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Environmental Study on Water Quality of the Upper Zab River in Asc Klk Within the Governorate of Erbil

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ABSTRACT

The quality of the water of the Upper Zab River in Asc Klk, Erbil, Iraq (UZAK River) was addressed in this research. Ten different samples were taken from two different sites along the river during five months (October 2019 - February 2020), with one sample each month for each site. These samples were chemically, physically, and biologically tested. The results indicated that the quality of the UZAK River water was deteriorating in both locations. The increases in dissolved oxygen were found to be inversely proportional with decreases in temperatures. The highest concentrations of dissolved oxygen, 13.6 and 15.2mg/ L, were registered in January and February at both studied sites. Although the concentration of both NO_3^{-1} and PO_4^{-2} ions increased in September at both sites compared to the rest of the time, they are still within the standard limits of drinking water set by World Health Organization (WHO). The biological tests showed the presence of pathogenic bacterial species (*Pseudomonas*, *Klebsiella*, and *Pneumonia*) in the water of the first site and *Micrococcus* and *Staphylococcus* in the water of the second site.

INTRODUCTION

All the civilizations started in places where water is available; only 3% is the percentage of the fresh water. Therefore, it should be preserved because it is vital for supporting habitats, maintaining hydrological balance, and providing the needs of human societies **(Rabeea *et al*., 2020; Hussien *et al*., 2021)**. Water pollution is an international problem, especially inland water pollution **(Rabee *et al*., 2021)**. The current study was carried out in the Erbil Governorate north of Iraq, which is located between the latitudes of 35° N and 30° N, and longitude 43° 18E and 44° 18 E. Greater Zab River is situated between 36°-37° North latitudes and 43° -44° East longitude **(Shareef & Aziz, 2023)**, as shown in Fig. (1).

The area drained by the upper Zab is to the east of the Tigris. The upper Zab is originated from Van lake in Turkey, and flows within Duhok Governorate in the

Kurdistan Region of Iraq. The river also forms a natural border between the governorates of Nineveh and Erbil. It is considered the second tributary of the Tigris River along with the Khabbor and Lower Zab Rivers, forms one of the important branches of the Tigris River. The length of this river is 400km, and the area of its basin is 40,300km^2. This river generates 13.18km^2 of water when it meets the Tigris River at the village of Safina in the Qayyarah District. About 62% of the total area of the basin of this river, which is 25,810km^2, is located in Iraq **(Al-Youzbakey & Sulaiman, 2021).**

