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Assessment of Water Treatment Efficiency and Aquatic Environmental Implications for the Euphrates River in Fallujah City

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ABSTRACT

The study was conducted on the Euphrates River water in the city of Fallujah. Four samples were collected in January 2023, and physical variables such as temperature, electrical conductivity, and turbidity, as well as chemical variables, were measured. Acidity, alkalinity, total dissolved salts, calcium, sodium, potassium ions, and sulfates, were compared with the river and station samples. The results showed that all physicochemical tests were within the permissible limits except for turbidity, calcium and sulfate. The data were statistically analyzed to calculate the correlation coefficient between the chemical and physical parameters. An experiment was conducted on household and sewage outlets on the Euphrates River, and differences in the percentage of pollution from one area to another were evident. The highest percentage was in the outlet and mixing area, and the lowest percentage was in the area before and after the outlet. Several types of bacteria appeared, such as *Sphingomonas paucimobilis*, *Klebsiella*, and *E. coli*. The percentage of *Klebsiella* was very high in the outlet area, where its percentage on the nutrient agar medium was 38.5% and on the Macconkey agar medium, 34.5% was recorded. Its presence is a significant and dangerous indicator, as it causes a number of diseases. The percentage of *E. coli* bacteria was high in the area after the outlet, where the percentage in the nutrient agar medium was 41.5% and in the Macconkey agar medium was 36.5%. It also causes many diseases and bacteria. Additonally, *Sphingomonas paucimobilis* had its highest percentage in the pre-estuary area, where its percentage in the nutrient agar medium was 51.5% and in the Macconkey agar medium was 39.5%.

INTRODUCTION

Water is the cornerstone of life and one of the most vital natural resources essential for human health, economic development, and ecosystem stability **(Jung *et al*., 2023)**. It plays an irreplaceable role in agriculture, industry, domestic use, and maintains the balance of natural habitats. Although it is the most abundant substance on our planet, a very small portion of water resources are available for human use rendering fresh water an extremely precious and limited commodity **(Saini *et al*., 2024)**. Increasing urbanization and industrialization due to rising population has led to the degradation in quality of surface water bodies including rivers, posing a serious concern to health of humanity and sustainability of environment. The Euphrates River is one of Iraq's and the Middle East's most important rivers, serving millions of people for drinking water, irrigation and industry. The water quality of river, is however being affected by various anthropogenic activities such as agricultural run-off, industrial effluents and domestic sewage **(Kadhim *et al*., 2023)**.

Water quality inspection is an important part in terms of providing the water according to human demand and protection of ecosystems (**Makanda *et al*., 2022**). It involves the analysis of physical, chemical, and biological parameters that determine the safety and suitability of water **(Sun *et al*., 2021)**. The presence of pathogenic bacteria like *Escherichia coli*, *Salmonella* and *Vibrio cholerae* suggests fecal contamination and waterborne disease spread **(Kristanti *et al*., 2022)**.

Microbial pollution remains one of the most critical challenges to ensuring clean and safe drinking water worldwide. Bacteria may find their way into water sources through several pathways including disposal of untreated sewage, agricultural runoff with animal feces and faecally contaminated wastewater due to failure in treatment systems **(Dawd, 2021; Kristanti *et al*., 2022)**. Whereas, once in the environment, a large group of pathogenic microorganisms can be responsible for several diseases including diarrhea, cholera dysentery typhoid disease and hepatitis A **(Rath, 2021)**. Such infections are especially lethal in the developing world where clean water and sanitation facilities are not easily available. Thus, monitoring of microbial indicators particularly total coliforms and fecal coliforms is also a crucial part of water quality evaluation **(Akhtar *et al*., 2021)**. Moreover, by associating bacteriological data with physicochemical parameters, underlining possible origin and character of the contamination, a better management of resources would be facilitated. The objective of this paper is to access the efficiency of the treatment plant in treating water by comparing various raw and treated water characteristics with emphasis on important physico-chemical and bacteriological parameters

MATERIALS AND METHODS

Sample location

Samples were collected during December 2023 from four locations on the Euphrates River within the city of Ramadi, Anbar Governorate. The locations of the sampling points are presented in Table (1) and Fig. (1).

