Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(2): 2393 – 2404 (2025)
www.ejabf.journals.ekb.eg

Evaluation of the Danfali Valley Discharges Which Flows into the Tigris River Within the City of Mosul Using the Canadian Model

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ARTICLE INFO
Article History:
Received: Jan. 15, 2025
Accepted: March 26, 2025
Online: April 19, 2025

Keywords:
Nitrate,
Phosphate,
CWQI,
Danfali Valley,
Tigris River

ABSTRACT

The current study dealt with the impact of the wastes of the Danfali Valley, located on the left side of the Tigris River, on the quality of the water of this river, which is considered the only surface resource for the residents of the city of Mosul, and evaluated the quality of this valley's water for drinking purposes using the Canadian Water Quality Guide. Monthly samples were collected from the water of this valley and were conducted on it. Many physical and chemical tests, in addition to performing a total bacterial count and diagnosing the bacterial species present, were conducted. The results of this study showed noticeable differences in the values and concentrations of the measured variables between the two sites. At the first site, the highest values recorded were: pH 9.4, turbidity 33.84 NTU, electrical conductivity (EC) 1093µS/ cm, total dissolved salts 587mg/ L, and total hardness 300mg/ L as $CaCO_3$. At the second site, the corresponding values were slightly different: pH 8.9, turbidity 39.22 NTU, EC 1103µS/ cm, total dissolved salts 480mg/ L, and total hardness 258mg/ L. While the concentrations of orthophosphate and nitrate also reached 0.58 and 0.63mg/ l in the water of the first site, while in the second site their concentrations reached 0.66 and 0.78, respectively. While the results of the Canadian Water Quality Guide showed that the water of the first site was of a questionable type in terms of its use for drinking compared to the water of the second site, since it was of a poor quality and both were unfit for drinking.

INTRODUCTION

Valleys are one of the phenomena spread within the geographical area of Nineveh Governorate, and usually the end of a part of them is thrown into the waters of the Tigris River, loaded with a lot of wastewater with various wastes, as the Tigris River is one of the important water resources in Iraq, and the largest Iraqi cities are located on it, including the city of Mosul. The river originates from the mountainous highlands located in southeastern Turkey and crosses Turkish territory to enter the Iraqi border near the village of Fishkhabur. After covering a distance of 400km from its source and entering Iraqi territory, five main tributaries flow into it along the river's path of 1,360km **(Ali, 2021; Al-Hamadany *et al*., 2024)**.

The river travels a distance of 188km from the Iraqi border to reach the city of Mosul, and the river currently intercepts the Mosul Dam 63km² before it reaches the city of Mosul. When it enters the city of Mosul, many types of pollutants are released into the river from different sources. Civilian sources are among the most prominent and most influential in the river because there is no treatment before releasing it, since it contains many organic, inorganic, and microbial pollutants. As for industrial waste, it constitutes another source of pollutants in the river's water because it contains large quantities and many types of pollutants. Large quantities of nitrogenous and phosphorous substances and pesticides used in agricultural activities also reach the river. About 500,000m^3/ day amounts of waste are estimated from the city of Mosul to the river. Natural sources also participate in increasing the concentration of some types of pollutants, and these include runoff and seepage from groundwater, as well as pollutants resulting from the activity of aquatic organisms **(Kannah & Shihab, 2022; Abd Alkader & Al-badrani, 2024)**.

The sources of pollution in the Tigris River can be divided into two main categories based on how pollutants enter the river: point sources and non-point sources.

Point sources refer to pollutants that enter the river from a specific, identifiable location—such as canals and valleys that have effectively become drains for wastewater, sewage, and industrial discharge. Some key examples include Wadi Al-Sharekhan, Wadi Al-Kharazi, Al-Khawsar River, Wadi Al-Danfeli on the left bank, and Wadi Akkab, Al-Harr River, along with several wastewater outfalls in old Mosul, especially near the old bridge and Qara Saray on the right bank.

Non-point sources, on the other hand, are more diffuse. These include runoff from agricultural lands, which carries fertilizers and pesticides into the river. In addition, general waste, garbage, and certain harmful human activities contribute further to the river's pollution **(Kannah & Shihab, 2021)**.