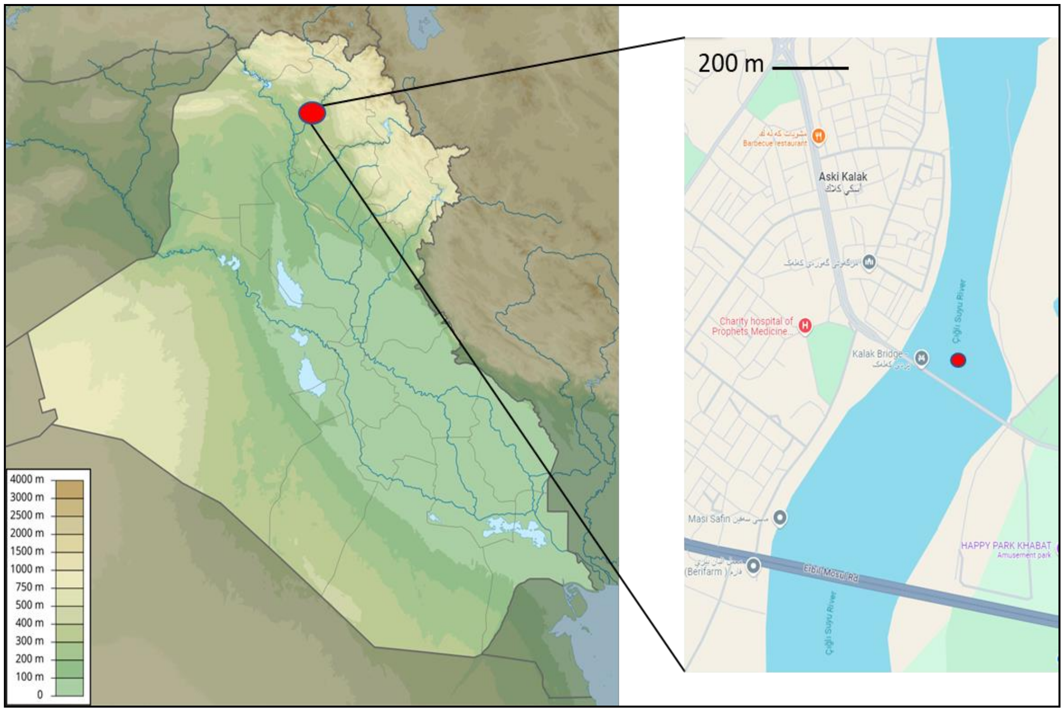

Fig. 1. Study sites of Upper Zab River in Asc Klk at Erbil Governorate

Many studies have been conducted on studying Tigris River water properties whether chemical, physical and/or biological. For example, the study of **Abdulmoneim (2021)** concluded that the river water in Mosul City is still within the Iraq specifications of the protection of water resources No25-A1, 1967 **(Al-Sarraj, 2019; Abdulmoneim & Shihab, 2021)**. **Majeed *et al*. (2022)** studied 19 physicochemical parameters of the Tigris River. Their results indicated that the water was well-aerated and alkaline. The demand of biological oxygen was found to be below 5mg/ L during the investigation; however, high values of conductivity, total dissolved solids, and total hardness were found. In addition, it was deduced that the Tharthar Canal affected the Tigris River by increasing the chemical components **(Majeed *et al*., 2022)**.

MATERIALS AND METHODS

Ten samples of water were collected from two different sites from October 2019 to February 2020, with one sample per site each month, as shown in Fig. (1). Tests were conducted, including physical and chemical properties, using internationally approved methods **(APHA, 2017; Baird *et al*., 2017)**.

Physical and chemical properties

The air temperature was measured using a graduated mercury thermometer (0-100°C) by placing the thermometer in the shade at a height of one meter from the surface. The water temperature was measured in the field using a graduated mercury thermometer by immersing the mercury-containing end of the thermometer in the water sample for approximately two minutes, and then the temperatures were recorded.

Electrical conductivity (EC) and total dissolved solids (TDS) were measured in the field using a HANNA HI 9811-5 EC meter, with readings taken in µS/cm at 25°C. pH was measured using a HANNA Instruments HI 8424 pH meter, calibrated with buffer solutions of pH 4, 7, and 9.

The modified azide method **(Hmoshi *et al.*, 2024)** was used to measure the dissolved oxygen (DO) in the water. To this, 1mL of concentrated sulfuric acid was added, followed by mixing. The solution was then titrated with a 0.025N sodium thiosulfate solution in the presence of starch as an indicator, until the blue color disappeared. The dissolved oxygen in the water was then calculated using the following equation:

$$\text{Do mg/L} = \frac{N \times V \times \text{eq.wt} \times 100}{\text{ml}}$$

V = volume of the standard sodium thiosulfate solution; N = titers of the standard solution; Eq.wt = equivalent weight of oxygen.

To analyze total hardness, 50ml of the sample was taken, and an amount of the buffer solution was added to make the pH = 10. Drops of EBT indicator (Erichrom black T) were added to form a purple color, and the titration process was slowly carried out with the standard solution 0.02N (Na_2 EDTA) until the color changed to blue-green. The total hardness was calculated from the following equation:

$$\text{T.H mg/L as } CaCo_3 = \frac{N \times V \times \text{eq.wt} \times 100}{\text{ml}}$$

V = volume of the corrected standard solution, N = standard solution standard, Eq.wt = equivalent weight of calcium carbonate.