Table 1. Description of sampling location and pollution sources

Sampling Site	Description
S1	The Euphrates River
S2	Near Fallujah Bridge
S3	50 meters after Fallujah Bridge
S4	Heavy Water Lifting Station

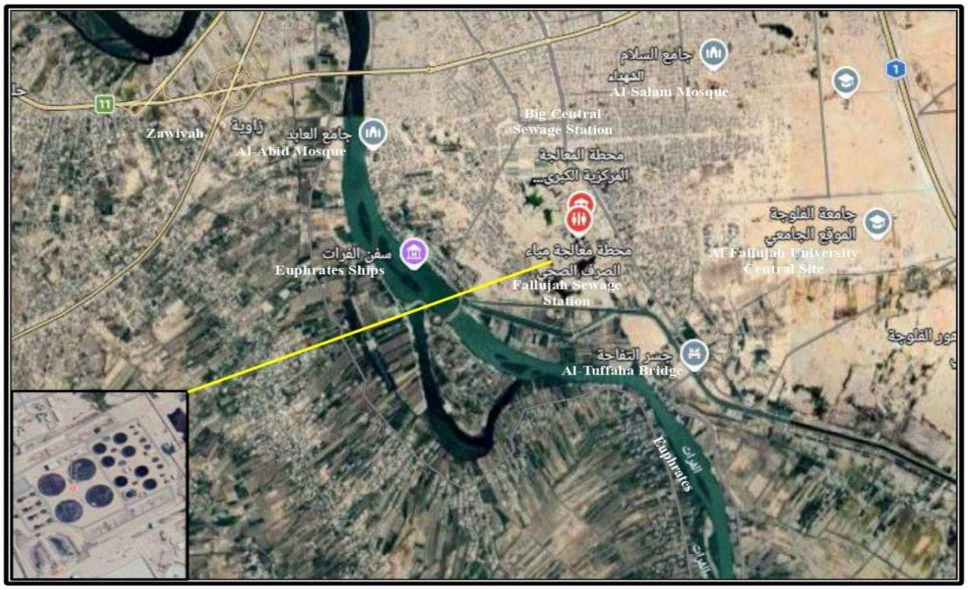

Fig. 1. Map showing sample collection areas

Water sampling

The samples were collected at a depth of 50cm below water surface in sterilized polyethylene bottles, subsequently kept inside ice-cold containers and delivered directly to the laboratory for further analysis. All tubes and bottles were immediately stored in a cooling pack after sampling as per the guidelines of American Public Health Association. They were later brought to the laboratory within 2-3 hr for examination **(Rice *et al*., 2012)**.

Physicochemical parameters

Some physicochemical parameters of the collected water samples such as water temperature, turbidity, pH, EC (electrical conductivity), alkalinity, total hardness and TDS (total dissolved solids) were determined with the help of Hach HQ40D multi-parameter water analysis meter (USA) according to the standard procedures described in the APHA Standard Methods for the Examination of Water (**APHA, 2017**). Calcium ions (Ca^{2+}) were measured by complexometric titration using standard EDTA, with phenolphthalein and Eriochrome Black T as indicators, in accordance with APHA Method 2340 C. Chloride ions (Cl^{-}) were determined by Mohr's argentometric titration, using standardized silver nitrate ($AgNO_3$) and potassium chromate as an indicator, according to APHA Method 4500-Cl^- B **(Kaur *et al*., 2022)**, through titration with standardized $AgNO_3$ solution using potassium chromate as an indicator.

Potassium (K^+) concentrations were quantified using a flame photometer (Jenway PFP7, UK) following APHA Method 3500-K. Sulfate ions (SO_4^{2-}) were analyzed by the turbidimetric method, based on $BaSO_4$ precipitation after addition of barium chloride ($BaCl_2$), with turbidity measured spectrophotometrically at 420 nm, following APHA Method 4500-SO_4^{2-} E. All procedures were conducted using analytical-grade reagents and calibrated glassware supplied by Merck, Germany.

Bacterial tests

Total live aerobic bacterial counts were determined using the plate pour technique described in APHA **(Association *et al*., 1917)**. Stories of the water sample were diluted out and 1ml from each dilution was pipetted with a sterile glass pipette. It was then transferred into a sterile plate, and poured into the glue nutrient (15ml) that is cooled to 45°C, stirred clockwise and anti-clockwise several times and allowed to set. The dishes were then inverted and placed in the incubator at 37 degrees centigrade for 24-48 hours, depending on the cfu counts/ml of bacteria present in the water samples. The bacterial colonies were counted and indicated as log^{10} colony forming unit per ml (log^{10} CFU/ml). For the collection area, codes according to the type of bacteria diagnosed are shown in Table (2).

