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The Effect of the Succession of Seasons on Some Parameters of the Tigris River in Mosul City, Iraq

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ABSTRACT

Nineveh Governorate is the largest city in northern Iraq, which is completely and mainly dependent on the Tigris River, as it is its lifeline. The current study included an assessment of the state of pollution resulting from chemical pollutants released into the Tigris River in the city of Mosul. Samples were collected from five sites, the first was the Rashidiya area and the last was the Al-Busif area during September, November, January and March. Samples taken from the aforementioned sites were used to measure acidity, temperature, oils and grease in addition to sulfates, nitrates, total hardness, calcium and magnesium hardness, turbidity, dissolved solids, and electrical conductivity. The acidity values ranged between 6.2 and 6.99l the temperatures fluctuated between 13.1 & 21.5ºC; the conductivity was -223-621µs/ cm, and the dissolved solids were 227-673PPm, while the turbidity ranged between 10.6 and 954NTU. The values of BOD and COD ranged between (1-31) and (10-93) mg/L, respectively, while the values of oils and fats ranged between (0.2-9) mg/L, and sulfates ranged between (0.076-111.5) mg/L. For nitrates, values were recorded with ranges between 0.104 & 36.9mg/ L. The total hardness and the hardness of calcium and magnesium were between (304-940), (120-520), and (22.4-166) mg/L, respectively. The research aimed to evaluate the water properties of the Tigris River in the city of Mosul during seasonal changes and compare it with the parameters set by official Iraqi and international environmental authorities.Through the present study, it can be concluded that most of the tests indicated that the water of the Tigris River are within the Iraqi and international limits allowed for drinking water and daily uses, except for the vital requirement of oxygen and hardness of all kinds.

INTRODUCTION

Since water is a component of the environmental system and is thought to be the first essential requirement for people, it is considered as the lifeblood of all living things. Regarding the research area, the Tigris River serves as the main and crucial source for supplying the region's economic and social demands. Since it flows through the study area, natural and man-made variables have an influence on the region's features. The efficiency and appropriateness of river water for different uses are influenced by its physical and

chemical characteristics, The study's findings demonstrated, via samples collected from various locations, that the Tigris River's water was contaminated due to sewage discharges, residential and commercial buildings located close to the river, and salt-containing groundwater in the area. The outcomes of the sample analyses were contrasted with the reference values. The appropriateness of the Tigris River for human existence was ultimately assessed using a variety of classifications, including the TODD classification, for each application and in accordance with the seasons of the year **(Kazem, 2021)**.
The study area is located along the Tigris River in Iraq, inside the administrative borders of the Nineveh Governorate. As indicated in Table (1), a number of locations were selected for the investigation.

Table 1. Sites selected for investigation

Location No.	Location Name	Latitude	Longitude
FIRST SITE	Alrashidia	36°23'57''N	43°05'10''E
SECOND SITE	The Fifth Bridge	36°21'19''N	43°07'46''E
THIRD SITE	The Old Bridge	36°20'44''N	43°08'15''E
FOURTH SITE	The Fourth Bridge	36°19'55''N	43°09'05''E
FIFTH SITE	Albusif	36°15'54''N	43°09'22''E

The purpose of the study was to shed light on the factors that have caused changes in the river's water quality and discharge amount.

Additionally, by analyzing river water samples and comparing the results to international and Iraqi standards and specifications, the study focused on ascertaining the physical and chemical properties of the water as well as the degree of its efficiency and suitability for various applications. The potential for water investment across all sectors of the economy. Water has been categorized according to several criteria to show its usefulness for various purposes.

The Tigris River serves as Mosul's only surface water resource, and its water is utilized for a variety of commercial, industrial, and residential purposes (**Al-Sarraj *et al.*, 2014)**. According to **Al-yazichi and Mahmood (2018)**, the city of Mosul releases approximately 300 m³ of water into the Tigris River per second.

It is estimated that 500,000 m³ of liquid trash are dumped into the Tigris River every day in the city of Mosul **(Mustafa & Jankeer, 2007)**, which may affect the physical, chemical, and biological characteristics of the river. It might also raise the concentration of chemical elements and the amount of suspended materials, which would alter the amount of dissolved oxygen since it depends on the kind and volume of pollutants released **(Al-yazichi & Mahmood, 2018)**.

