Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(2): 1067 – 1082 (2024)
www.ejabf.journals.ekb.eg

Study of the Physicochemical Characteristics of some Valleys and Estuaries in the City of Mosul/Iraq

Ramadhan A. M. Al-Hadedi[1]*, Shaymaa Khaleel Abdullah [1], Mahmood Ismail Mohammed [2]

[1]College of Environmental Sciences, University of Mosul, Mosul, Iraq
[2]College of Science, University of Mosul, Mosul, Iraq

*Corresponding Author: ramadhan.ev121@student.uomosul.edu.iq

ARTICLE INFO

Article History:
Received: March 13, 2024
Accepted: April 9, 2024
Online: April 30, 2024

Keywords:
Mosul,
Estuaries,
Tigris River,
Aquatic pollution,
Physicochemical characteristics

ABSTRACT

Several physicochemical characteristics of the water of some of the wastewaters draining into the Tigris River within the city of Mosul were studied from September to November 2023. Physicochemical characteristics were measured, viz. turbidity, pH, electrical conductivity, dissolved and suspended solids, dissolved oxygen, biological oxygen demand, total hardness, and hardness calcium and magnesium. An increase was detected in most of the physicochemical characteristics at some sites under investigation compared to the Iraqi values. While, the concentrations of the biological oxygen demand and suspended solids exceeded the Iraqi values. On the other hand, the acidity values were within the normal range, with respect to all the sites. In additon, a decrease was observed in the concentration of dissolved oxygen in the water. Furthermore, the values of turbidity and hardness showed an obvious increase at some sites and throughout some months of the study.

INTRODUCTION

Aquatic ecosystems face several challenges due to the industrial, agricultural, and social developments taking place in the world, as these systems are exposed to pollution resulting from the discharge of municipal, industrial, and agricultural wastes **(Al-Saffawi & Al-Maathi, 2017)**. In past eras, a restricted impact was recorded on the rivers due to human activities, as this is consistent with the low population density in addition to the simplicity of the activities that were practiced by humans **(Al-Sarraj, 2013)**. However, at the present time, as a result of population growth, industrial and agricultural expansion, adding to the lack of planning in building cities, water sources suffer from great pollution **(Kannah & Shihab, 2022).** Therefore, rivers and streams have become the main repository for large quantities of different types of waste **(Shihab, 2021)**. The issue of providing potable water is a global issue, as approximately 844 million people in the world do not have the opportunity to obtain potable water **(Al-Mtewti, 2018)**. Given that statistics elucidated that the percentage of water consumption during the period (1990-1995) has increased six-times, which is equivalent to more than double the rate of population increase, one third of the world's population will face serious water crises in 2025, because of the increasing need of water associated with the increase in the world's population **(Al-Saffawi & Al-Maathi, 2017)**.

Water quality is considered one of the very important issues in the world, in general, and in Iraq, in particular, due to the limited water resources in Iraq and its geographical location within the dried and semi-dried region **(Saghir, 2017)**, as dry and semi-dried areas constitute 90% of the area of Iraq **(Shabib, 2020)**. In a speech by the spokesman for the Iraqi ministry of water resources, the water reserve has now reached extremely critical stages, and that the water revenues that come to Iraq today are 30% of its actual entitlement **(Al-Assadi, 2023)**, and here it is mandatory to note that the reason behind this is the policies of the countries in the neighborhood. Water scarcity has caused a disaster regarding the biodiversity in rivers and marshes **(Makki, 2023)**.

The Tigris River is the only surface water resource in the city of Mosul; its water is used for various human, industrial, and service uses **(Al-Sarraj *et al.*, 2014)**. The discharges of the Tigris River water in the city of Mosul is estimated at about (300) m^3/second **(Al-yazichi & Mahmood, 2018)**. While, the amount of liquid waste thrown into the Tigris River within the city of Mosul is estimated at approximately (500,000) m^3/day **(Mustafa & Jankeer, 2007)**, which may lead to a change in the river's physical, chemical, and biological properties, causing an increase in the amount of suspended materials and the concentration of chemical elements, adding to experiencing changes in the amount of dissolved oxygen since the latter depends on the type and quantity of pollutants released **(Al-yazichi & Mahmood, 2018)**.

In fact, the danger in the Tigris River in the city of Mosul is in the large quantities of sewage reaching the river **(Al-Rawi, 2005)**. Individual abuse has reached the point of some citizens discharging water septic tanks to the public drainage network, and this in turn will exacerbate the problem in addition to the risk of the transmission of epidemics and diseases **(Al-Saffawi, 2018; Al-Mashhadany, 2019)**.

It is mandatory, as a result of the river's pollution and low levels, efforts must be intensified to reduce these pollutants by continuously conducting environmental studies on liquid pollutants that flow into water sources. These studies would address the effects of pollutants and find the best ways to treat them **(Al-Saffawi & Al-Maathi, 2014; 2017)**.