Table 2. Samples collection areas according to the bacterial type diagnosed

Sample	Study area description
B	Located 50 meters upstream from the outlet of the water treatment plant.
M	The discharge point where domestic wastewater from the treatment station enters the river.
K	The mixing zone where the effluent merges with the river flow.
A	Located 50 meters downstream from the outlet of the treatment plant.

Bacteria identification

Several tests were conducted to detect types of bacteria (KOH test, oxidase test, catalase test, oxidation and reduction test, movement test, the shape of the colonies and gram stain test).

Standardization of bacterial inoculum density

The bacterial inoculum density was adjusted according to the McFarland standard to ensure uniform turbidity for all isolates prior to biochemical testing. Table (3) illustrates the McFarland turbidity range used for different microbial groups.

Table 3. McFarland turbidity ranges used for different microbial groups

McFarland turbidity range	Product / Microbial group
0.50 – 0.63	Gram-negative bacteria (GN)
0.50 – 0.63	Gram-positive bacteria (GP)
1.80 – 2.20	Yeasts and yeast-like organisms (YST)
1.80 – 2.20	Spore-forming Gram-positive bacilli (BCL)

Statistical analysis

Statistical analysis was conducted using Genstat Tenth Edition (v10.3.0) to analyze data related to the physical and chemical characteristics of the Euphrates River water quality. Descriptive statistical analysis included calculating means and standard deviations for the various variables under study.

RESULTS

Physiochemical properties

Table (4) shows the mean values of physicochemical characteristics of Euphrates River water at four stations in Fallujah City compared with the standard permissible limits. The recorded temperature values ranged between 17.000– 18.333°C, which are within the permissible limit (≤ 25°C). Turbidity values showed a noticeable variation among stations, ranging from 6.850 to 23.567 NTU, which exceeded the permissible limit (≤ 5 NTU) at all stations. The pH values ranged between 8.390–8.700, remaining within the acceptable range (6.5–8.5) for natural waters.

Electrical conductivity (EC) values were recorded at 1.157– 1.181µS/ cm), indicating low ionic concentration and remaining below the standard limit (≤ 1500 µS/cm). Alkalinity values varied between 139.233 and 152.000mg/ L, all within the permissible limit (≤ 200mg/ L). Total hardness (TH) values ranged from 467.667–499.667mg/ L, which are close to the upper permissible limit (≤ 500mg/ L).

Calcium concentrations ranged between 123.400– 132.600mg/ L, which are higher than the recommended limit (≤ 75mg/ L). Chloride concentrations were recorded between 120.690 & 126.007mg/ L, remaining below the allowable limit (≤ 250mg/ L). Sulfate values ranged from 376.333– 387.333mg/ L, exceeding the standard limit (≤ 250mg/ L) for all sampling stations. Potassium concentrations ranged between 3.000 & 3.633mg/ L, remaining below the standard value (≤ 12mg/ L). Total dissolved solids (TDS) values showed close readings among all stations, ranging from 835.667 to 847.000mg/ L, which are within the acceptable limit (≤ 1000mg/ L).

Overall, the obtained results indicate that most parameters were within the standard permissible limits for surface water, except for turbidity, calcium, and sulfate, which showed higher concentrations than the recommended levels.

Table 4. Physicochemical characteristics of Euphrates River water

Parameter	S1	S2	S3	S4	Standard Value (Sn)
Temperature (°C)	17.000	18.333	17.000	17.000	≤ 25
Turbidity (NTU)	6.850	12.033	23.567	8.973	≤ 5
pH	8.700	8.480	8.423	8.390	6.5 – 8.5
EC (μS/cm)	1.179	1.176	1.157	1.181	≤ 1500
Alkalinity (mg/L)	150.400	139.233	152.000	148.333	≤ 200
Total Hardness (mg/L)	492.333	467.667	496.667	499.667	≤ 500
Calcium (Ca^{2+} mg/L)	128.333	124.767	132.600	123.400	≤ 75
Chloride (Cl^{-} mg/L)	125.337	126.007	122.460	120.690	≤ 250
Sulfate (SO_4^{2-} mg/L)	387.333	382.333	382.667	376.333	≤ 250
Potassium (K^{+} mg/L)	3.633	3.067	3.067	3.000	≤ 12
TDS (mg/L)	847.000	835.667	836.333	836.000	≤ 1000