For calcium hardness analysis, 50ml of the sample was taken, and 3ml of sodium hydroxide solution (1N) was added to set a pH of 12. A little Muroxide indicator was added, and titration with Na_2EDTA solution 0.02N was added aligned with stirring using a glass stirrer until the color changed from pink to violet. After that, the calcium hardness was calculated by the following equation:

$$Ca.H\ mg/L\ as\ CaCo_3 = \frac{N \times V \times eq.wt \times 1000}{ml}$$

V = volume of the solution

Na_2EDTA Standard Drop; N = Standard Solution Molarity; Eq.wt = Equivalent Weight of Calcium Ion.

Magnesium hardness was calculated from the equation:
Magnesium hardness (mg/L) = Total hardness $CaCO_3$ (mg/L) – Calcium hardness (mg/L).

Nitrate ion ($NO3^{-1}$) was measured according to the Ultraviolets Spectrophotmetric Screening method, by taking 50ml of the filtered sample and then adding 1ml hydrochloric acid with a molarity of (1N) at λmax 220-275nm.

For phosphate ion ($PO4^{-2}$), the Stannous Chloride Colorimetric **(Anh *et al*., 2023)** was followed by taking 100ml of the sample and adding 4ml of ammonium molybdate and 10 drops of stannus chloride solution while shaking, and a blue complex was formed whose intensity is proportional to the phosphate concentration at λmax 690nm, as determined by a spectrophotometer.

Sulphate ion $SO4^{-2}$ was measured using the turbidimetric method. A known volume of the filtered sample was taken, and barium chloride was added while continuing mechanical shaking for a minute. The concentrations were read using a turbidimeter.

Biological tests

The total number of bacteria was measured using the standard plate count method, in addition to identifying the pathogenic species among them, which were identified by the WHO **(Abbawi & Hussan, 1990)**.

RESULTS

Table 1. The average of physical properties of (UZAK River) during the months of study at both sites

Parameters	Average Site 1	Average Site 2
Water temperature	13.2	13.01
Air temperature	17.13	17.2
Electrical conductivity	343.3	343.5
Total dissolved solids	171.6	171.6
Turbidity	91.41	78.91
pH	8.21	8.46
Phosphate	0.13	0.16
Nitrate	0.52	0.97
Sulfates	40.0	40.0
Total hardness	160.66	170.0
Calcium	86.00	120.0
Magnesium	74.66	50.0

Table 2. Concentration of DO, saturation ratio and total number of bacteria at 1st site

Month	D.O (mg/l)	%D.O	Total number of bacteria (cell/100ml)	Pathogenic bacterial species
Sep.	8.8	110	22×10^4	*Pseudomonas, Klebsiella, pneumoniae*
Oct.	9.2	115	18×10^3	
Nov.	8.4	105	3×10^3	
Dec.	9.2	115	5×10^3	
Jan.	13.6	170	2×10^3	
Feb.	11.2	140	3×10^2	

Table 3. Concentration of DO, saturation ratio and total number of bacteria at 2nd site

Month	D.O (mg/l)	%D.O	Total number of bacteria (cell/100ml)	Pathogenic bacterial species
Sep.	9.7	121.25	16×10^3	*Micrococcus, Staphylococcus*
Oct.	10	125	5×10^2	
Nov.	9.7	121.25	1×10^2	
Dec.	10.1	126.25	2×10^2	
Jan.	15.2	190	30×10^3	
Feb.	10.8	135	2×10^1	

DISCUSSION

Air and water temperature

From Fig. (2a, b), the range of air and water temperature fluctuated between 31 and 21.2°C at the 1st site during September and 31 to 21°C at the 2nd site during October. It was found that the lowest value of air and water temperature was recorded at both sites during December, which ranged from 7.2 to 5.8°C.