Therefore, the current study aimed to evaluate the physicochemical characteristics of some wastewater valleys and sewages that drain their water into the Tigris River in the city of Mosul.

MATERIALS AND METHODS

Description of the study area

The current study was conducted in the laboratories of the College of Environmental Sciences and the laboratories of the College of Science at the University of Mosul. The study area included six sites on both the sides of the Mosul City (Table 1).

Table 1: Study locations

Location	Downstream	Longitude	Latitude
First site	Wadi Akkab	36°22'04" N	43°06'20" E
Second site	Kara saray	36°21'11" N	43°07'28" E
Third site	The medan	36°20'44" N	43°08'11" E
Fourth site	The khuser	36°20'51" N	43°08'26" E
Fifth site	Dandan	36°20'07" N	43°08'46" E
Sixth site	Danville	36°19'25" N	43°10'14" E

Samples collection

Samples were collected in the study area on a regular basis (Table 1), starting from September till November 2023. In fact, the samples were collected to conduct laboratory tests and analysis using clean and well-washed glass bottles with 1000ml of distilled water. For the determination of dissolved oxygen (DO) and the biological oxygen demand (BOD_5), samples were stored in special bottles with a capacity of 500ml that were used to collect them without creating air bubbles. In addition, bottles were then kept in boxes away from light until the samples were measured **(APHA & WCPE, 1998)**.

Physical tests

Electrical conductivity (EC)

The EC was measured in the field using a pH & 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.

Turbidity

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

Total dissolved solid (T.D.S)

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

Total suspended solid (T.S.S)

Total suspended solids were measured in the laboratory using a filter disc after drying it at a temperature of 103-105ºC for an hour to get rid of moisture. The filter disc was weighed after cooling using a sensitive electronic balance. A certain volume of the mixed sample was placed on top of the filter disc; the disc was dried again and weighed. As a result, the total suspended solids value was calculated according to the following law:

$$T.S.S_{mg\backslash l} = (A - B) * 10^6 \backslash V_{\mathrm{ml}}$$

A: The weight of the filter disc after the sample was passed.

B: Weighing the filter disc before passing the sample.

V: Sample volume.

Chemical tests

pH

The pH was measured in the field using a pH & 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.

Dissolved oxygen in water (DO)

Dissolved oxygen was measured in the laboratory using a DO meter electrode, type WTW, model Oxi 3310, of German origin, after placing the model in a clean, well-washed glass beaker with distilled water; it is measured in mg/L.

Biological oxygen demand (BOD_5)

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, and according to Table (2). Three grains of (NaOH) were added to the plastic piece, then the bottles 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 BOD_5 value was obtained by the law:

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

Table 2: Factor values for calculating BOD_5

Sequence	**BOD_5 Expected (mg\l)**	**Appropriate model size (ml)**	**Factor**
1	0-40	432	1
2	0-80	365	2
3	0-200	250	5
4	0-400	164	10
5	0-800	97	20
6	0-2000	43.5	50
7	0-4000	22.7	100

Total hardness (T.H)

The total hardness was laboratoryly measured by a titration with Na_2EDTA, where a certain volume of the sample and 1ml of buffer solution (buffer) were added. A pH value reached (10), then a little dry index (EBT) Eriochrome Black T, was added, followed by a slow titration with a solution of Na_2EDTA while shaking until the color changed from red to blue. The total hardness value was calculated in terms of $CaCO_3$ by the following equation:

$$T.H_{(mg\backslash l)} \text{ as } CaCO_3 = V * eq.wt * N * 1000\backslash\ Sample\ volume\ (ml)$$

V: Volume of filtered Na_2EDTA flushed.

eq.wt: Equivalent weight of calcium carbonate.

N: Standardize solution Na_2EDTA.

Calcium hardness (Ca H.)

Calcium hardness was measured in laboratory using the filteration method Na_2EDTA by adding a certain volume of the sample and 2ml of NaOH solution, followed by a little dry meroxide indicator. The sample was filtered with Na_2EDTA and shaked until the color changed from violet to pink and subsequently blue. The value of calcium hardness was calculated in terms of $CaCO_3$ through the following equation:

$$Ca\ H._{(mg\backslash l)} \text{ as } CaCO_3 = V * eq.wt * N * 1000 \backslash Sample\ volume\ (ml)$$

V: Volume of filtered Na_2EDTA flushed.

eq.wt: Equivalent weight of calcium.

N: Standardize solution Na_2EDTA.

Magenecium hardness (Mg H.)

