on both sides of the river inside the city, it harms the environment and public health [8].

The present study aims to assess the water quality specification in Tigris River inside Al Kut city. Also, displaying and comparing the water quality data and related information and distribution of river contaminate in simply predicted maps might be employed by the makers of decisions using geographical information system GIS mapping through implementing the quantum GIS established on the Inverse Distance Weighted IDW method. IDW interpolation predicted color maps of stations along the river established according to water quality parameters.

Material and Methods

The study area lies between the Latitude of 31˚55'N, 33˚28'N and Longitude 44˚30'E, 46˚35' E as shown in Figure 1. Al-Kut city is the center of Wassit province in eastern Iraq. The eastern section of the province coincides with Iraq and Iran boundary 70 kilometers from the Wassit province center. The city is divided into a left and right area by Tigris River through a flow from north to south direction. The province of Wassit bonds internal limits with Baghdad (172 km), Meissan (182 km), Diyala (238 km), Qadissiya (353 km), Babil (272 km), and Thi Qar (187 km) [9]. The Tigris river crosses the city of Al Kut and is divided into two parts almost identical in area, north and south, on the other hand, different in public activities and intensity. The population of Al Kut city is approximately (515315) according to the 2010 census, with an annual growth rate of 3% [10].

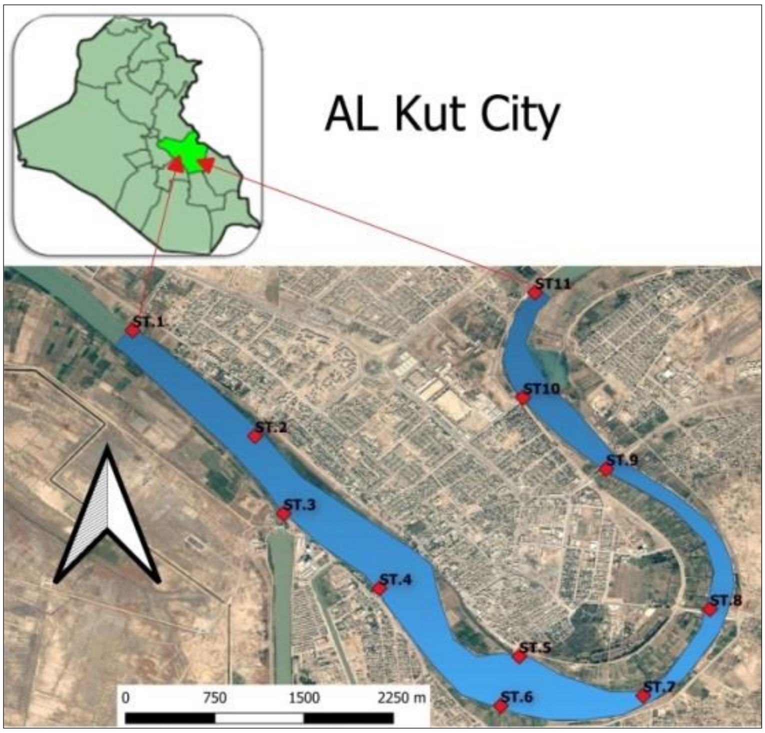

Figure 1. Location of the study area sampling point in Al Kut city.

Fieldwork in the present study was carried out in Al Kut city along Tigris River. A total of 11 stations were selected to collect and measure six water quality parameters for monthly tests during six months in 2020, and each station sample was given ID such as ST.1 to ST.11. Figure 1 shows the location of the sampling point. These locations were chosen for the whole river flow distance in Al Kut city. The locations of the station were collected by using a mobile GPS (Table.1). Physical and chemical water quality parameters include pH (by using pH meter), BOD_5 (by using Winkler methods), TDS (by using EC-meter), SO_4, NO_3, and TH (by using spectrophotometric methods). The samples were examined and evaluated for different water quality parameters [11].

Table 1. Sample sites and their GPS values.

Station	Station Name	X	Y
ST.1	Al Khajia outfall	45.79443	32.5196
ST.2	Beginning of Kurnish	45.80544	32.5107
ST.3	Al Garaf regulator	45.80788	32.5031
ST.4	Al Kut barrage	45.81629	32.4965
ST.5	Al Eza bridge left bank	45.82886	32.4904
ST.6	Al Eza bridge right bank	45.82728	32.4862
ST.7	After icland	45.84007	32.4871
ST.8	Zain Alqus bridge	45.84600	32.4947
ST.9	Al Falahya bridge	45.83686	32.5072
ST.10	Al Kut textile company	45.82913	32.5137
ST.11	Al Dhubat outfall	45.83022	32.5231

The methodology details used in the study involve two approaches; quantum GIS spatial mapping and field data measurements. The descriptions of the flowchart illustration of the methodology approach are given in Figure 2.