MATERIALS AND METHODS

Samples collection

Samples were frequently collected from the research region between September 2023 and March 2024 (Table 1). The samples were collected in sterile, thoroughly cleaned glass bottles holding 1000ml of distilled water in order to perform laboratory tests and analysess. Samples were kept in special bottles with a capacity of 432ml; they were utilized to collect them without causing air bubbles in order to determine the biological oxygen demand (BOD). Furthermore, until the samples were tested, the bottles were stored in boxes away from the direct sunlight **(Al-Abawi & Hassan, 1990, 1998; Alpha, 2017; Al-Hamdani, 2022)**.

Physical tests:

Temperature (C°):

A mercury thermometer was used to measure the temperature of water by immersing the part of the thermometer in water for several minutes and then the reading was recorded.

Electrical conductivity (EC):

The EC was measured in the field using a pH and EC meter, type HANNA INSTRUMENTS, model HI-98129, Romanian origin, and the reading was calculated from the device directly after setting the temperature at 25°C and in the unit of µs/cm.

Total dissolved solid (T.D.S):

Total dissolved solids were measured in the field using a Chinese TDS meter and were measured in mg/l.

Turbidity:

Turbidity was measured in the laboratory-wise after well shaking the sample using a turbidity meter, type WTW, model TURB 750 IR, of a German origin, and was measured in units (NTU), as the device is calibrated with special standard solutions and different turbidity values.

Chemical tests:

pH:

The pH was measured in the field using a pH and EC meter, type HANNA INSTRUMENTS, model HI-98129, Romanian origin, and the reading was calculated from the device directly after calibrating the device with buffer solutions.

Biological oxygen demand (BOD) (mg/l):

The biological oxygen demand was measured in the laboratory using an OxiTop device, type WTW, model IS 12, of German origin. For this test, special glass bottles with a magnetic stirrer were used, then an appropriate volume of the sample was placed, depending on the amount of expected sample contamination. Three grains of (KOH)) were added to the plastic piece, then the bottles were tightly closed with the plastic cap, and the device was returned to zero and was placed in the incubator at a temperature of 20 ºC for five days. The BOD5 value was obtained by the succeeding law:

$BOD_{5\ mg\backslash t}$ = Reading Day Five * Factor

Chemical oxygen demand (COD) (mg/l):

The samples were examined using a commercial device of the COD-reactor type, where ready-made standard solutions were used. According to the manufacturer's instructions, 2ml of water was added to the sample in an oblique manner (with an angle of approximately 35 degrees). We shook the mixture several minutes to homogenize the sample. After that, the solutions were placed in the COD incubator for two hours at a temperature of 120°C, and after cooling, the samples were placed in the COD-reader device to read the results, checking the Blank to set the device at zero after each measurement.

Total hardness (T.H):

The total hardness was measured by a titration with EDTA, where a certain volume of the sample and 1ml of buffer were added. When the pH value reached 10, a reagent (EBT) Eriochrome Black T was added, followed by a slow titration with a solution of EDTA while shaking until the color changed from red to blue. The total hardness value was calculated in terms of CaCO by the following equation:

$T.\ H_{(mg\backslash l)}$ as CaCO= V* eq.wt * N * 1000\ Sample volume (ml)

V: Volume of filtered Na_2-EDTA flushed.

eq.wt: Equivalent weight of calcium carbonate.

N: Standardize solution Na_2EDTA.

Calcium hardness (Ca H.):

Calcium hardness was measured in the laboratory using the method EDTA by adding a certain volume of the sample and 2ml of NaOH solution, followed by a little dry indicator. The sample was filtered with EDTA and shaked until the color changed from violet to pink, and subsequently blue. The value of calcium hardness was calculated in terms of CaCO through the following equation:

$Ca\ H._{(mg\backslash l)}$ as CaCO3 = V * eq.wt * N * 1000 \ Sample volume (ml)

V: Volume of filtered Na_2EDTA flushed.

eq.wt: Equivalent weight of calcium.

N: Standardize solution Na_2EDTA

Magnesium hardness (Mg H.

Magnesium hardness was calculated through estimating the difference between total hardness and calcium hardness according to the following equation:

$Mg\ H._{\ mg\backslash l}$ = (T.H - Ca H.)