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

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

RESULTS AND DISCUSSION

Table 3. The lower and upper limits and average of the physicochemical indicators at the sites during the study period

Esuariest \ Indicator		Turbo (NTU)	pH	EC (μs/cm)	TDS (mg/l)	TSS (mg/l)	DO (mg/l)	BOD_5(mg/l)	T.H as $CaC0_3$ (mg/l)	Ca H. as $CaC0_3$(mg/l)	Mg H. as $CaCO_3$ (mg/l)
Wadi Akkab	Min	5.5	7	1097	397	21	0.5	40	150	80	70
	Max	34.8	7.3	1204	559	66	1.1	70	250	160	90
	Mean	16.8	7.2	1147.6	486	48.3	0.7	55	196.6	120	76.6
Kara saray	Min	16	6.7	528	193	11	0.1	35	125	60	65
	Max	79	7	641	272	372	3.4	140	255	160	76
	Mean	40.5	6.8	568.3	261.6	160.3	1.36	73.3	173.3	94.6	68.6
The	Min	135	6.4	710	225	77	0.2	175	100	44	56
	Max	256	6.8	790	408	310	3.5	618	230	120	170

medan	**Mean**	199.6	6.6	758.6	329.3	180	1.38	341	171.6	74.6	97
The khuser	**Min**	7.2	6.8	973	362	15	0.09	15	125	64	48
	Max	35.7	7.3	1014	451	26	1.3	35	210	140	70
	Mean	17.7	6.8	996.6	416.6	66	0.7	26.6	165	105.3	59.6
Dandan	**Min**	48.4	6.3	1136	568	68	0.3	48	100	48	52
	Max	64	6.8	2182	1091	110	3.1	600	480	240	272
	Mean	55.8	6.6	1702.3	760	92	1.29	279.3	313.3	165.3	148
Danville	**Min**	14.5	7.1	1025	378	37	0.09	50	90	40	50
	Max	48.9	7.2	1042	472	80	1.2	90	200	84	116
	Mean	27	7.1	1031	430.3	53	0.8	65	148.3	64	84.3

Turbidity

Turbidity values showed a clear difference between the study sites. Its maximum rate reached was 199.6 NTU in Al-Mwdan estuaries, while its lowest rate was recorded in Wadi Akkab, with a value of 16.8 (Table 3 & Fig. 1) when compared with the parameters in Table (4), which shows the measure of water clarity in terms of turbidity **(Water watch, 1997)**. It was noticed that, the Qarasaray, Al-Midan, and Dandan estuaries fall within the dirty water classifications based on turbidity levels, while low turbidity values were observed in the Wadi Akkab, Al-Khusar, and Danveli estuaries, where the water of these estuaries was classified as good water according to turbidity. The reason for the high turbidity values in the Al-Midan estuary was due to the presence of the fish market (Souq Al-Midan) near this estuary, which drains highly turbid waste water in addition to rainfall in some months during the current study.

Table 4. The relationship between water clarity and turbidity values **(Water watch, 1997)**

Category	Turbidity (NTU)
Less than 10	excellent
10 – 30	dلgo
More than 30	Bad

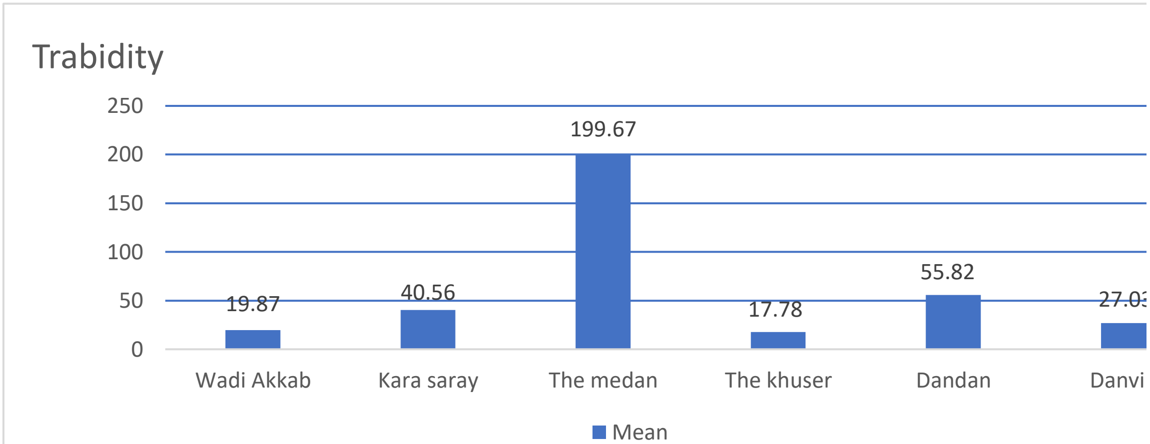

Fig. 1. Average turbidity values (NTU) for sites under study during the investigation period

The pH values

The results of the study showed that the pH levels during the study period were between 6.6 & 7.2) (Fig. 2), which are within the normal values of water. The current outcome coincides with the findings of **Al-Saffawi and Al-Maathi (2017)** concerning the qualitative assessment of the effluents of Wadi Akkab, as the pH values of the valley water ranged between 6.1 & 7.4 and agrees with those of **Shehab (2017)** who confirmed during his study conducted on the environmental effects of excreta on the water of the Tigris River in the city of Mosul that the pH values were within the ideal range, ranging between 7.3 & 8.2.