Many studies have been conducted on the water quality of the Tigris River, which indicates the deterioration of its water quality over time, including studies conducted on bacterial pollution of the Tigris River water in the city of Mosul. This study indicated the presence of significant contamination in bacterial species resulting from the discharge of waste and various excretions to the river without a treatment process **(Kannah *et al*., 2018)**. Additionally, studies on water pollution in the Tigris River south of Mosul have highlighted the impact of industrial waste—particularly from tanning and yeast factories—on water quality. **Sabawi and Kannah (2023)** reported a decline in water quality in this region, marked by bacterial contamination, low dissolved oxygen levels, and high concentrations of organic matter. **Al-Safawi (2018)** found that liquid waste discharged from human activities into the river contributes to increased water hardness. **Al-Rifai (2005)**, in his study of discharges from Wadi Al-Murr, observed elevated nitrate concentrations. Similarly, **Talaat (2012)** reported low dissolved oxygen levels along with high concentrations of organic matter, phosphates, and sulfates. **Al-Abadi (2018)** noted that the discharge rate of the valley reached 94.65m³/ min, and concluded that, in some cases, the water could be suitable for irrigating crops.

MATERIALS AND METHODS

Contaminated water samples were collected from some estuaries located on the Tigris River in Danifli Valley. The study area included two sites of Danifli Valley (Table 1), as these samples were subjected to many physical and chemical tests according to the methods proven by the US World Health Authority **(APHA, 1999)**.

Table 1. Study location

Location	Longitude	Latitude
First site	36°19'38.74" N	43°10'18.29" E
Second site	36°19'25.96" N	43°10'13.99" E

Fig. 1. The first site of the study Danfali Valley (Google Earth)

Fig. 2. The second site of the study Danfali Valley (Google Earth)

pH: Measured using a Hanna instruments HI 8424 field pH meter.
Turbidity: Measured using a Turbidity meter.
Electrical Conductivity (C.E): Measured using HANNA HI 9811-5 EC field meter and μm/cm.
Dissolved Oxygen: Measured using HANNA HI 9811-5 type field device.
Total Hardness as $CaCO_3$: It is a measure of bivalent positive ions caused by calcium and magnesium ions, measured using the EDTA Titration Method and using the EBT Manual (Eriochrome Black T).
Calcium hardness as $CaCO_3$: It is a measure of the concentration of divalent calcium ions and was measured using the EDTA Titration Method using the murexid ammonium borbaurate guide.
Magnesium hardness as $CaCO_3$: The scale of divalent magnesium ions is calculated from the following equation:
Magnesium hardness (mg/l) = Total hardness (mg/l) – Calcium hardness (mg/l)
Nitrates (NO^{-3}): Measured using an optical spectrometer Ultraviolet Spectrophotometric
Phosphate (PO_4^{-3}): Followed the Stannous chloride (colorimetric method)
Biological examinations: The total number of bacteria was measured using the standard plate count method, in addition to identifying the pathogenic species identified by the World Health Organization **(Abawi & Hassan, 1990)**.

Calculation of the water quality index

The Canadian Water Quality Index (CWQI), known for its high accuracy, has been widely used by researchers, including Salman et al. (2015). In this study, the

Canadian model was applied to ten parameters listed in Table (2) to calculate the water quality index. The calculation followed the stages outlined by **Lumb *et al*. (2006)**:

1. Scope (F1): The number of factors that exceeded the standard criteria divided by the number of total factors studied.

$$F_1 = \frac{Number\ of\ Failed\ Variables}{Total\ Number\ of\ Variables} \times 100$$

2- Frequency (F2): The number of tests exceeding the permissible limit value during the study period divided by the total number of tests measured.

$$F_2 = \frac{Number\ of\ Failed\ Tests}{Total\ Number\ of\ Tests} \times 100$$

3- Amplitude (F3): The number of failed tests whose value does not match the standards. This was calculated in three steps:

A- Excursion when the readings' values are higher than the standard parameters' values were calculated according to the following equation:

$$Excursion\ i = \left\{\frac{Failed\ Test\ Valuei}{Objective}\right\} - 1$$

B- The standard deviations, the Normal Sum of Excursions (NSE), and the average deviation were calculated using the method of summing the individual deviations from the guideline values and dividing this total by the number of tests conducted.

$$nse = \frac{\sum_{j}^{n}=1\ excursion}{total\ number\ of\ lests}$$

c- Then F3 was calculated according to the following equation:

$$F_3 = \frac{nse}{0.01\ nse + 0.01}$$

The Canadian Water Quality Index (CWQI) was calculated according to the following equation:

$$CWQI = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right]$$

Table 2. Classification of well water for water quality values **(Lumb *et al*., 2006**)

Grade	**Classification**	**CWQI values**
1	Excellent	95 _ 100
2	Good	80 _ 94
3	Fair	60 _ 79
4	Marginal	45 _ 59
5	Poor	0 _ 44

RESULTS AND DISCUSSION

pH

Table (3) indicates that the values of the pH function in the first and second sites ranged between 8.7 – 9.4 and 8.5 – 8.9, respectively. If the pH levels at the first and second sites are 9.8 and 7.6 respectively, the breakdown of organic matter by microorganisms releases carbon dioxide gas. This CO_2 interacts with water to form bicarbonates, which can influence the pH balance—either stabilizing it or causing a shift toward alkalinity, depending on the buffering capacity of the water **(Najeeb & Saeed, 2022)**.