Oil/Grease (mg/l):

The oils were estimated via the extraction method:

One liter of the sample was taken and placed in a separating funnel, then 5ml of Dilute hydrochloric acid was added to it. The sample bottle was initially washed with 15ml of ether, followed by washing with 25ml of the same solvent (ether) as well, added to the sample in a separating funnel. The mixture was shaken well for several minutes, then left to settle for ten minutes until the aqueous layer was isolated from the organic layer. The aqueous layer was emptied into a measuring bottle, while the organic layer was placed on filter paper to be filtered. It contained 0.5 grams of dry sodium sulfate after placing it on a funnel over a distillation flask. We repeated the process of washing the aqueous layer with the solvent twice. The washed aqueous layer and the filtered organic layer were combined in a distillation flask after washing the filter paper with 10ml of solvent.

The distillation flask was heated using a water bath and the organic solvent was distilled, then the distillation flask was weighed (previously weighed before measuring) with the remaining residue after cooling it to find the weight **(Al-Abawi & Hassan, 1990)**.

NO_3 (mg\l):

Using the ultra violet screening method, the nitrate ion was estimated using a UV-spectrophotometer. 25ml of the water sample was taken and 1ml of hydrochloric acid (1N) was added to it. The absorbance was measured at two wavelengths, 220-270 nm, and the difference between the two readings was recorded via comparing the result with a standard curve to determine the concentration of nitrate in the sample, taking into account checking the Blank for setting the device at zero (**Al-Sarraj *et al.*, 2014)**.

SO_4 (mg\l):

The sulfate ion concentration was estimated using a UV spectrophotometer using the spectrophotometer device by precipitating the sulfate in the form of barium sulfate by withdrawing 50ml from the sample and then adding 2.5 of the conditioned solution and a small amount of barium chloride while continuously stirring for several minutes. Then, the sample was placed in the device for measuring, and by measuring the amount of light scattering at a wavelength of 420 nanometers, we compared the results of the wavelength to a standard curve to obtain the sulfate concentration in the sample, taking into account checking the Blank to set the device at zero **(Al-Sarraj, 2020)**.

RESULTS AND DISCUSSION

Temperature (C°):

The study showed the lowest rate of temperature in the fourth bridge reached 15.7 °C, while the highest rate was observed in Albusif reaching 21.5°C (Fig. 1). This is an expected and natural result due to the geographical location, daily variation in air temperature, and fluctuation in climate temperature in Iraq.

The study results for temperatures agree with those of **Al-Hamdani and Fadl (2015) Al-Sarraj (2020)**.

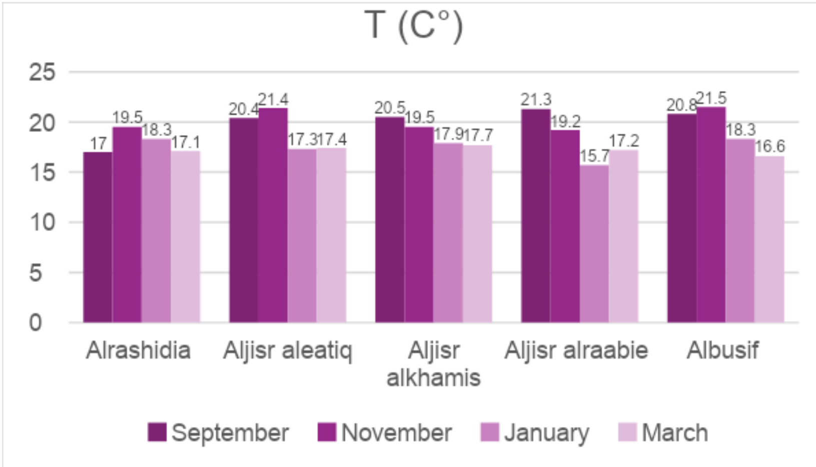

Fig. 1. Temperature values for sites during the study period

Electrical conductivity (EC):

Electrical conductivity rates showed an increase in Albusif in January, when the value was 621 µs/ cm, and the lowest rate was recorded in Al Rashidiya with 223µs/ cm (Fig. 2). This is related to the nature of the excreta, which contains various types of salts. This is consistent with the fact that as temperatures increase, conductivity increases by 2%. In addition, rainwater and torrential rains wash away quantities of salts into the Tigris River, and since the river passes through agricultural lands along its course, outfalls also transfer wastewater directly to the river. The present findings coincide with those of **Al-Tamir *et al.* (2007)**, **Matti and Nazem (2007)** and **Al-lmam *et al.* (2013)**