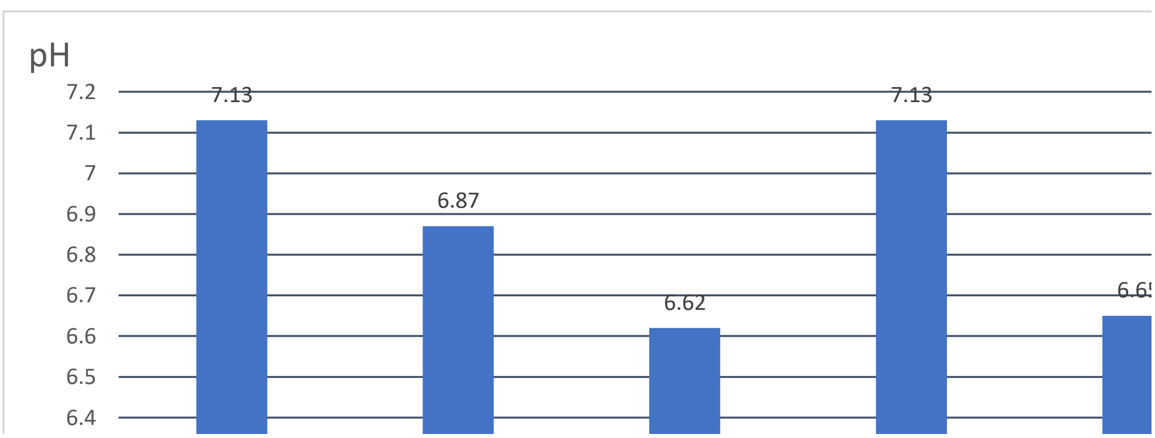

Fig. 2. Average pH values of the sites during the study period

Electrical conductivity (EC)

Electrical conductivity rates showed a noticeable increase in the Dandan Estuary, where the value was 1702.3µs/ cm, and the lowest rate was recorded in the Qarasaray Estuary (568.3) µs/cm (Fig. 3). This is related to the nature of the excreta, which contains various types of salts. This finding concurs with that of **Al-Hadidi (2018)** who detected noted an increase in the electrical conductivity values in the Tigris River for the city of Mosul, and attributed it to the increased concentration of pollutants resulting from the discharge of municipal, agricultural and industrial wastes into the river directly without any prior treatment.

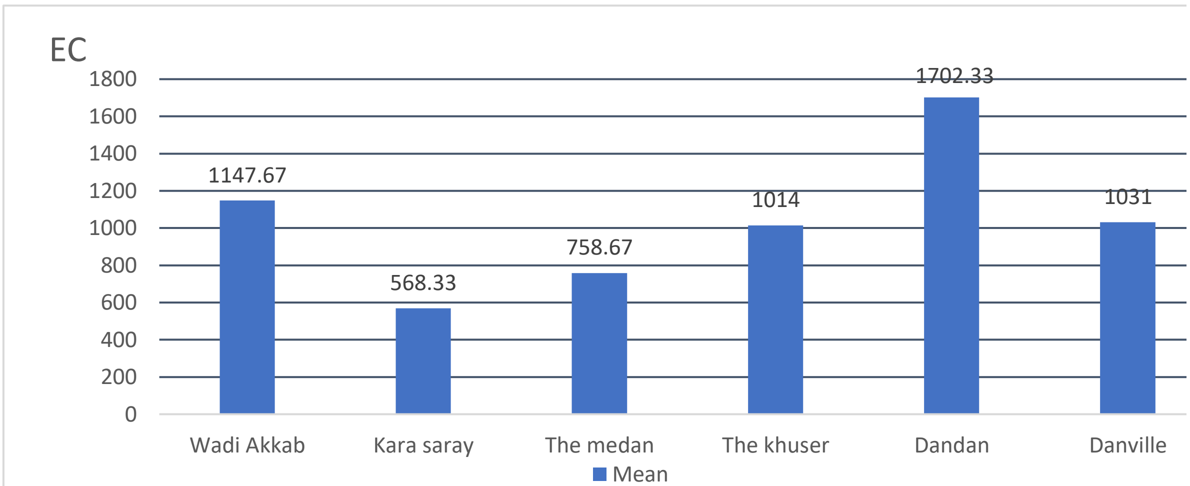

Fig. 3. Average EC values for sites during the study period

Total dissolved solid (T.D.S)

Total dissolved solids rates were high in the Dandan Estuary, reaching 760mg/ l, and their lowest rate was registered in the Karasaray Estuary, reaching 261.6mg/ l (Fig. 4). The total dissolved solids value depends on the electrical conductivity value and water temperature, which is directly proportional to the electrical conductivity and temperature **(Bhat *et al.*, 2018)**.