Table 3. Physical and chemical characteristics of the Two site (Danfli Valley)

Site	Parameter	D.O	NO_3	PO_4	Mg^{+2}	Ca^{+2}	T.H	T.D.S	E.C	N.T.U	pH
Mid	Min.	0.24	0.21	0.18	14	67	225	400	708	3.86	8.7
	Max.	5.2	0.63	0.58	25	82	300	587	1093	33.84	9.4
	Mean	1.98	0.36	0.33	19.8	72	261	479	872.6	18.12	9
Out	Min.	0.12	0.10	0.14	15	62	225	403	704	2.05	8.5
	Max.	5.35	0.78	0.66	25	77	285	480	1103	39.22	8.9
	Mean	2.09	0.42	0.33	19.2	69	252	452	862.4	20.02	8.76
	Determinants*	5<	50	0.5	100	75	500	1000	400	5	8.5_6.5

International Standards for Drinking Water **(WHO, 2006)**.

Turbidity

The results presented in Table (3) show that the highest turbidity value at the first location was recorded in March, reaching 33.84 NTU, while the lowest value was 3.86 NTU in December. Similarly, at the second location, the highest turbidity was also observed in March, at 39.22 NTU, whereas the lowest value was 2.05 NTU, also recorded in December. The increase in turbidity values is likely due to rainfall and the materials it washes into the aquatic environment. Turbidity tends to increase with higher rainfall, as well as with increased discharge and current velocity at both sites. It may also be influenced by the presence of organic plankton, colloidal particles, and other suspended matter in the water **(Hmoshi *et al.*, 2024)**.

Electrical Conductivity (E.C)

Table (3) shows that the highest electrical conductivity value at the first site was 1093µS/ cm, recorded in March, while the lowest was 708µS/ cm in January. Similarly, at the second site, the highest value was 1103µS/ cm in March, and the lowest was 704µS/ cm in January. The elevated electrical conductivity levels may be attributed to increased concentrations of pollutants, which are influenced by the volume and nature of wastewater discharged into the river. These discharges—originating from domestic, industrial, and agricultural sources—often occur without proper treatment and typically contain various types of dissolved salts, contributing to the rise in conductivity **(Al-Hadedi *et al*., 2024)**.

Total dissolved salts

The results in Table (3) indicate that the concentration of total dissolved salts (TDS) at the first site ranged from 400 to 587mg/ L, while at the second site, concentrations ranged from 403 to 480mg/ L. The average concentrations were 479mg/ L at the first site and 452mg/ L at the second site. The higher TDS levels may be attributed to the presence of dissolved inorganic substances in the water. In contrast, lower concentrations could be due to the sedimentation of these substances, as well as the possible oxidation and breakdown of organic matter into water and carbon dioxide **(Al-Hayani, 2018; Othman *et al*., 2021)**.

Dissolved oxygen

The results shown in Tables (3 and 4) indicate that the highest concentration of dissolved oxygen at the first site was 5.20mg/ L, with a saturation rate of 55.5%, recorded in February. The lowest concentration was 0.24mg/ L, with a saturation rate of 2.4%, observed in March. At the second site, the highest and lowest oxygen concentrations were 5.35 and 0.12mg/ L, with corresponding saturation rates of 57.3 and 1.8%, recorded in February and March, respectively.

These variations may be attributed to the nature and volume of waste discharged into the river, which includes domestic, industrial, agricultural, and service-related sources. Many of these wastes contain high concentrations of biodegradable organic matter. Additionally, rainfall and runoff can carry more pollutants into the river, further reducing oxygen levels. Dissolved oxygen is essential for the survival and respiration of aquatic organisms, and its depletion can lead to the death of these organisms or disrupt their early life stages, such as larvae **(Kanber, 1981; Kannah & Muhammed, 2022)**.