Bacteriological analysis

The results of the isolation and identification of bacteria from water samples collected from different stations in Fallujah City (Table 5) revealed a variation according to cultural property and biochemical between isolates. All isolates from Station (B) were Gram-negative, short rod motile. They were positive for the catalase, oxidase and KOH tests but their O/F test varied since some isolates displayed aerobic, while others fermentative activities. They were identified as *Campylobacter* and *Pseudomonas* bacteria. Station M isolates were all rod-shaped, motile and Gram-negative. O/F tests indicated that certain isolates were of the oxygenic type, whereas others were fermentative. All were catalase positive, and the majority of the strains were oxidase and KOH positive. They were identified as *Pseudomonas* and *Escherichia coli*.

Isolates from Station K exhibited diverse morphological components and one was categorized as Gram-negative rod, another as Gram-positive spherical and yet another as a Gram-negative rod. The O/F test yielded neither fermentative nor non-fermentative results. The isolates were catalase positive and the majority was oxidase positive. *Pseudomonas*, *Enterococcus faecalis* and *Campylobacter* were isolated. Regarding station (A), the isolates were Gram-negative, as well as, a single rod spiral form and a motility test-positive results of (O/F) test indicated that they behave as aerobic or fermentative elements. Doing catalase tests for those isolates we take positive reactions while doing oxidase tests show to be negative and because of these the isolates determine to belong to *Pseudomonas* and *Escherichia coli*.

Table 5. Results of farm and biochemical tests in the city of Fallujah

No.	Station	Dilution No.	Gram Stain	Shape / Arrangement	Motility	O/F	Catalase	Oxidase	KOH	Identified Bacteria
1	B	1	-ve	Bacilli	+	U	+	+	+	*Campylobacter*
2	B	2	-ve	Bacilli	+	U	+	+	+	*Campylobacter*
3	B	2	-ve	Bacilli	+	O/F	+	+	+	*Pseudomonas*
1	M	2	-ve	Bacilli	+	O/F	+	+	+	*Pseudomonas*

2	M	2	-ve	Bacilli (single)	+	F	+	–	+	*Escherichia coli*
3	M	2	-ve	Bacilli	+	O	+	+	+	*Pseudomonas*
1	K	1	-ve	Bacilli	+	F	+	+	+	*Pseudomonas*
2	K	3	+ve	Coccus	+	F	+	+	–	*Enterococcus faecalis*
3	K	3	-ve	Bacilli	+	U	+	+	+	*Campylobacter*
1	A	1	-ve	Bacilli	+	O	+	+	+	*Pseudomonas*
2	A	2	-ve	Bacilli (single)	+	O/F	+	–	+	*Escherichia coli*

Results in Table (6) show noticeable variations in the total bacterial counts among the sampling sites and between the two sampling months (December and March). In nutrient agar, the bacterial counts were generally higher compared to MacConkey agar, indicating the presence of a wide range of heterotrophic bacteria in the water samples. The highest count was recorded at the mixing point (K) during March (244.5 CFU/ml), followed by the after outlet (AF.M) station in December (170.5 CFU/ml), Conversely, the before outlet (BE.M) station showed the lowest bacterial counts. The counts on MacConkey agar were lower overall, representing a smaller proportion of enteric or Gram-negative bacteria which indicates that not all isolated bacteria were enteric pathogens. Seasonal differences also appeared, with generally higher bacterial counts in March.