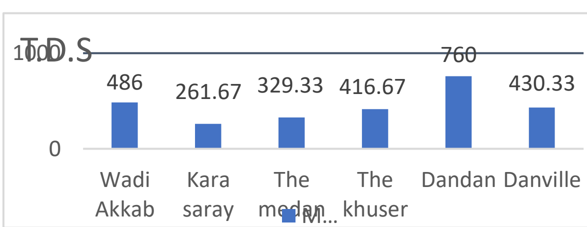

Fig. 4. Average T.D.S values for sites during the study period

Total suspended solid (T.S.S)

The results of the study showed that the highest rate of total suspended solid was in the Medan Estuary, which was 180mg/ l. In fact, the value surpassed the Iraqi allowed limits for disposal, which were set at 60mg/ l, as the maximum permissible limit **(Abawi & Hassan, 1990)**. While, the lowest rate was recorded in Wadi Akkab Estuary, where it reached 48.3mg/ l (Fig. 5). Actually, the value of suspended solids depends on the nature of the excreta, which depends on human activity **(Ahmed, 2015)**.

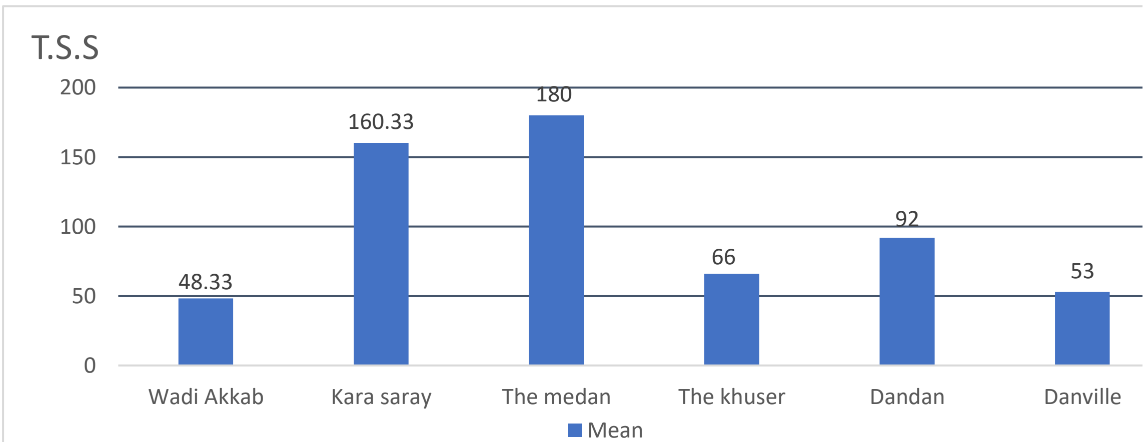

Fig. 5. Average T.S.S values for sites during the study period

Dissolved Oxygen in water (DO)

The lowest concentration of dissolved oxygen appeared in the Al-Khawsar and Wadi Akkab Rivers, as their rates reached 0.7mg/ l (Fig. 6). This is close to the values recorded in the study of **Al-Taee (2022)** conducted on the Al-Khawsar River, where she recorded the lowest value with 0.00mg/ l, while the highest value for the dissolved oxygen was in the Al-Midan, Qarasaray, and Dandan Estuaries, where the rates reached 1.38, 1.36, and 1.29mg/ l, respectively (Fig. 7). This can be traced back to the increased solubility of dissolved oxygen in water, as well as the relative decrease in the viability of microorganisms and thus the less oxygen consumption **(APHA & WCPE, 1998)**.

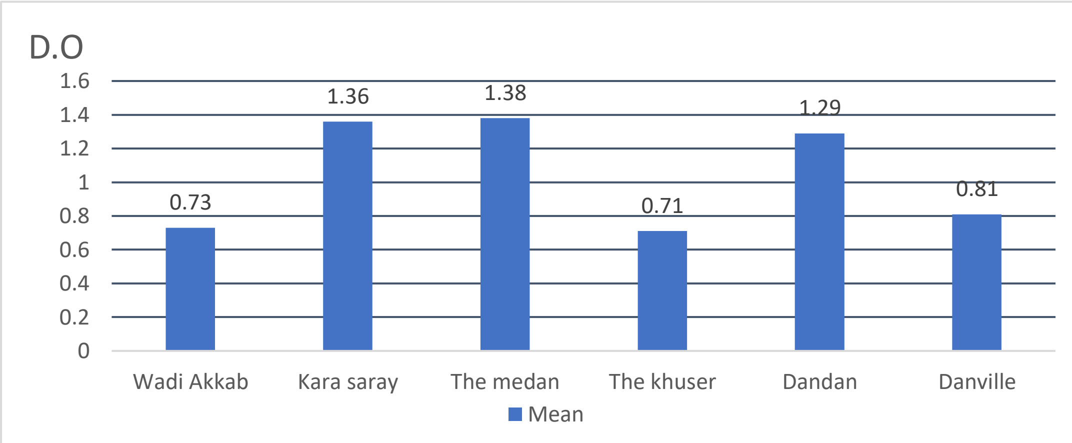

Fig. 6. Average D.O values for sites during the study period

Biological oxygen demand (BOD_5)