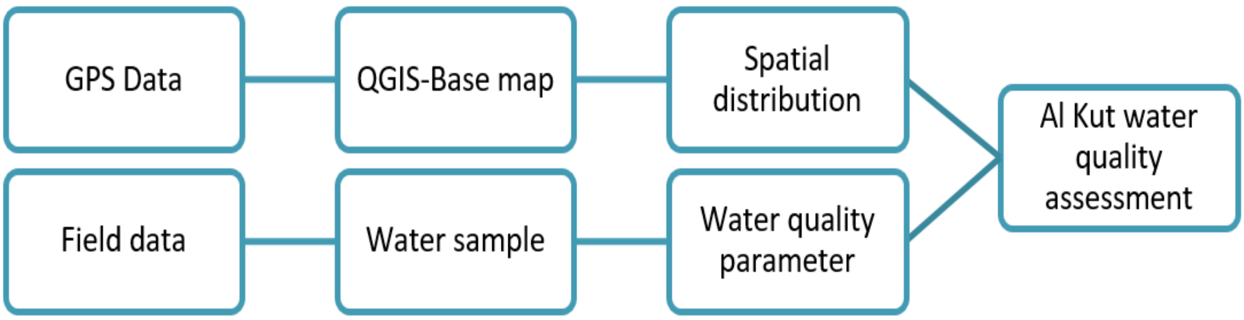

Figure 2. Methodology flowchart illustrates various steps of Al Kut water quality assessment.

Then, the water quality analysis results were used for input data in QGIS 3.8.3 software, which represents the average concentration per station point. The sampling site stations were combined with the water quality measurements to generate predicted spatial maps. The current study applied the IDW technique for a spatial interpolation map of water quality distributions. The IDW interpolation process is recommended to predict the unidentified values at a specific site as an average distance value known to the surrounding areas of unidentified points. In the IDW method, the prediction position's closest points will affect the predicted values more than the farther away points. The interpolation of the IDW method has implemented the following mathematical expression Eq.1 [5]:

$$Y_0 = \frac{\sum_i^n Y_i \frac{1}{X_i^r}}{\sum_i^n \frac{1}{X_i^r}} \tag{1}$$

Where:

Y_0: the predictable value of zero, Yi: the y rate of identified point i, Xi: length among point i and 0, N: identified points used in the prediction process, r: the definite power greater than 1.

Results and Discussion

The results of the physical and chemical parameters (BOD, TDS, SO_4, NO_3, pH, and TH) examined in all the sampler stations, which compared with two standards WHO [12] and Iraqi standard (specification Iraqi regulation standard No.25) [13] are given away in Table 2.

Table 2. Results of physico-chemical concentrations along Tigris River inside Al Kut city.

Symbol	TH (mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	BOD_5(mg/l)	pH	TDS (mg/l)
ST.1	309	320	2.1	20	7.2	500
ST.2	330	335	4	24	7.6	520
ST.3	370	360	8.05	30	7.6	480
ST.4	350	345	4.1	40	7.8	495
ST.5	390	370	6.3	30	8	1200
ST.6	410	386	7	40	7.6	515
ST.7	430	395	4.89	66	7.9	800
ST.8	470	410	5	110	8	870
ST.9	500	397	6.5	121	7.7	1100
ST.10	530	400	12.1	90	8.7	1210
ST.11	541	420	8.7	110	7.8	1250
Average	421	376	6.23	62	7.81	813
SD	80	33	3	39	0.4	327
Min	309	320	2.1	20	7.2	480
Max	541	420	12.1	121	8.7	1250
WHO	200	250	10	5	6.5-8.5	500
Iraq limits	500	200	40	5	7-8.5	500

The Tigris River receives water from an existing pumping station on the Eastern bank of the City of Al-Kut, where high levels of pollutants are present [7]. In the current study, the predicted spatial distribution map for six physical and chemical water quality parameters was measured from a sequence of sites located along the river inside the al Kut city produced in 2020. Eleven site locations were chosen to create prediction maps by implementing the IDW interpolation method for the QGIS computer program. Spatial distribution maps provide indicators for the assessment of water quality and give data on the concentrations of parameters from upstream to downstream in Al Kut City at each station on the Tigris River, through some chemical and physical parameters.