Table 6. Total bacterial count in nutrient agar and MacConkey agar media

Sample	**Nutrient Agar (CFU/ml)**		**MacConkey Agar (CFU/ml)**	
	December	March	December	March
Before outlet (BE.M)	87.5	33	15.5	2.5
Outlet (M)	106.5	196.5	33.5	0.5
Mixing point (K)	139.5	244.5	26	4.5
After outlet (AF.M)	170.5	18	15.5	0.5

Results in Table (7) show the percentage distribution of bacterial isolates obtained from water samples cultured on both nutrient agar and MacConkey agar media at different sampling sites. Before the outlet (BE.M), the dominant bacterium on both media was *Sphingomonas paucimobilis*, representing 51.5% on nutrient agar and 39.5% on MacConkey agar, followed by *E. coli* and *Klebsiella pneumoniae* spp. with lower percentages. At the outlet (M), *Klebsiella pneumoniae* spp. showed the highest percentage on both media, reaching 38.5% on nutrient agar and 34.5% on MacConkey agar, while *E. coli* and *S. paucimobilis* appeared at lower levels. At the mixing point (K), *Klebsiella pneumoniae* spp. also dominated, with noticeable values on both media, followed by *E. coli* and *S. paucimobilis*. After the outlet (AF.M), *E. coli* recorded the highest percentages on both media, with 41.5% on nutrient agar and 34.5% on MacConkey agar, while *S. paucimobilis* and *K. pneumoniae* spp. were less frequent.

These findings indicate a variation in the dominance of bacterial species across sampling points and between the two culture media.

Table 7/ Percentage distribution of bacterial isolates in nutrient agar and MacConkey agar

Sample	Nutrient Agar (%)			MacConkey Agar (%)		
	K. pneumoniae ssp.	*E. coli*	*S. paucimobilis*	*K. pneumoniae ssp.*	*E. coli*	*S. paucimobilis*
Before Outlet (BE.M)	12.2	21.5	51.5	18.2	36.6	39.5
Outlet (M)	38.5	19.1	10.6	34.5	16.5	18.5

**Mixing point

DISCUSSION

Water temperature is one of the most important physical parameters that govern biological, chemical and physical processes of aquatic ecosystems. It influences gases, mainly oxygen, solubility and govern the metabolism of aquatic organism **(Bonacina *et al*., 2023)**. In the current research, the temperature of Euphrates River water was between 17.000 & 18.333°C, which is regarded within the agreed limit (≤ 25°C). These values suggest that the sampling period was within moderate climatic conditions and that there were no sources of thermal pollution. Similar temperature intervals were reported by **Al-Obaidi *et al.* (2023)** along the Euphrates River at Ramadi, recording temperatures of 16–19°C **(Al-Obeidi & Al-Tamimi, 2023)**. On the other hand, **Hassan *et al.* (2022)** found slightly higher values at Al-Najaf with values reaching 21– 24°C in summer. This is due to seasonal variation in temperature **(Hassan & Ghazi, 2023)**.

Turbidity reflects the presence of suspended particles such as clay, silt, organic matter, or microorganisms, which affect light penetration and photosynthesis in water bodies **(Sehgal *et al*., 2022)**. In this study, turbidity ranged from 6.850 to 23.567 NTU, exceeding the WHO permissible limit of 5 NTU. Such high turbidity levels may result from surface runoff, domestic discharges, and sediment resuspension caused by flow turbulence. Similar high turbidity was reported by **Rashid *et al.* (2024)** in central Iraq, where values exceeded 20 NTU during high-flow periods **(Rashid *et al.*, 2024)**. However, **Kahami *et al*. (2023)** observed lower values (< 7 NTU) in upstream regions with limited human activity, indicating that local anthropogenic factors contribute significantly to turbidity elevation **(Kahami *et al.*, 2023)**.

The pH is an important parameter in the water chemistry and biological equilibrium, affecting metal solubility and nutrient availability **(Saalidong *et al*., 2022)**. The pH values in the present study have fallen within acceptable limits (6.5–8.5) with a range of 8.390– 8.700. Weak alkalinity indicates that bicarbonate is the dominant buffering characteristic in the rivers. Similar pH values (8.2–8.7) have been reported by

Dey *et al.* (2021). They reported a higher pH value (> 7.5) for the Euphrates River water, with a reduced reading (~7.5) in influents of the Tigris River, reflecting geochemical differences among basins.

Electrical Conductivity (EC) reflects the total ionic concentration and provides a rapid estimate of dissolved salts in water **(Dewangan *et al*., 2023)**. The EC values recorded in this study (1.157–1.181 µS/cm) were below the standard threshold (≤ 1500 µS/cm), implying moderate mineralization. These findings align with those of **Rahman *et al.* (2023)**, who documented EC values of 1.10– 1.30µS/ cm in the same region. However, moderate conductivities (2.1–11.34 µS/cm) were reported downstream by **Mahmood *et al.* (2025)** indicating gradual ion enrichment along the river flow due to agricultural return flows.