The average air and water temperature ranged between 17.13 and 13.2°C during the study period at both sites (Table 1). This difference in air and water temperatures is due to the seasonal change in air temperatures, which is reflected in water temperature. Studies have shown that temporal changes in water temperature are closely linked to changes in air temperature. Temperature is important because it affects water properties, including taste and color, as well as influencing chemical reactions **(Ali & Ali, 2023; Shalishe, 2024)**.

Electrical conductivity and total dissolved salts concentrations

Fig. (2c and d) illustrates a direct proportionality between the rates of electrical conductivity (E.C.) and TDS. The highest values of electrical conductivity and TDS concentrations during the study period were 372.186 and 383.191mg/ L, respectively, at both sites. These values were observed compared to the lowest values, 306.153mg/ L at both sites, recorded in January. This variation may be due to the presence of dissolved materials or the release of salts from various types of waste along the river course, in addition to the increased activity of microorganisms in decomposition processes **(Hussien *et al.*, 2020; Alaarajy *et al.*, 2023; Uddin *et al.*, 2024)**.

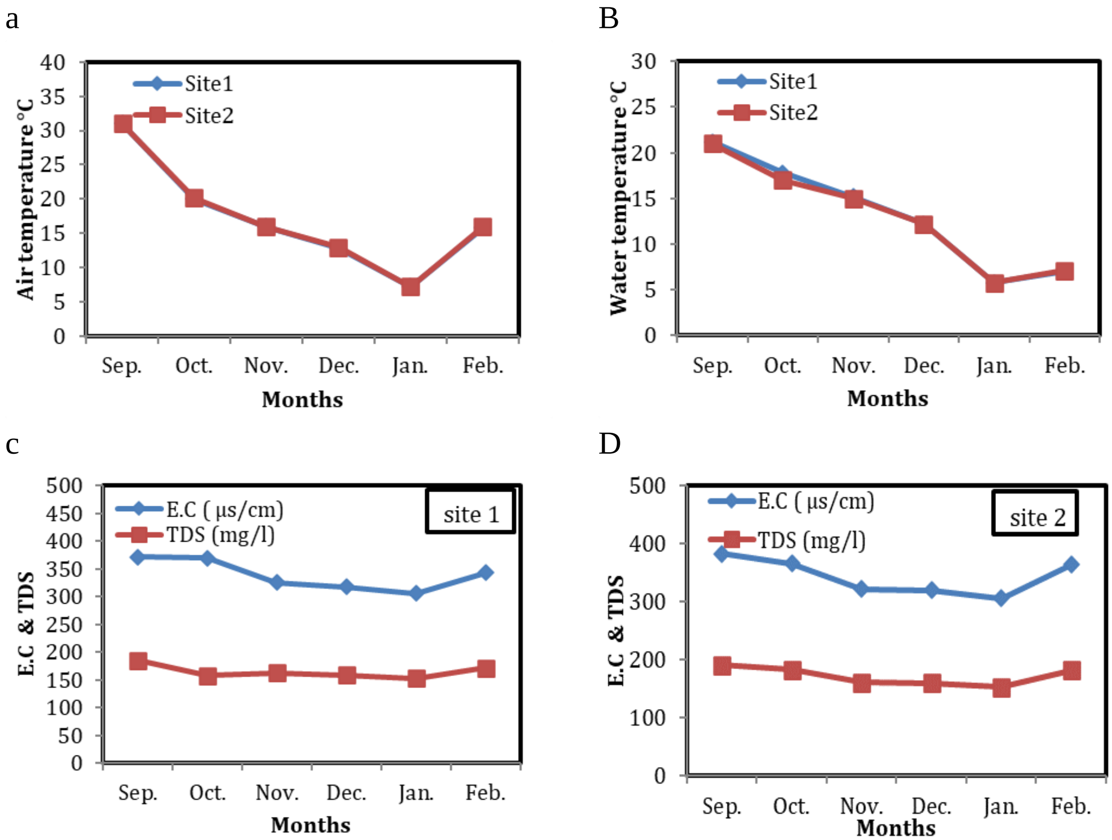

Fig. 2. Average monthly values of (a) air and (b) water temperature, (c) E.C, (d) TDS at the study sites on the UZAK River