The concentration of hydrogen ions pH is a significant indicator of water quality and the degree of pollution in river and basin areas and is used to measure water acidity or alkalinity. The average pH values varied from the minimum value of 7.2, which was recorded in station ST.1 while the maximum value of 8.7 was recorded in station ST.10 with an average value of 7.81as shown in Figure 3A. The pH value is connected directly to the bicarbonate and carbonate-ion current in the water, in which CO_2 pressure and the ionic strength of water solutions are closely linked. It is known that pH value is a significant factor for assessing the water balance between acid and base. The spatial distribution of pH in water samples collected in the study area is shown in Figure 3B. These values are considered to be within the neutral range attributable to the decomposition of organic matter and to the discharge of organic acids with wastewater into the river. The results were slightly higher than those reported by [7]. In general, the pH concentrations are in the narrow range and slightly alkaline, in the WHO standards and Iraqi standards of the allowable limit of pH (Table.2) in all places, while in station ST.10, they slightly exceeded these limits due to outfall flow from the paper mill and textile company.

The sum of all the solids dissolved in a water sample is known as the Total Dissolved Solids TDS. Therefore, the concentration of TDS is the most important contaminant to study. In the present study, TDS values in Al-Kut city ranged from the lowest mean value of 480 mg/l for ST.1 to the highest mean concentration of 1250 mg/l at ST.10 site, and the average TDS concentration of 813 mg/l. The TDS values exceeded the standard limits of 500 mg/l (Table.2 and Figure 4A)). The highest values were recorded after the Al Kut barrage in the middle and last part of a river inside the city due to the mixing of polluted water resulting from residential and agricultural areas adjacent to the river. Therefore, these water samples are considered brackish (greater than 1000 mg/l). These values can come from suspended matter such as soil and fat and animal waste (hair, fat, meat and tripe) from slaughterhouses. The results were slightly lower than those reported by [7,8]. TDS values are closely related to discharge. On the other hand, the concentration increases when the river's water level decreases, which leads to an increase in mud and turbidity in the river at the outlet. The spatial distribution of the TDS concentration along the river in Al-Kut city is shown in Figure 4B. Where dark places represent the lowest concentration of TDS. According to the WHO classification, the water in this study area is in the high salt category.

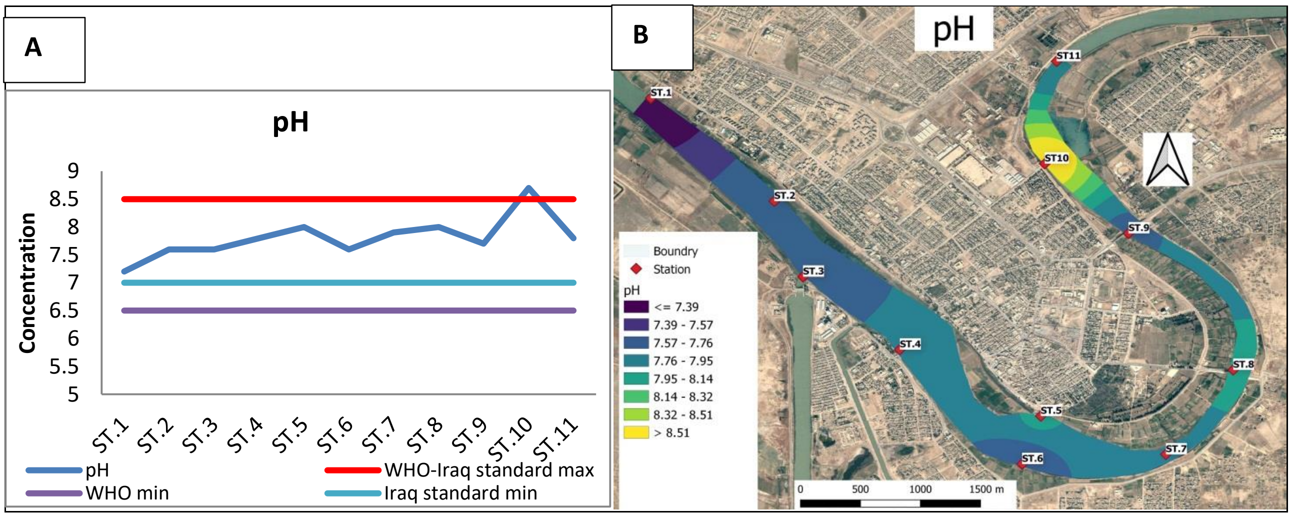

Figure 3. Average pH value in water sample along the Tigris River in Al Kut city A. concentrations comparison with limitation B. spatial distribution map.