Alkalinity measures the water's ability to neutralize acids and is mainly derived from bicarbonate and carbonate ions. It plays an essential role in buffering against pH fluctuations **(Boyd, 2019)**. The recorded alkalinity values (139.233–152.000 mg/L) fall within the permissible limit (≤ 200mg/ L), suggesting that the Euphrates River in Fallujah retains good buffering capacity. Similar findings were reported by **ALP *et al*. (2010)**, who found alkalinity levels between 130 and 160mg/ L in the central Iraqi reaches.

Total hardness (TH) represents the combined concentration of calcium and magnesium ions and directly influences water usability for domestic and industrial purposes **(Hailu *et al*., 2019)**. In this study, TH values ranged from 467.667– 499.667mg/ L, which are near the upper permissible limit (≤ 500mg/ L), classifying the water as "hard." Comparable hardness levels were documented in the study of **Ingin *et al*. (2024)** with values in the Euphrates River reaching 480– 510mg/ L.

Calcium (Ca) plays a critical role in aquatic ecology and contributes largely to total hardness **(Ingin *et al.*, 2024)**. The measured concentrations (123.400– 132.600mg/ L) exceeded the standard limit (≤ 75mg/ L), indicating high Ca content likely derived from carbonate and gypsum dissolution. Similar enrichment was reported by **Islam and Majumder (2020)**. They found Ca concentrations of 120– 135mg/ L in the same watershed. Elevated Ca levels may result from local geology and reduced flow velocity favoring ionic accumulation.

Chloride (Cl) concentrations ranged from 120.690– 126.007mg/ L, which is well below the maximum allowable limit (≤ 250 mg/L). Chlorides typically originate from natural mineral leaching and domestic discharges **(Feth, 1981)**. Comparable concentrations were reported by **Kothari *et al*. (2021)** in the Euphrates (110– 140mg/ L), suggesting stable chloride input along this section of the river. Sulfate ions originate mainly from gypsum and anhydrite dissolution and industrial effluents. In this study, SO_4 concentrations ranged between 376.333 & 387.333mg/ L, surpassing the permissible limit (≤ 250mg/ L). Such high levels may reflect the influence of the local gypsum-rich formations and agricultural drainage. Comparable findings were obtained by **Al-Hadithi**

(2021), who reported SO_4 values of 340– 400mg/ L in the Fallujah sector, whereas lower levels (~200 mg/L) were observed upstream near Hit City **(Dawd *et al*., 2024)**.

Potassium (K) concentrations varied between 3.000 and 3.633mg/ L, which are below the WHO limit (≤ 12 mg/L). Potassium is an essential macronutrient for aquatic plants but is usually present in low concentrations due to its biological uptake **(Arega, 2020)**. Similar values (2.8– 4.1mg/ L) were reported by **Al-Moussawi (2020)** in Euphrates waters, confirming the natural range of K^+ in non-polluted environments. Total dissolved solids (TDS) represents the total content of dissolved inorganic and organic matter and is a major indicator of water salinity and quality. In this study, TDS values ranged from 835.667– 847.000mg/ L which is within the permissible limit (≤ 1000mg/ L). These results correspond with those of **Chabuk *et al*. (2021)** who reported TDS values of 800– 900mg/ L in the central Euphrates. Elevated TDS may affect taste and water usability, but the recorded levels remain acceptable for irrigation and domestic use.

The presence of bacteria in river water is scientifically expected, because even "clean" water contains natural microbial communities. However, the presence of multiple types of bacteria at high levels is due to several factors, including sewage flow, animal waste, surface runoff after rain, sewage leakage, farm drainage, and sometimes from surrounding soil and dust **(Satam *et al*., 2024)**.

According to World Health Organization guidelines, drinking water should be completely free of *E. coli* or coliform bacteria in a specified sample volume (e.g., 0 CFU per 100ml). Any presence of *E. coli* is indicative of a health hazard that threatens human safety. Additionally, total coliform counts should be very low or undetectable in safe drinking water. In Iraq, similar standards apply the 0 *E. coli*, no indicator bacteria **(Jamal *et al*., 2025)**, while the results of present study show the presence of *E. coli* and *Klebsiella* in significant percentages in water which indicates that health standards have been exceeded. Previous studies have shown that coliform counts and *E. coli* in river water or distribution systems often exceed health standards. In a study on the Euphrates River, coliform counts and enterococci exceeded international recommended limits in most water treatment **(Mustafa, 2009)**.