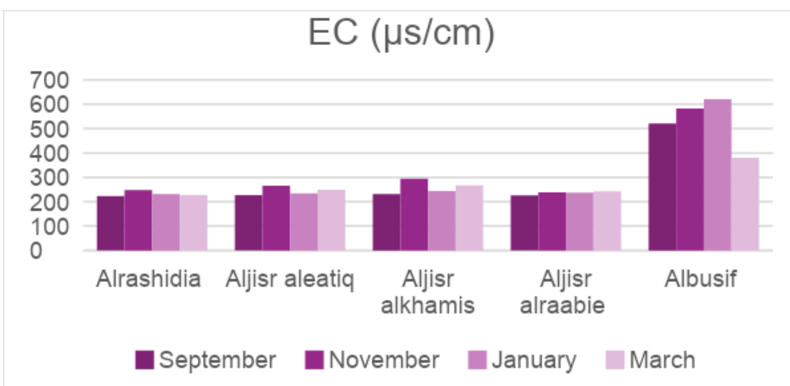

Fig. 2. EC values for sites during the study period

Total dissolved solid (T.D.S):

Total dissolved solids rates were high in Albusif, reaching 673 ppm, and their lowest rate was registered in Alrashidia, reaching 227 (mg\l) (Fig. 3). The total dissolved solids value depends on the electrical conductivity value and water temperature, which is directly proportional to the electrical conductivity and temperature. As stated by **Mahmoud and Dhannoun (2014)**, the relationship between conductivity and total dissolved solids is a direct relationship because they depend on the concentration of both negative and positive ions in the water sample. Thus, the greater the conductivity, the greater the suspended solids, and these outcomes concur with those determined in the studies of **Al-Hamdani (2022)**.

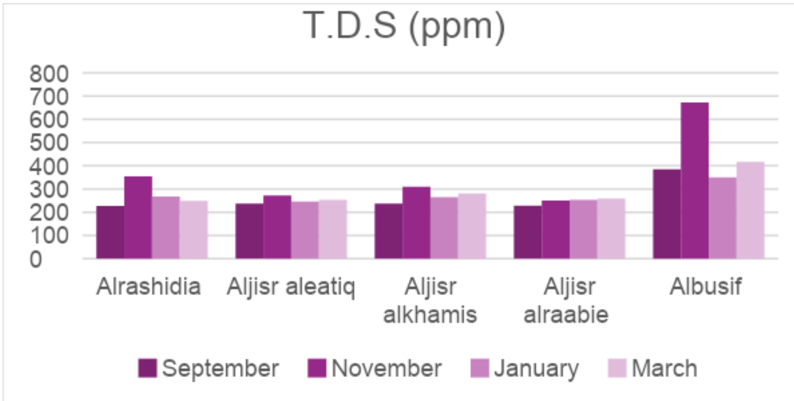

Fig. 3. T.D.S values for sites during the study period

Turbidity:

Turbidity values showed a clear difference among the study sites. Its maximum rate was 954 NTU in the Old Bridge, while its lowest rate was recorded in Alrashidia, with a value of 10.6 (Fig. 4) when compared with the parameters inTable (2), which shows the measure of water clarity in terms of turbidity **(Water watch, 1997)**. The high turbidity is explained by the heavy rain (early rainfall) that occurred during the sampling period, which tells us that the turbidity is greatly affected by weather conditions and the increase in the river level, which led to the rapid flow of water and the lack of sedimentation of suspended particles, in addition to the presence of many sand and gravel quarries on the banks.

It causes an increase in turbidity in the water. In this context, our study match with the studies of **Al-Kubaisi and Ibrahim (2004)** and **Alobaidy and Al-Nama (2013)**.