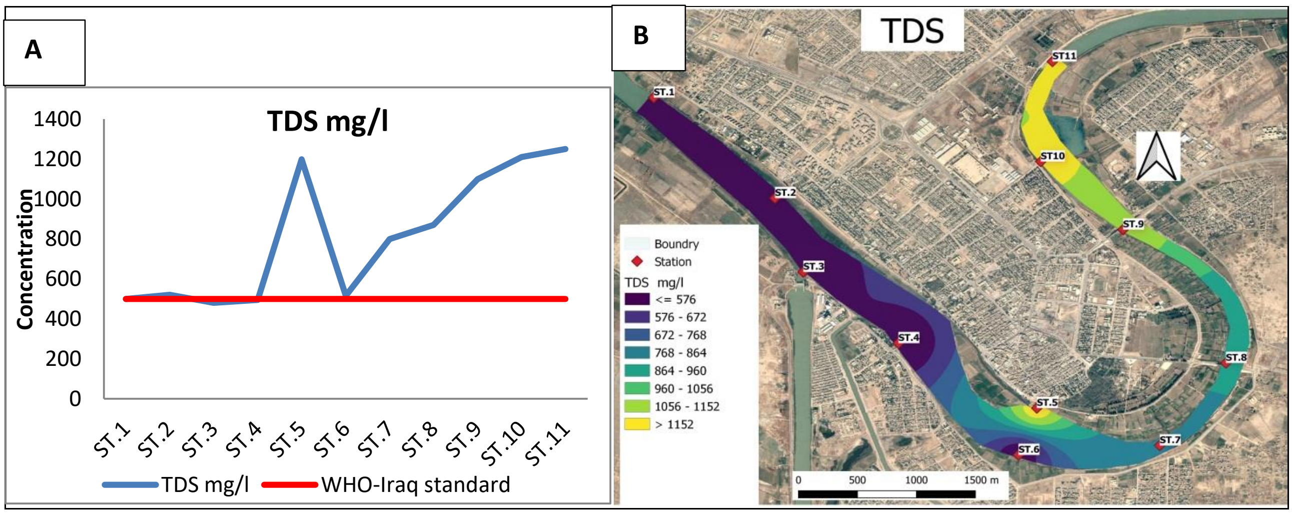

Figure 4. Average TDS value in water sample along the Tigris River in Al Kut city A. concentrations comparison with limitation B. spatial distribution map.

Biological Oxygen Demand BOD shows the extent of pollution in water bodies and is a measure of organic material contamination. BOD is defined as the amount of oxygen that can oxidize organic constituents in the water body with the aid of microbes for experimental conditions defined. The average BOD_5 values in the Tigris River in the city of Al-Kut show an increase in concentration from the Tigris River upstream at ST.1 (minimum value 20 mg/l) towards station ST.11 (highest average value 121 mg/l was calculated at station ST.9), with an average value of 62 mg/l (Fig. 5A). The spatial distribution of these values in the studied area is shown in Fig. 5B. In general, the results show that an increasing in BOD_5 concentration, especially after site location ST.7, may be as a result of the organic substances decomposition that flows straight to the Tigris River with domestic wastewater from slaughterhouses, factories and residential waste directly disposing of the river without treatment. These results were higher than those reported by [5]. The results indicated that the average concentrations of BOD_5 exceeded the WHO's permitted limit and the value of Iraqi standard guidelines for limiting water surface No. 25 across all sites.