The results showed a high increase in BOD_5 rates in the Al-Maydan and Dandan estuaries, which respectively reached 341 and 297.3mg/ l (Fig. 7) 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 Al-Khosar River, which amounted to 26.6mg/ l (Fig. 7). Upon comparing the results with the Iraqi limits allowed for draining, being 40mg/ l as the highest value for BOD_5 **(Abawi & Hassan, 1990)**, it was observed that most BOD_5 values for the sites under study exceeded the permitted limits.

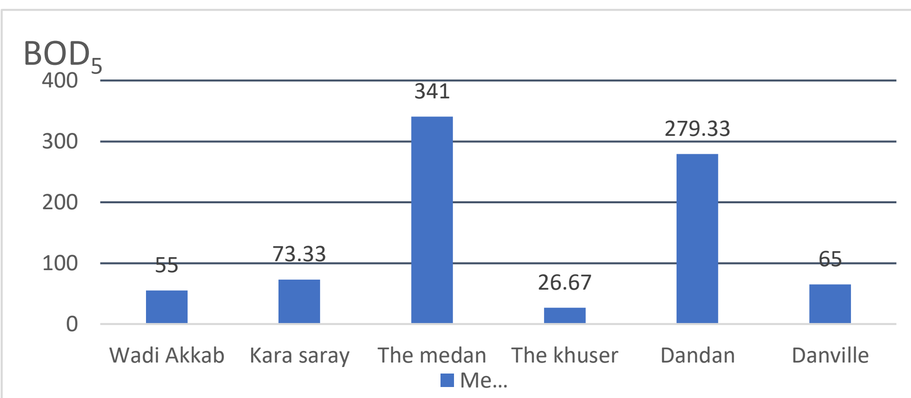

Fig. 7. BOD_5 rates for sites during the study period

Total hardness (T.H)

The water hardness showed a clear difference in its rates, as its lowest rate was in the Danveli Valley, with a value of 148.33mg/ l, and its highest value was in the Dandan Estuary, reaching a value of 313.3mg/ l (Fig. 8). These results are close to the results obtained by **Al-Taee (2022)** in her study about the Al-Khosar River, where the total hardness value reached 533mg/ l during the autumn season. In fact, the increase in the values was due 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 **(Al-Mashhadany, 2023)**.

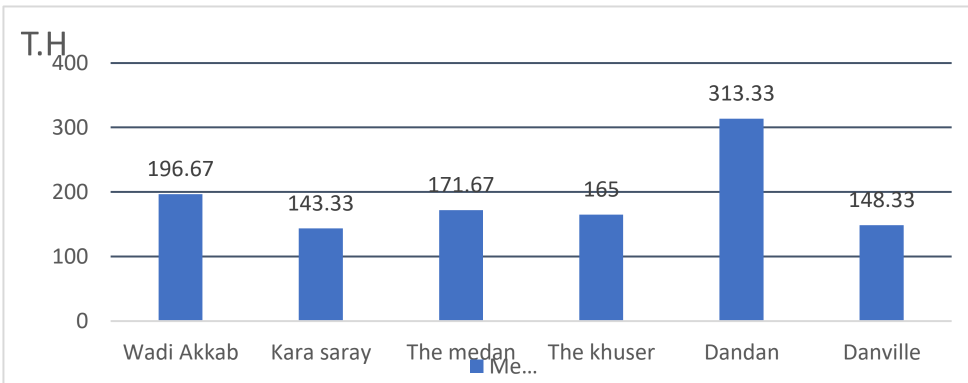

Fig. 8. Average T.H values for the sites during the study period

Calcium hardness (Ca H.)

The study showed the lowest rate of observed calcium hardness in the Danveli Valley, reaching 64mg/ l, while the highest rate was observed in the Dandan Estuary, reaching 165.3mg/ l (Fig. 9). These results are similar to what was found in the study of **Al-Mashhadany (2023)** addressing Wadi Akkab, where the rate at one of its sites was recorded at 166mg/ l during summer. Actually, is due to what is released from sewage water containing high concentrations of calcium and drained into the Al-Khosar River **(Al-Taee, 2022)**.