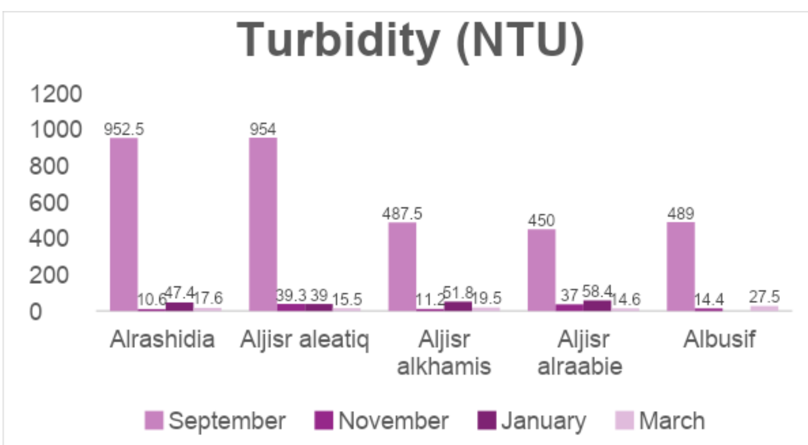

Fig. 4. Turbidity values (NTU) for sites under study during the investigation period

The pH values:

The results of the study showed that the pH levels during the study period were between 6.6 and 6.99 (Fig. 5), which are within the normal values of water. This is due to rainfall and soil erosion, which helped wash away and dissolve some substances such as sulphate, nitrates, chlorides, and other salts with an acidic effect, which contributed to lowering the pH, especially since the water temperature in some months during the study did not rise enough to help the growth and spread of microorganisms and phytoplankton. In turn, it works to raise the acid function through its activity and spread. These findings coincide with the results reported in the studies of **Al-Bajji (2014)** and **Al-yazichi and Mahmoud (2018)**.

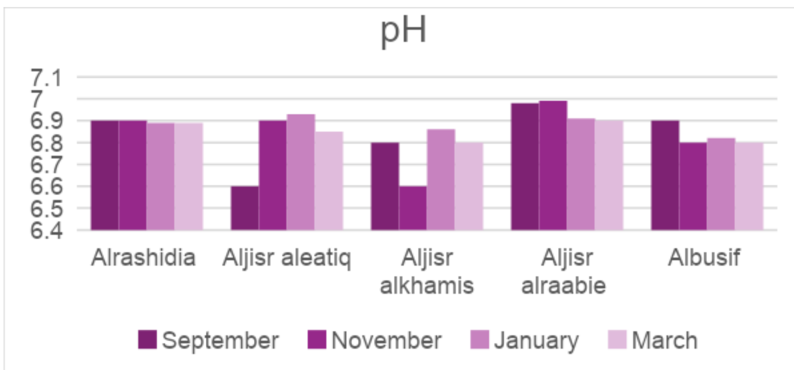

Fig. 5. pH values of the sites during the study period

Biological oxygen demand (BOD_5):

The results showed a high increase in BOD_5 rates in the Fifth Bridge in March, reaching 31 mg/ l (Fig. 6) due to the huge amount of organic wastes leading to an increase in the activity of microorganisms decomposing these wastes **(Al-Saffawi & AL-Taay, 2013)**. Whereas, the lowest rate was evaluated in the Old Bridge, which amounted to 1mg/ l (Fig. 6). Upon comparing the results with the Iraqi limits allowed for draining, 40mg/ l is the highest value for BOD5 **(Al-Abawi & Hassan, 1990)**. This is ascribed to the abundance of excreta and organic waste reaching the river due to rain. The high concentration also reflects the high untreated organic load, as study indicated that 15% of the total wastewater (sanitary and industrial) is unjustly thrown directly into the sewers, without subjecting it to any treatment process or passing it through septic tanks, and because the sewage system in the city of Mosul is of the combined type, which led to an increase in the values of the biological requirement for oxygen, in addition to that, at times the temperatures were suitable for the activity of microorganisms that consume dissolved oxygen as a result, and thus the organic load increases, especially with the availability of appropriate conditions. This result agrees with that of **Al-Tamir (2014)**.

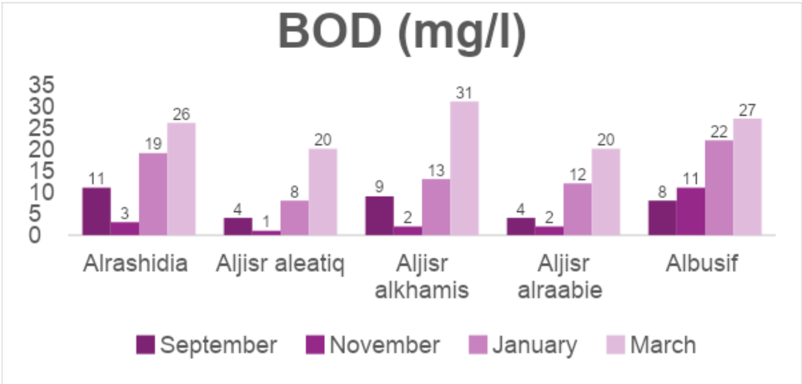

Fig. 6. BOD5 rates for sites during the study period

Chemical oxygen demand (COD) (mg/l):