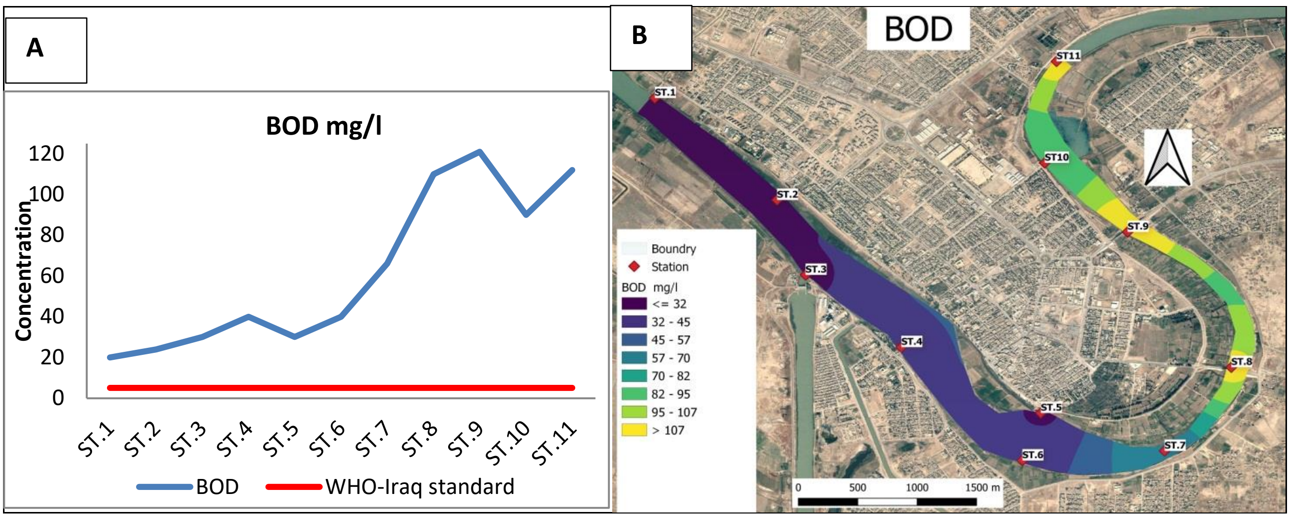

Figure 5. Average BOD value in water sample along the Tigris River in Al Kut city A. concentrations comparison with limitation B. spatial distribution map.

The excessive use of inorganic nitrogen manures is the major source of NO_3 in surface waters and wastewater. Furthermore, the whole oxidation of nitrogen resulting from the decomposition of organic matter in sediments and surface waters is a significant issue in nitrite, nitrate, and ammonia production. The mean NO_3 nitrate concentrations during the 2020 seasons were 6.23 mg/l. The NO_3 value increased from one site to another beginning from the river upstream at the beginning of station ST.1 (the minimum values were 2.1 mg/l) towards station ST.10, which represents a high concentration of 12.1 mg/l found at the end of the city of Al Kut (Figure 6A). The maximum values were above the WHO maximum allowed limit of 10 mg/l, and all NO_3 concentrations are below those permitted by Iraqi standards. Nitrate is rarely exceeded by 10 mg/l in natural waters (lakes and rivers) in the form of nitrogenous compounds that make up most of the feats of plants. Stations ST.10 and ST.11 have peak concentrations of 12.1 and 8.7 mg/l, respectively, due to the Al Anwar slaughterhouse, which significantly affects these levels. Figure 6B shows the spatial distribution of the NO_3 concentration along the river, where the dark positions represent the weakest results and the brightest the highest concentration in the study area. The study's result may be associated with the decomposition of organic matter, use of detergents, and agricultural land. On the other hand, human activities and industrialization were observed at the eleven study sites.