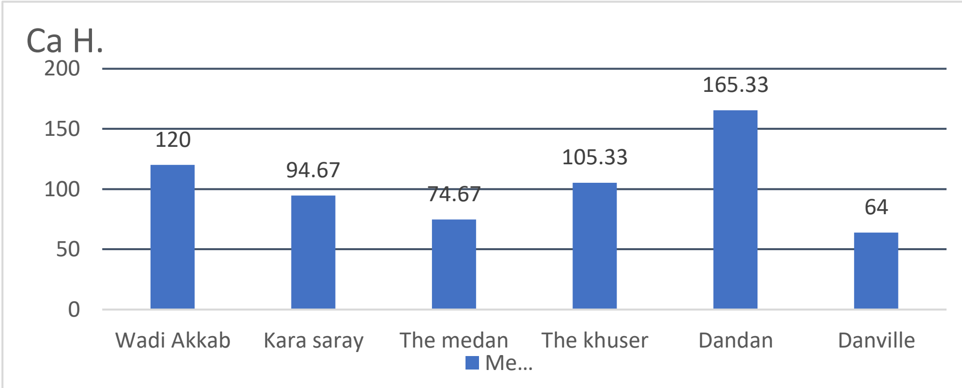

Fig. 9. Average Ca H. values for sites during the study period

Magnesium hardness (Mg H.)

The results showed a clear difference in the values of magnesium hardness, as its lowest rate in the Al-Khusradh stream reached 59.6mg/ l, and its highest rate in the Dandan estuary reached a value of 148mg/ l (Fig. 10). These values are close to those reported in the study of **Al- Taee (2022)** examining the Al-Khosar Stream, where her study rate reached 159.7mg/ l in the second station of the Al-Khosar River.

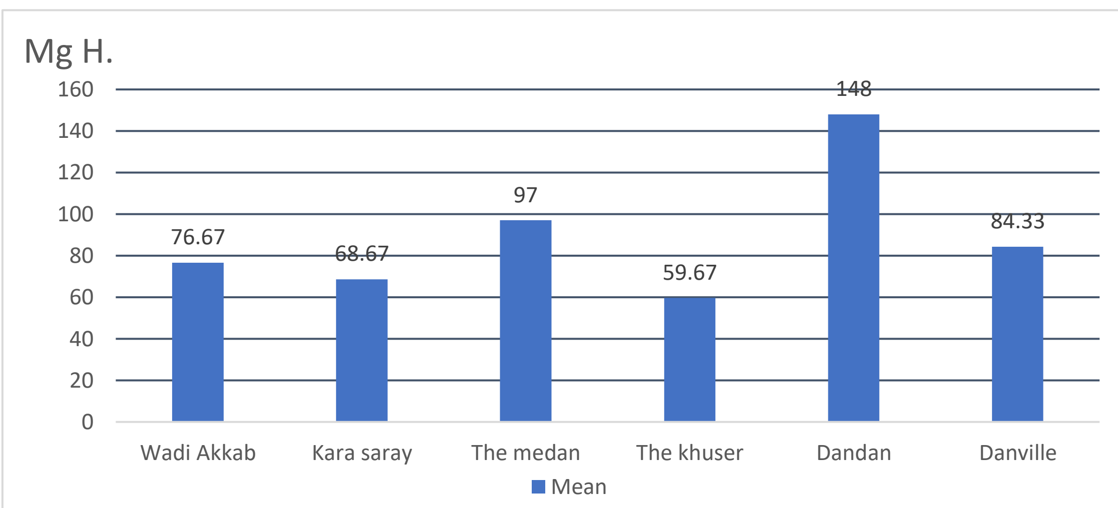

Fig. 10. Average Mg H. values for sites during the study period

CONCLUSION

It was deduced that, most of the physicochemical characteristics exceeded the safeguards at some study sites. The concentration values of the biological oxygen demand and suspended solids surpassed the permissible limits for release into rivers. The pH values were within the normal range at all study sites and throught all the months of the year. A low concentration of dissolved oxygen was detected in water. In addition, a distinct increase was recorded in turbidity and hardness values at some study sites and during some months. Thus, it is recommended to continously investigate the water quality of the Tigris River to eliminate pollutants and determine the best ways to aquire a healthy environment for the sake of the aquatic organisms and human.

REFERENCES

Abawi, Soad A. and Hassan Mohammed S. (1990). Environmental Engineering Water Analysis, one ed. Mosul, Iraq, 250pp.

Ahmed, Hozan Sabah (2015). Evaluation of physical and chemical properties of the water stream Valley Al-Sharikhan within the city of Mosul.the Degree of M.Sc., College of Environment, University of Mosul, Iraq.

Al-Assadi, Karar (2023). non14.iq. https://non14.iq/154988

Al-Hadidi, Amina Faris Farhan (2018). Assessment of Tigris River water Quality between Mosul Dam and Al-Qayara for different uses. The Degree of Master in Environmental Science, College of Environmental Sciences and Technology, University of Mosul, Iraq.