Table 4. Saturation ratio and total count of bacteria at the two sites (Danfli Valley)

Site	**Parameters**	**Saturation ratio %**	**T.C.B Cell/ml**
Mid	Min.	2.4	$8*10^6$
	Max.	55.5	$90*10^6$
	Mean	20.2	$34.6*10^6$
Out	Min.	1.8	$1*10^6$
	Max.	57.3	$105*10^6$
	Mean	22.46	$58.4*10^6$

Total hardness and calcium and manganesum hardness

The results in Table (3) show that the average values of the three types of hardness were higher at the first site compared to the second. At the first site, the hardness values were 261, 180, and 81mg/ L as $CaCO_3$, while at the second site, they were 252, 172.8, and 78.2mg/ L as $CaCO_3$, respectively. One of the main factors contributing to increased hardness is the discharge of liquid waste from various sources, as well as runoff during the rainy season, which can carry pollutants from nearby lands into the river through erosion **(Al-Safawi, 2018)**.

Nitrates (NO_3^{-1})

The results in Table (3) indicate that nitrate concentrations were generally higher at the second site compared to the first. At the first site, nitrate levels ranged from a high of 0.63mg/ L in March to a low of 0.21mg/ L in December. In contrast, the second site recorded a higher peak of 0.78mg/ L in March and a lower minimum of 0.10mg/ L in December. The presence of nitrogen in the water can be attributed to various sources, with wastewater being the most significant. Additional contributions come from the runoff and erosion of topsoil, which often contains organic matter and agricultural fertilizers **(Goldman & Horne, 1983)**.

Phosphate (PO_4^{-3})

As shown in Table (3), phosphate concentrations varied noticeably between the two sites. At the first site, the highest concentration was recorded in November at 0.58mg/ L, while the lowest was 0.18mg/ L at the second site in December. The average phosphate concentration at the first site was 0.331mg/ L, compared to 0.334mg/ L at the second site. Phosphates enter the water at both sites through a variety of human and industrial activities. These include wastewater from domestic sources—such as laundry and cleaning products—as well as discharges from industrial processes. Additionally, phosphate fertilizers and human excretion (with the average person releasing approximately half a kilogram annually) also contribute to phosphate levels in the water **(Al-Sarraj, 2013)**.

Bacteria

The results presented in Tables (4, 5) show significant variation in bacterial growth in wastewater at both the first and second sites. At the first site, the highest bacterial count was recorded in November at 90×10^6 cells/mL, while the lowest count was 8×10^6 cells/mL in December. In the second site, the highest count reached 105×10^6 cells/mL, with the lowest being 1×10^6 cells/mL, also in December.

Additionally, several pathogenic bacterial genera were identified in the wastewater from Wadi Danfali at both sites, as shown in Table (5). These varying bacterial counts highlight the high level of contamination in the water, reflecting the large volume of pathogens—particularly bacteria—being discharged daily into the Tigris River. Such contaminated water serves as a carrier for many waterborne diseases, posing a serious public health risk **(Toohi *et al*., 2025)**.

Table 5. Bacterial genera diagnosed for the studied sites

Site	Identified pathogenic bacterial species
Mid	*Pseudomonas, and Klebsiella* *E.coli*
Out	*Pseudomonas, and Klebsiella* *E.coli*

Environmental evidence

Water quality guide for drinking

The water quality index for drinking depends on some important criteria and characteristics, which is considered as a guide to water quality, and thus it gives some potential problems for water **(Rabeea, 2021; Kannah & Muhammed, 2022)**. The results of the study, as shown in Table (6), indicate that the Canadian Water Quality Index (CWQI) values for drinking water classify most of the samples as having “moderate” quality. However, water sample No. 10 was categorized as “doubtful,” with the lowest recorded CWQI value of 51.8. In contrast, sample No. 2 achieved the highest CWQI value of 83.6, classifying it as “good” quality. The study also revealed that the concentrations of total dissolved solids and sulfate ions consistently exceeded the standard limits, while calcium ion concentrations surpassed the standards in some individual samples.

Table 6. Values and classification of water quality from wells in some areas of the city of Mosul for drinking

Site	Classification CWQI	Values CWQI	F_3	F_2	F_1
Mid	Marginal	48.15	53.53	40	60
Out	Poor	44.39	51.85	38	60

CONCLUSION

This study highlights the urgent need for a wastewater treatment process for the valley, as its waters carry substantial pollution from residential, industrial, and agricultural areas before being discharged into the Tigris River. Given that the Tigris serves as the sole source of raw water for the city’s residents, untreated discharges pose a significant public health and environmental risk. Analysis of the valley's wastewater revealed that several parameters exceed the permissible limits for discharge into surface waters. Furthermore, the presence of multiple types of pathogenic bacteria was confirmed, underscoring the potential for the spread of waterborne diseases if proper treatment measures are not implemented.

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