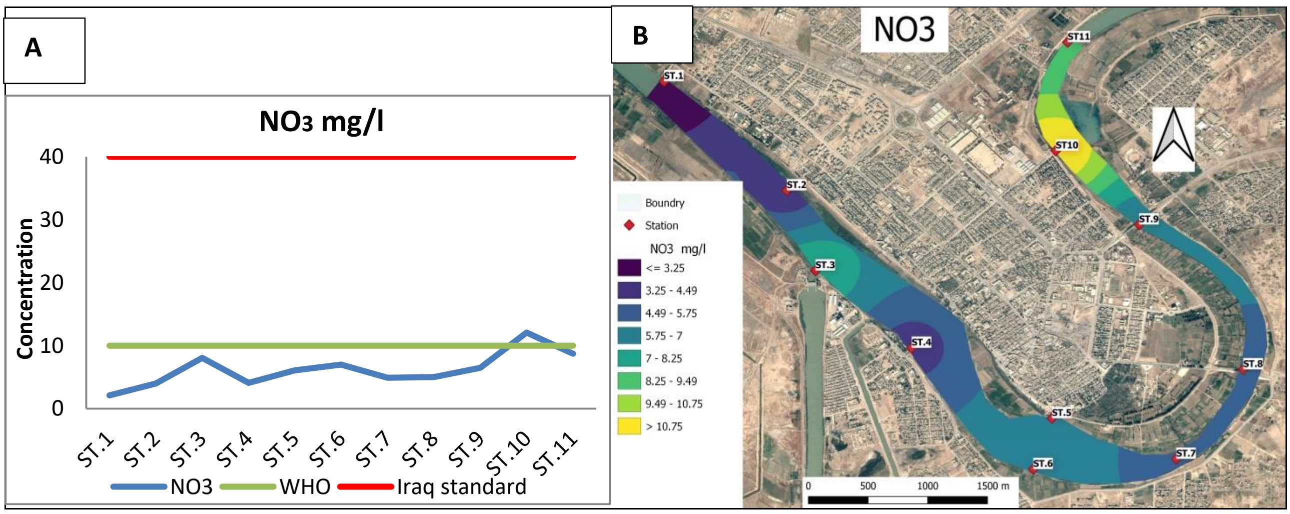

Figure 6. Average NO_3 value in water sample along the Tigris River in Al Kut city A. concentrations comparison with limitation B. spatial distribution map.

The hardness of the water is due to dissolved calcium and, the low extent of magnesium. It is generally expressed as an equivalent amount of calcium carbonate. The hardness of the water reflects the nature of the geological formations it has been in contact with. In the present study, along the Tigris in the city of Al Kut, the concentrations of Total Hardness (TH) in 2020 increased from station ST.1, indicating the lowest values of 309 mg/l along the Tigris to station ST.11 maximum value of 541 mg/l (Fig.7A). The mean values were 421 mg/l; all recorded TH readings were above the WHO limit of 200 mg/l. The extreme increase in TH values compared to the Iraqi standard at sites ST.10 530 mg/l and ST.11 541 mg/l is due to increased dissolved calcium. In addition to its mixing with the paper mill and the textile company's saline water flow, these waters are considered challenging water. The results were slightly higher than those reported by [14, 15]. The spatial distribution of the TH concentration along the river, where the dark distribution represents the low TH results, and the brighter color provides the highest concentration in the study area, may be related to human activities, use of detergents, agricultural drainage, and industrialization that was observed with the eleven study sites as shown in Figure 7B.

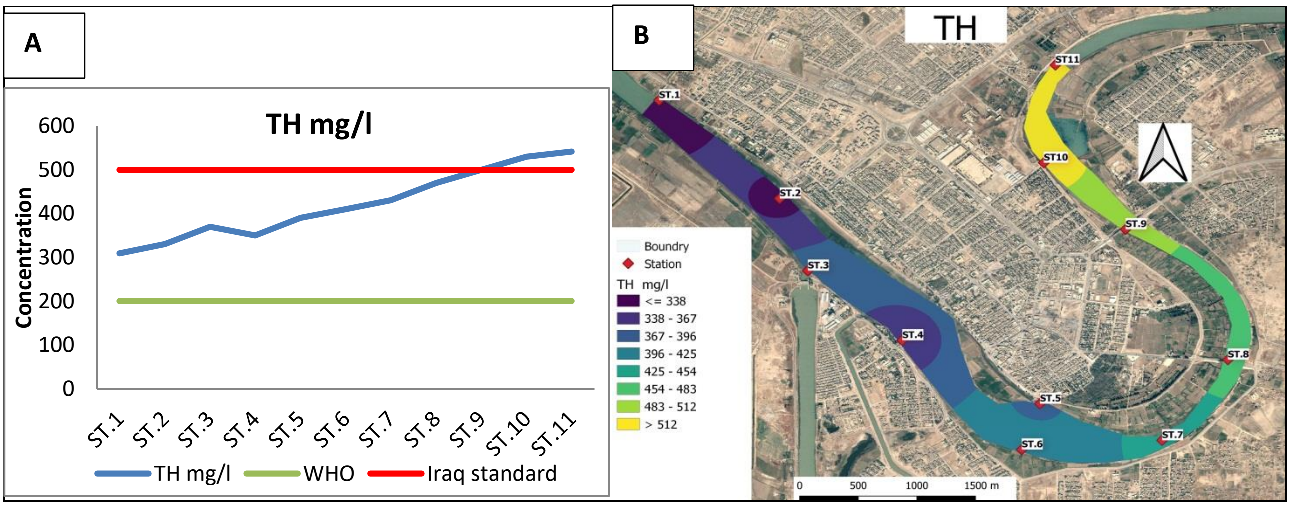

Figure 7. Average TH value in water sample along the Tigris River in Al Kut city A. concentrations comparison with limitation B. spatial distribution map.