The study showed the lowest rate of COD in the Old Bridge in January, reaching 10mg/ l, while the highest rate was observed also in the Old Bridge but it was in March reaching 93mg/ l (Fig. 7). The reason for the increase in this is the large use of various chemicals and detergents at home, the disposal of waste from factories and plumbing and manufacturing workshops without prior treatment, and the addition of chemical fertilizers added in haphazardly in many cases, which reach the river in impressive quantities because most of them are stable, especially if they contain heavy elements. What makes matters worse is that the river's water is already polluted before it enters Mosul, and it gets worse as it passes through it **(Al-Tamir *et al*., 2007; Mustafa & Jankeer, 2007).**

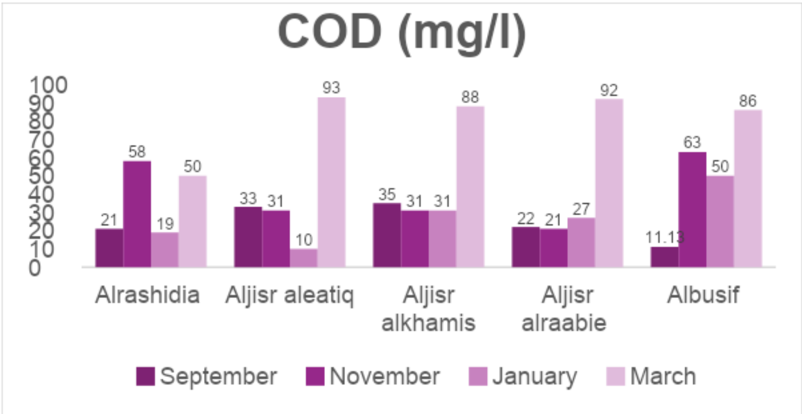

Fig. 7. COD rates for sites during the study period

Total hardness (T.H)

The water hardness showed a clear difference in its rates, as its lowest rate was in Alrashidia, with a value of 304 mg/ l, and its highest value was in Albusif, reaching a value of 940 mg/ l (Fig. 8). In fact, the increase in the values was attributed to the nature of the sediments and discharged wastewater, especially that the domestic water contains table salt, impure salts, and in autumn it is rich in calcium and magnesium salts. This is related to the human waste (frequent use of detergents), agricultural (use of phosphate fertilizers), and industrial wastes that are washed into the river, as well as the rainwater and floods that lead to the dissolution of gypsum and limestone rocks, especially since the waters of the Albosif area have been classified as bad for more than a quarter of a century. The current study results agree with those of **Mustafa and Gankir (2007)** and **Al-Sarraj (2019)**.

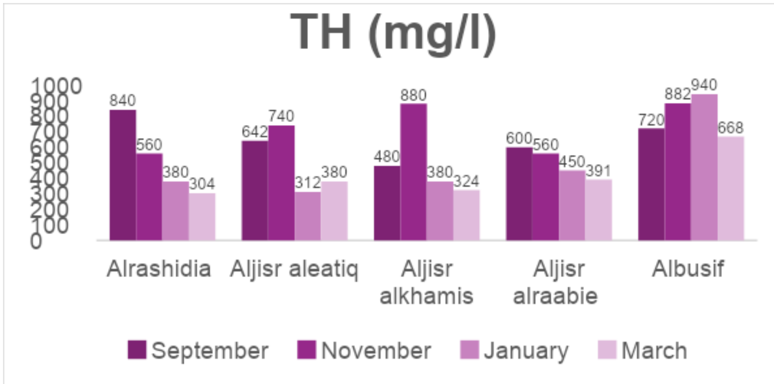

Fig. 8. T.H values for the sites during the study period

Calcium hardness (Ca H.)