Turbidity and pH

The results of the current study showed an increase in turbidity values in most of the study months and at both study sites, as it exceeded the limits permitted by the WHO **(Rabeea & Owaid, 2022)** in some months of the year, as shown in Fig. (3a) and Table (1). Its highest values reached 244 and 227 NTU during December at both sites. This increase in turbidity values in the waters of the Upper Zab River at the studied sites is due to the increase in rainfall amounts, as turbidity is directly related to the amount of rainfall, current speed and river discharge **(Mahmood *et al.*, 2021)**.

Fig. (3b) showed that the water of both sites on the Upper Zab River tends towards alkalinity during most of the months of the current study. The values of the acidity function ranged between 7.85 - 8.60 in the water of the first site and 7.90 - 8.46 in the water of the second site. While the average values of the acidity function across both sites were 8.21 and 8.22. Most of the natural water tends toward basicity due to the presence of carbonate and bicarbonate ions, and this was reflected in the results of the current study within the Upper Zab River in Erbil Governorate **(Huang *et al.*, 2021; Alsaadoon *et al.*, 2023)**.

a b

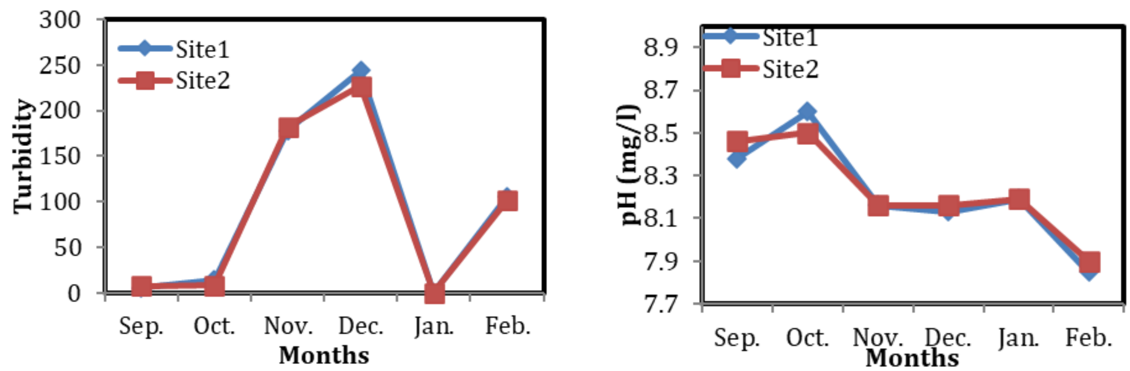

Fig. 3. Average monthly values of: (a) Turbidity and (b) pH

Nitrate ion (NO_3^{-1}), phosphate (PO_4^{-2}) and sulfates (SO_4^{-2}):

Fig. (4a) shows that the concentrations of nitrates at both sites during the different months of the study did not exceed the global limits set by the WHO. The highest concentrations were 1.28 and 0.97mg/ L during the months of November and September in both sites, compared to the lowest concentrations of 0.06 and 0.12mg/ L during the months of February, respectively, in the first and second sites. This is attributed to the large amount of sewage discharged into the Upper Zab River, as there were studies that had proven an increase in nitrate concentrations in the waters of the Upper Zab River during its flow towards the south, leaving the city. In addition to the fact that the source of nitrates in the water is the oxidation of organic nitrogenous water, and it can be found in most types of discharges, the most important of which are fertilizer for agriculture **(Alsaqqar *et al.*, 2013; Alahi & Mukhopadhyay, 2018; Singh *et al.*, 2022)**.