The difference in bacterial populations in March is due to the fact that bacteria are biologically active at favorable temperatures. In warmer months such as March, temperatures rise, increasing bacterial reproduction and enhancing growth capacity, while in December, temperatures are lower, reducing division and reproduction rates. This phenomenon has been observed in studies of microbial communities in rivers, where seasonal changes are a crucial factor in shaping bacterial community composition. The results of the current study are consistent with a study indicating a decline in bacterial populations in winter (**Hao *et al*., 2020)**. This is due to increased runoff rates due to rain, which can dilute bacteria in the water or dislodge them from their habitats. Bacteria are serious health hazards and cause gastroenteritis, diarrhea, as well as opportunistic infections especially in children, old people and those who are immunocompromised

(Cohen, 2022). Several studies have shown that contaminated surface waters represent a dangerous reservoir for resistant bacteria such as *K. pneumoniae* and *E. coli*. A genetic analysis of 149 *K. pneumoniae* isolates from surface waters in several countries revealed important resistance genes, such as carbapenem and colistin resistance, reflecting the ability of these aquatic bacteria to transfer drug resistance to the human environment **(Rolbiecki *et al*., 2025)**.

Physicochemical properties such as pH, conductivity (EC), dissolved oxygen levels, turbidity, and inorganic nutrients can play a key role and may change between summer and winter **(Guan *et al.*, 2023)**. These changes influence the selection of suitable and successful bacteria in the medium. Some bacteria prefer specific pH, salinity, or oxygen conditions, and their seasonal populations are therefore affected. The results of the current study are consistent with numerous studies on rivers and water sources which detected an increase in bacterial counts during warmer seasons compared to colder seasons due to accelerated growth, nutrient availability, and reduced high flow **(Fang *et al.*, 2023)**. While the results of the current study are inconsistent with the study of **Turner (2021)**, which denoted a decrease in summer bacterial counts in rivers due to other conditions such as solar disinfection, summer ultraviolet radiation, or a lack of organic nutrients may prevail, resulting in lower numbers appearing in summer compared to other seasons.

The physicochemical qualities of the Euphrates River water, as measured in this investigation, show values that are higher than those that are accepted as standard limits and may compromise public health of Fallujah's residents. High turbidity, especially at the S2 and S3 sites will lower the disinfection efficiency of water treatment which may increase potential microbial contamination and health risks for waterborne diseases. High levels of calcium and total hardness indicates high mineral content that causes scale in your household water system, and can cause gastrointestinal upset in sensitive consumers. Moreover, high levels of sulfate well over the standard maximum amount could also have a laxative effect, particularly in young children and old people. pH and TDS in the studied water sources were within the acceptable limits, however, since most parameters values exceeded the normalized limits, it is necessary to exert more efforts for monitoring and treatment process to provide safe domestic and drinking water for the sake of Fallujah residents.

CONCLUSION

The present study reveals an extensive evaluation of the physicochemical and microbiological properties, with respect to different sampling locations for Euphrates River water within the city of Ramadi. The environments were found to have acceptable levels of most of the physicochemical parameters such as temperature, pH, EC, TH, ALK and TDS that did not exceed completely those set by the WHO (2017) and Iraqi drinking water standards (IQS 417/2009). These results further suggest that the overall chemical and physical status of water is of good quality and indicates stable hydrological nature prevailing during studies time frame. However, three water-quality parameters turbidity, phosphate and calcium exceeded standard limits at limited stations. This water does not meet drinking-water standards in terms of safety as per the biological results for the presence of *E. coli, Klebsiella pneumoniae* and even enteric bacteria in large numbers. Drinking water in the untreated condition puts residents at risk of waterborne diseases. Thus, it is recommended to intensify routine microbiological monitoring of Euphrates River water and prevent the discharge of untreated wastewater into the river. Strengthening water treatment processes and raising public awareness about safe water use are essential to reduce potential health risks for Fallujah residents.

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