The study showed the lowest rate of observed calcium hardness was in the fifth Bridge and the Fourth Bridge, reaching 120mg/ l, while the highest rate was observed in Albusif, reaching 520mg/ l (Fig. 9). The reason for its increase is traced back to the effect of rain falling on the limestone rocks that characterize Iraqi soil, as rain water washes away the rocks and dissolves the soil, causing an increase in the amount of calcium ions in the water. Our study match that of **Mandil (2012)**.

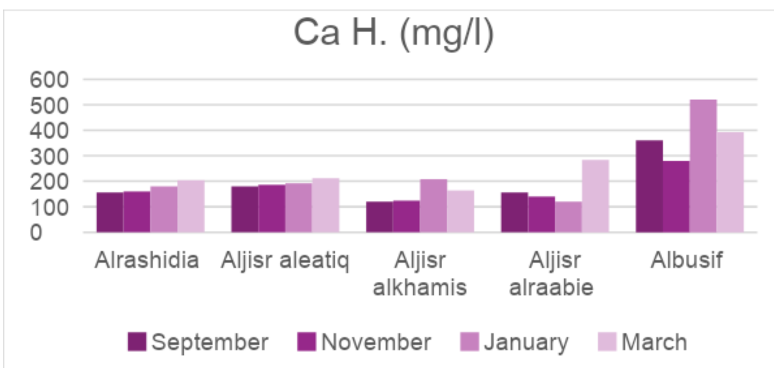

Fig. 9. Ca H. values for study sites during the study period

Magnesium hardness (Mg H.)

The results showed a clear difference in the values of magnesium hardness, as its lowest rate in Al Rashidiya reached 22.4mg/ l, and its highest rate in the Fifth Bridge reached a value of 166mg/ l (Fig. 10).

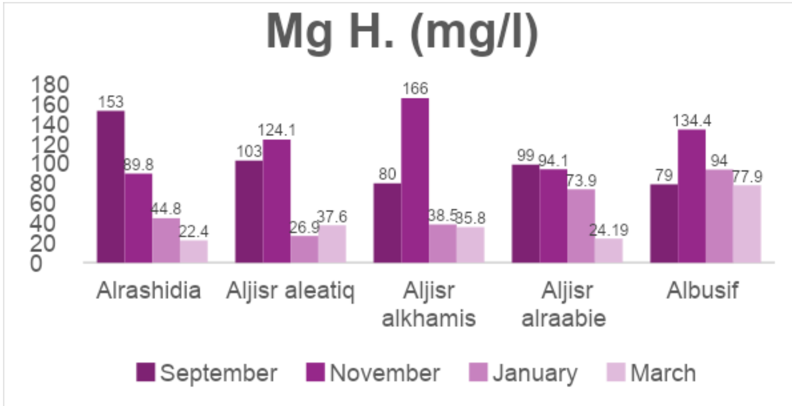

Fig. 10. Mg H. values for sites during the study period

Oil and greases(mg/l)

The results showed a clear difference in the values of fats, as its lowest rate in the Old Bridge reached 0.2mg/ l, and its highest rate in Albusif reached a value of 9mg/ l (Fig. 11). The reason for the appearance of some oil stains in the Tigris River is sometimes due to some of it leaking from the desalination plants located on both banks of the river, or through wastewater that contains sewage and industrial wastewater, especially water coming from the right and left industries, washing and lubrication places, maintenance workshops, plumbing, and laboratories, and oil refineries **(Duaij, 2016; Al-Sayegh, 2021)**.

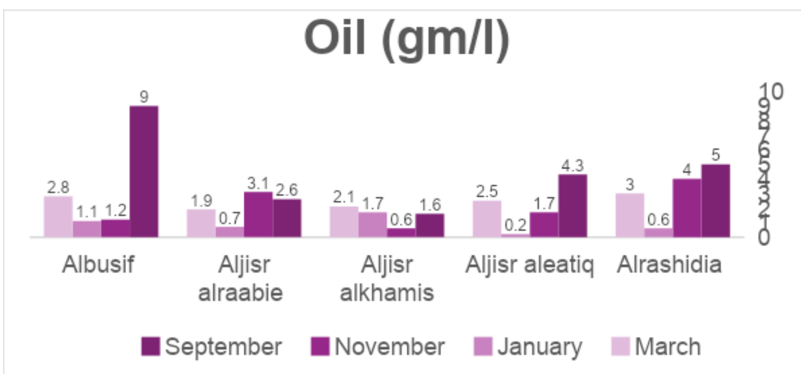

Fig. 11. Oil values for sites during the study period

NO_3 (mg\l)