Fig. (4b) shows that the concentrations of phosphate did not exceed the WHO standard limits in some months of the year at both sites. The highest concentrations were 0.17 and 0.16mg/ L during December and September at both sites, respectively, compared to the lowest concentration of 0.10mg/ L during September and January. This is ascribed to the discharge of more animal waste as well as water pollution with washing powders and detergents with high concentrations of phosphate **(Asadollah *et al.*, 2021; Latif *et al.*, 2022)**.

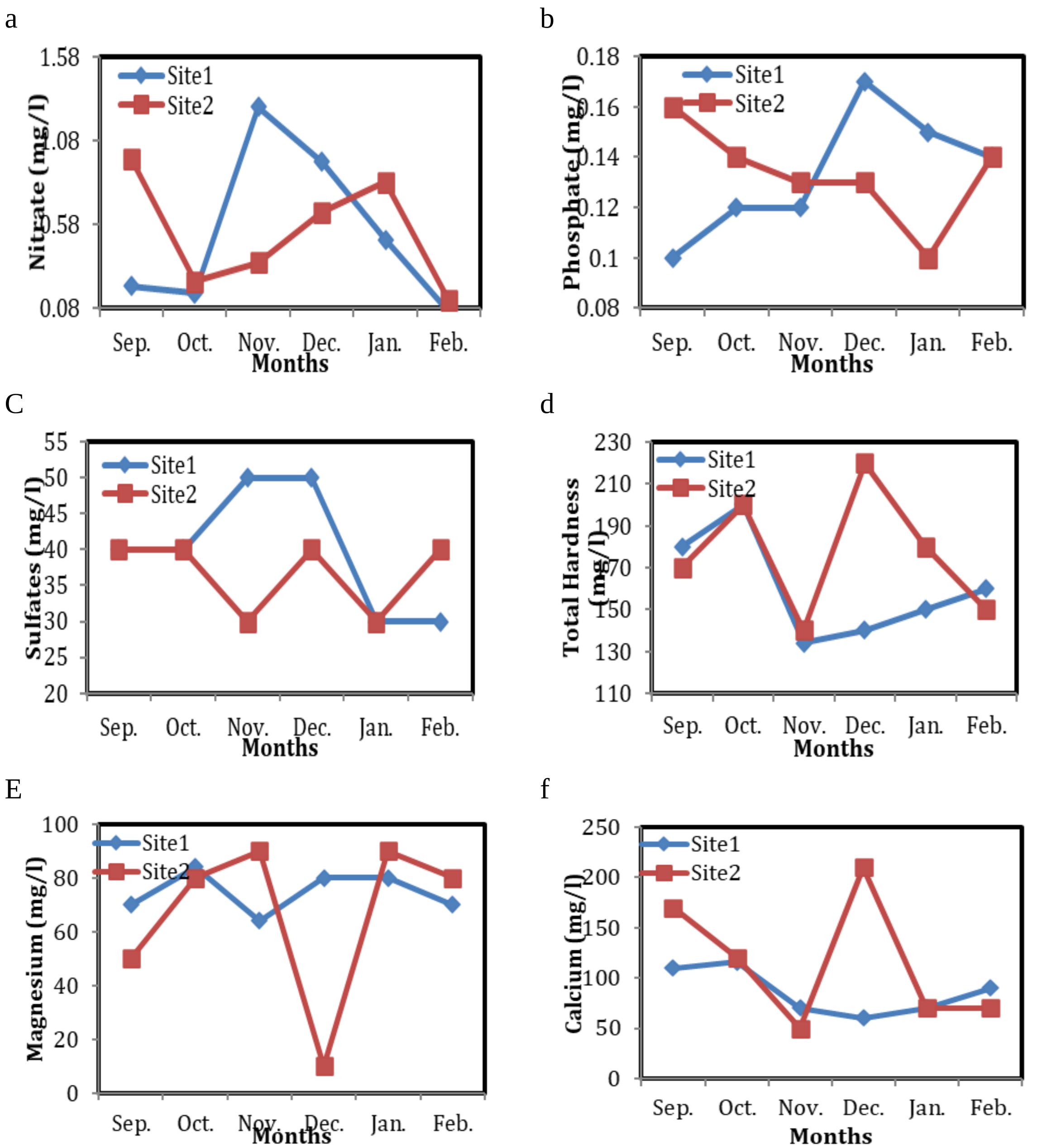

Fig. 4. Average monthly values of NO_3^{-1} (a), PO_4^{-2} (b), SO_4^{-2} (c), T.H (d), Mg (e), and Ca (f) at the study sites of the UZAK River