Al-Mashhadany, Mhmood Fayz M. (2023). The environmental Impact Assessment of the Danvali Valley the Tigris River, using Some Mathematical models in the city of Mosul/Iraq. Thesis, Biology, College of Education, University of Mosul, Iraq.

Al-Mashhadany, Mohammed Hazim Sabry (2019). Study the Environmental Status for Khosar River Water and the Application of Some Mathematical Models. Ph.D. Thesis, College of Education for Pure Sciences, University of Mosul, Iraq.

Al-Mtewti, Musa'ab Obaid Hamad Ballo (2018). Detection of Bacterial Contamination of Drinking Water in Nineveh Governate. the Degree of M.Sc., College of Education for Pure Sciences, University of Mosul, Iraq.

Al-Rawi, S. M. and Shihab, A. S. (2005). Application of factor analysis as a tool for water quality management of Tigris River within Mosul city. Rafidain journal of science, 16(1E): 56-64.

Al-Saffawi, A. Y. T. and AL-Taay, N. D. S. (2013). Aecological and bacteriological studyof wastewater from Hospitals In Mosul city, Tikrit Journal of Pure Science, 18(4): 86-97.

Al-Saffawi, Abdul-Aziz Y. (2018). Application of the CCME WQI to Evaluate Water Quality for Drinking Purpose: A Case Study for Groundwater Quality of Al-Mahalibiyah SubDistrict, Nineveh Province/ Iraq. Rafidain journal of science, 27(5): 193-202.

Al-Saffawi, Abdul-Aziz Y. T. and Al-Maathi, Alaa. T. H. (2014). Use aluminum sheets as reflectors in treating sewage with solar radiation. Journal Of Education And Science, 27(3): 1-18.

Al-Saffawi, Abdul-Aziz Y. T. and Al-Maathi, Alaa. T. H. (2017). The quality evaluation of Wady Eqab wastewater in north of Mosul city for Irrigation. Tikrit Journal of Pure Science, 22(12): 14-20.

Al-Sarraj, Eman S.; Jankeer, Muna H. and Al-Rawi, Sati M. (2014). Some Indicators of Water Quality of the Tigris in Mosul City an Inferential Study. Rafidain journal of science, 25(1A): 1-22.

Al-Sarraj, Eman Sami Yaseen Hussein (2013). Study of Tigris River Pollution with Different Wastes in Mosul City and its Effect on Some Local Fishes. Ph. D. Thesis. College of Science, University of Mosul, Iraq.

Al-Taee, Haneen Hani Taha (2022). Using Biological Indices to Assess the Water Quality of The Tigris River and Al-khawsar Stream in Nineveh Governorate. The Degree of M. Sc., College of Education for Pure Science, University of Mosul, Iraq.

Al-yazichi, Yasir M. and Mahmood, Hazim J. (2018). The Qualitative Characteristics and the Trace Elementsfor Tigris River Water in Mosul City. Iraqi National Journal of Earth Science, 8(2): 33-49.

APHA, A. and WCPE (1998). "Standard Method for Examination of Water and Wastewater American Public Health Association, 23RD ed., Washington DC, USA.

Bhat, M. A.; Wani, S. A.; Singh, V. K.; Sahoo, J.; Tomar, D. and Sanswal, R. (2018). An overview of the assessment of groundwater quality for irrigation. Journal of Agriculture Science and Food Research, 9(1): 1-9.

Kannah, Abdulmonein M. A. and Shihab, F. A. (2022). Heavy Metals Levels in the Water of the Tigris River in the City of Mosul, Iraq. Egyptian Journal of Aquatic Biology & Fisheries, 26(6): 1007-1020.

Makki, Hendren (2023). Iraq News Agency. https://www.ina.iq/189385--.html

Mustafa, M. H. and Jankeer, M. H. (2007). Quality Difference Between Two Location on Tigris River Within Mosul City. Rafidain journal of science, 18(1A): 111-124.

Saghir, Abdullah (2017). Industrial Wastewater Treatment in the Arabic World, One ed. Beirut, Lebanon, 13pp.

Shabib, Adel Abdel Zahra (2020). Desertification in Iraq: causes and ways to combat it. https://m.ahewar.org/s.asp?aid=690225&r=0.

Shehab, Zakariya Nafea Mahmood (2017). Environmental Effects of Sewage and Pollutants on Tigris River Water between Al-Rasheedia and Al-Qiara Districts. The Degree of M.Sc., Environmental Science, College of Environment, University of Mosul, Iraq.

Shihab, Hiba Fares Ahmed (2021). Study of some Physical, Chemical and Biological Properties of the Water of the Tigris River within the City of Mosul-Iraq. The Degree of M.Sc., College of Science, University of Mosul, Iraq.

Water watch (1997). Water quality parameters and indicators phosphorus. Namoi. Catchment Management Authority, Australian Government, 1-6.