The study showed the lowest rate of NO_3 in Albusif in March which reached 0.104 ppm, while the highest rate was observed in the Fifth Bridge, but in September it reached 36.9ppm (Fig. 12). This is due to the heavy rainfall that led to the washing of agricultural lands located on both banks of the river, to which organic and chemical fertilizers and the waste of livestock that are raised close to the river were added, as these wastes were discharged directly into the river. The present results coincide with those of **Al-Safawi and Al-Taay (2013)** and **Al-Yozbaki and lbrahim (2024)**.

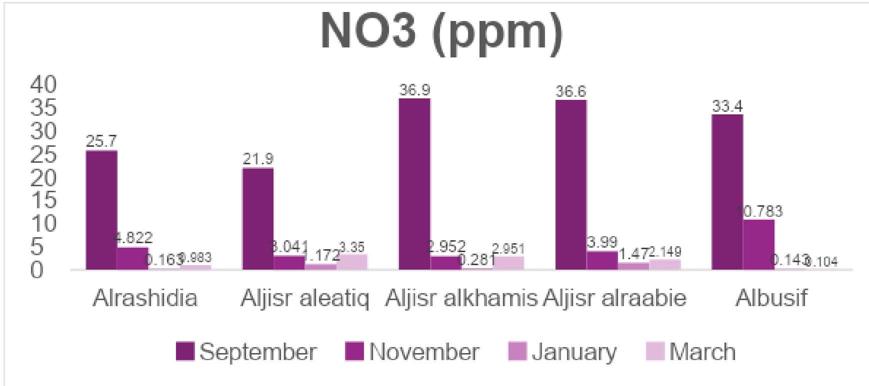

Fig. 12. Nitrate rates for sites during the study period

SO_4 (mg\l)

The study showed the lowest rate of SO_4 was in the Fifth Bridge in March, with a value of 0.076ppm, while the highest rate was observed in Albusif during November, reaching 116.923ppm (Fig. 13). The high concentration of sulfates may be the result of the nature of the Tigris River Basin, which contains gypsum sedimentary rocks, which are the main source of sulfates dissolved in water, or the result of sulfur oxidation and its leakage from the Mishraq sulfur factory, as well as the frequent use of fertilizers containing sulfates, as previous studies have shown that Iraqi fertilizers contain high levels of sulfates, nitrates, and heavy metals. This outcome agrees with that of **Al-Sarraj (2020)**.

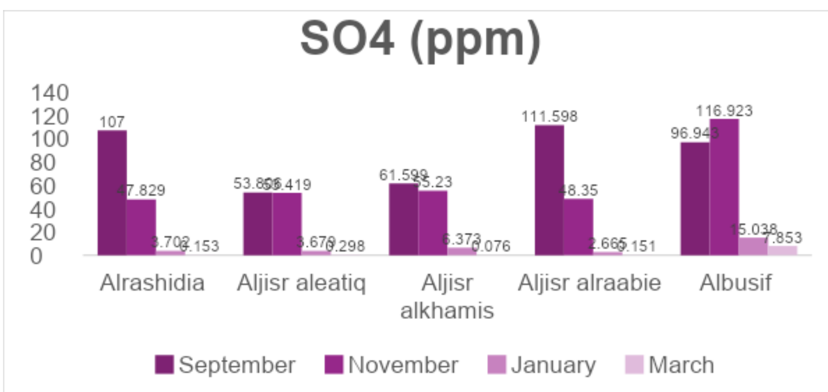

Fig. 13. Sulfate rates for sites during the study period

CONCLUSION

The study recorded that some characteristics exceeded the Iraqi standard limits and World Health Organization water parameters, such as turbidity, vital oxygen requirement, total hardness, and calcium and magnesium hardness. Pollutant concentrations increase as the river moves south. Notably, the river has been greatly affected by estuaries that transport sewage and industrial water directly into the river. Thus, the city needs advanced treatment plants because the pollutants that reach the river exceed the capacity of existing treatment plants, given that they have become traditional type plants over time. What has increased the pollution problem of the river is the type of sewage (combined type) that transports rainwater and floods with wastewater, which leads to a phenomenon of the polluted water reaching the river faster during the rainy seasons.

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