Fig. (4c) shows clear changes in the concentration of $SO4^{-2}$ ions at both studied sites and during the months of the study. The highest concentrations reached 50 and 40mg/ L at both the first and second sites in the November and December, while the lowest concentrations were 30 and 30mg/ L. These results are consistent with what was mentioned by **Niraula *et al.* (2022)**, as they attributed this to the increased use of sulphuric acid in the manufacture of batteries and their reactivation and other leather industries, which was confirmed, in addition to fertilizer production plants **(Mezhevova *et al*., 2024)**.

Total hardness and calcium and magnesium hardness

The rates of the three types of hardness, as shown in Fig. (4d, e, and f), at both study sites and during the study months, were as follows: 160.66 and 170.66, 86 and 106.66, and 74.66 and 66.66mg/ L in terms of calcium carbonate. The highest concentrations recorded were 200, 116, and 220, 210, and 90mg/ L in terms of calcium carbonate, respectively. These were compared to the lowest concentrations of 134, 60, 64, and 150, 50, 10mg/ L in terms of calcium carbonate. This variation is attributed to the introduction of industrial, human, and agricultural waste into the river from areas located along both sides. Additionally, the accumulation of calcium and magnesium salts, whose concentrations depend on geological factors like the type of rocks, plays a role. The ions present in the riverbed—particularly from limestone, marl, dolomite, gypsum, and evaporites—directly contribute to the supply of these ions to the waters of the Upper Zab River **(Ewaid *et al.*, 2020)**.

Dissolved oxygen in water and the saturation rate

Tables (2, 3) demonstrate significant variations in the dissolved oxygen concentrations in the waters of both sites, across all months of the year. The highest concentrations of dissolved oxygen in the water reached 13.6 and 15.2mg/ L, and saturation rates were 170 and 190%, respectively, during the month of January at both sites. During the remaining period, the water's dissolved oxygen concentrations reached 10.06 and 10.91mg/ L. Temperatures relate to the difference in dissolved oxygen concentrations in the water during the study months. When temperatures are high, they work to reduce the water's ability to carry oxygen, resulting in a low concentration of oxygen in the water. However, when the temperature decreases, the low activity of microscopic organisms during decomposition processes leads to an increase in the concentrations of dissolved oxygen. In addition, the ventilation resulting from the rapid flow of the Upper Zab River waters **(Mohammed & Scholz, 2021; Salman *et al.*, 2021)** is another attributed reason.

Numbers of bacteria and extracted genera

Tables (2 and 3) show that the total numbers of bacteria exceeded the standard limits set by the WHO. The total numbers of bacteria during the study months ranged between 2×10^3 - 22×10^4 and 1×10^2 - 30×10^3 cells/100 ml in the first, and second sites respectively. The bacterial genera identified were *Pseudomonas*, *Klebsiella*, and *Pneumoniae* at the first site, and *Micrococcus* and *Staphylococcus* at the second site. This presence is traced back to the pollution of the UZAK River waters from various pollutants, resulting from the improper disposal of wastewater into the river **(Alexandre *et al*., 2020)**.

CONCLUSION

All variables examined showed distinct changes during the period of the study months and across all locations. The turbidity levels during the study period exceeded the established standards limit permitted by the WHO. Pathogenic bacterial species were found in the water samples, which could have serious consequences for human life. The sequence of negative ions showed an ascending order with sulphate being less than nitrate, followed by phosphorus.

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