Sulphates SO_4 can be defined as soluble minerals in the soil and can be transferred to surface waters by discharge. SO_4 sulfate is generally distributed in the environment and can be found on water surfaces. Rocks close to the water body and the biochemical effect of anaerobic microbes represent the principal sulfate source. The measured values of SO_4 in the study area varied from the minimum average value of 320 mg/l at station ST.1 to the highest average concentration of 420 mg/l at station ST.11, while the mean values were 376 mg/l. All SO_4 concentrations on all sites of the river in the study area exceed the limits allowed by the WHO and Iraq standards of 250 and 200 mg/l, respectively (Figure 8A). The spatial distribution of SO_4 in water in the study area of al Kut city is shown in Figure 8B, where the SO_4 soluble in the residential district wastewater was released into nearby canals which were connected to septic tanks then transferred from the pumping station to the Tigris River without treatment this leads to a higher value at all stations.

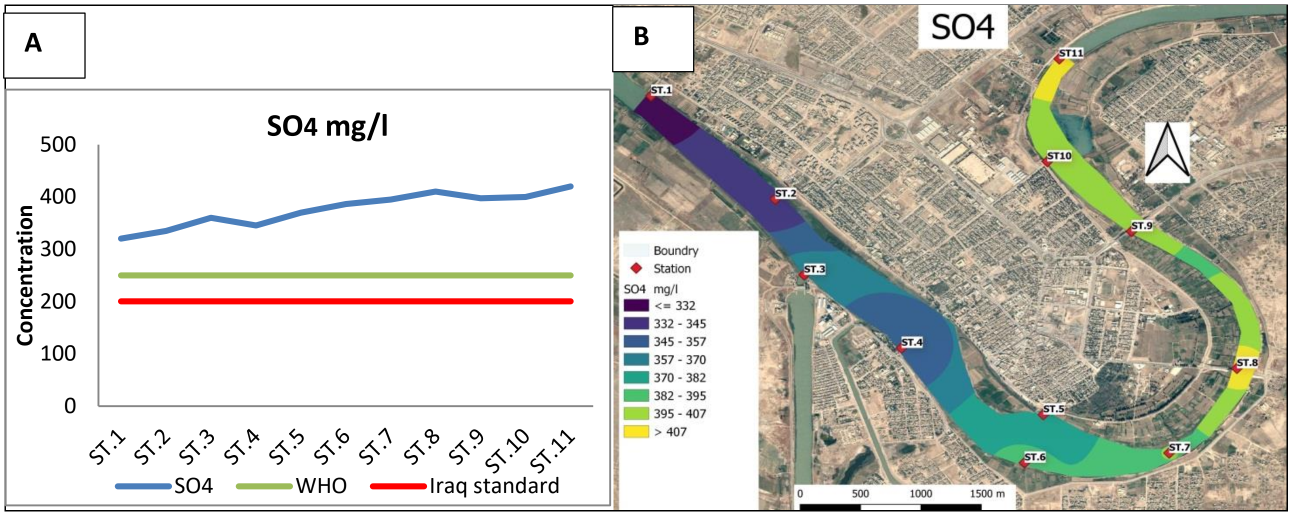

Figure 8. Average SO_4 value in water sample along the Tigris River in Al Kut city A. concentrations comparison with limitation B. spatial distribution map.

Conclusions

The Tigris River is the main water source in the city of Al Kut. Samples from eleven positions selected along the Tigris River in the study area were measured in 2020 to examine six Physico-chemical concentration parameters in the selected sites. Water quality parameters are pH, TDS, TH, SO_4, NO_3, and BOD_5. The results demonstrated that the study period's concentration values had been increased from ST.1 to ST.11 at the end of Al Kut city. In addition to values in SO_4, TDS, TH, and BOD_5 were above the permissible standard WHO-Iraq. Results indicated that for selected stations along the Tigris River's water path in Al Kut city from upstream to downstream, the water quality parameter was gradually increased. The current study employed the IDW technique to predict spatial distribution maps' visual water quality for the nominated parameters within the study field in QGIS software for a spatial analysis tool. This will help identify sample sites or areas along the river that are highly impaired and help implement standards and pollution control activities.

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