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Evaluation of the Effects of Tigris River Water Quality on the Rotifers Community in Northern Baghdad by using the Canadian Water Quality Index (CCME-WQI)

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Abstract

The water quality index was used for the evaluation of the quality of water, as well its impacts on the rotifer abundance, in the Tigris River as it passes through Mishahda City, northern Baghdad. Five sites were selected and samples were collected during October 2019 to September 2020. It was noticed that the index values in most sites have exceeded the upper limits of river waters. The values ranged from 40 (Poor) to 45 (Marginal) in all sites. While, the values were from 42 (Poor) to 65 (Fair) during different seasons. As for drinking usages, the results demonstrated poor or undrinkable (31-40) water in all sites. Meanwhile, the values ranged from 39 (Poor) to 56 (Clear) in regard to seasons. The index values recorded for the purpose of Conservation of Aquatic Organisms ranged from 36 (Poor) to 66 (Fair) in the all sites, and 56 (Clear) to 69 (Fair) during different seasons. Twenty five rotifer species were recorded, including 11, 2, 1, 5, 2, 1, 2, and 1 species of Brachionidae, Euchlanidae, Gastropodidae, Lecanidae, Lapadellidae, Notomanatidae, Synchoetidae, and Trichotoidae, respectively. It is concluded that the water of the Tigris on Mishahda City is considered to be highly contaminated and not suitable for human consumption without the necessary treatment. It was also noticed that the population density of the rotifers community was affected by the river water quality. However, despite the presence of environmental pressures, the rotifers continued to reproduce and conserve.

Keywords: Rotifera; Water quality; Tigris River; CCME.

تقييم تأثير جودة مياه نهر دجلة على مجتمع الدولابيات عند شمال بغداد حسب مؤشر جودة المياه الكندي (CCME-WQI)

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الخلاصة

تم تقييم مؤشر جودة المياه لنهر دجلة أثناء مروره عبر مدينة المشاهدة و اثرها في وفرة الدولابيات. اختيرت خمسة مواقع وتم جمع العينات خلال شهر تشرين الاول 2019 الى ايلول 2020. تم ملاحظة ان معظم

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المتغيرات قد تجاوزت الحدود المسموح بها لقياس جودة مياه الأنهار، والتي تراوحت بين 40 (فقير) إلى 45 (حافي) للمحطات، في حين تراوحت قيم الدليل بين 42 (فقير) إلى 65 (مقبول) للفصول. أما قيم دليل نوعية المياه لأغراض الشرب فقد سجلت النتائج قيم تتراوح بين 31-40 للمحطات ضمن الفئة فقير أو غير صالح للشرب، في حين سجلت قيماً تتراوح بين 39 (ضعيف) إلى 56 (صافي) للفصول. سجلت قيم الدليل لمعيشة الاحياء المائية قيماً تراوحت بين 36 (ضعيف) إلى 66 (معتدل) للمحطات و 56 (صافي) إلى 69 (مقبول) للفصول. سجل 25 نوعاً تعود الى 10 و 12 و 15 و 2 و 3 و 1 نوع تابعة لكل من Brachionidae و Euchlanida و Eastropodidae و Lecanidae و Lapadellidae و Cephalodella و Synchoelidae و Trichotoidae على التوالي. وبذلك تعد مياه نهر دجلة عند مدينة المشاهدة ملوثة بشكل كبير وغير صالحة للشرب إلا بعد اجراء المعالجات الضرورية له، كما لوحظ ان كثافة الدواليبات قد تأثرت بنوعية المياه، وعلى الرغم من وجود الضغوط البيئية فقد استمرت بالتكاثر والحفاظ على النوع.

1. Introduction

Freshwater is regarded as one of the most important natural resources to sustain life and environment [1]. The Canadian Water Quality Index is considered as an efficient mathematical tool for measuring the quality of water, due to its capacity so summarise large amounts of data and convert them to more understandable information for the decision makers and the public [2]. This advantage comes from the fact that the index is based on comparing the different variables that determine the quality of water to the acceptable limits and standards, and it produces a range value of 0-100 that represents the overall water quality [3].

Zooplanktons are heterotrophic microorganisms that rely on phytoplanktons and smaller zooplanktons as the main source of nutrition [4]. However, they play a role in improving the quality of water by feeding on algae and bacteria [5].

Rotifers constitute a major group of zooplanktons [6] and its proliferation and distribution are affected by different biological and non-biological factors, some might be related to nutrients accessibility, seasonal climate, and their tolerance to the different chemical and physical factors [7].

There are many studies that have been conducted on the quality of the Tigris water. For example, Al-Azawii *et al.* [8] classified water of Tigris River near Al-Rasheed power plant as poor in winter and fair to marginal in the other seasons, for both drinking and aquatic life. As for the study of Al-Janabi *et al.* [9], it pointed out the decline in the quality of Tigris water and the exceeding of the acceptable limits of the tested variables. As for Al-Obaidy *et al.* [10], they found that Tigris water passing through Baghdad was not suitable for biological life and was rated poor.

Rotifers have shown dominance in most studies, which is due to their small size, short life cycle, and tolerance to the environmental factors, as well as for the fact that they are opportunistic species that are capable of swallowing microorganisms like bacteria and detritus [11]. Many studies, such as those of Al-Bahathy and Nashaat [12], recorded highest density of rotifers in the Euphrates River near Hindiya Dam during winter. While the study of Salman *et al.* [13] in Al-Gharraf River recorded the highest density during spring and summer. As for AL-Azzawi [14], he recorded the highest density in the Tigris River during spring. However, Abed and Nashaat [15] recorded the highest density in Dijaila River in Wassit Governorate during spring and autumn.

As a result, the present study's aims were to evaluate the Tigris River's water quality as it passes through Mashahda City by measuring some of the water's physical and chemical characteristics. A database of rotifer communities in the studied region was also produced, while the impact of water quality on Mashahda rotifer communities was investigated.

2. Materials and Methods

Five sites were selected along Tigris River between Tarmia and Taji City (Figure 1), as follows:

First site: This site is located on an agricultural and residential area at 33, 63°N ;44, 35°E and characterised by its wide sector, with abundance of *Phragmites australis* , *Typha domingensis* , algae, and other aquatic plants.

Second site: This site is located on an agricultural and residential area at 33, 61°N ;44, 34°E and characterised with abundance of *Phragmites australis*, *Ceratophyllum demersum* L., and algae.

Third site: This site is located on an agricultural and residential area at 33, 59°N ; 44, 33°E and characterised by its narrower sector than the second site, with abundance of *Phragmites australis*, *Ceratophyllum demersum* L., and algae.

Forth site: This site is located on an agricultural and residential area at 33, 58°N ;44, 32°E. The river is wider at this site, with abundance of *Phragmites australis* , *Typha domingensis*, *Ceratophyllum demersum* L., algae, and other aquatic plants.

Fifth site: This site is located on an agricultural and residential area at the end of Taji City, near Shaikh Hamad's masjid, at 33, 56°N ;44, 32°E and characterised by its narrower sector than the forth site, with abundance of *Phragmites australis*.

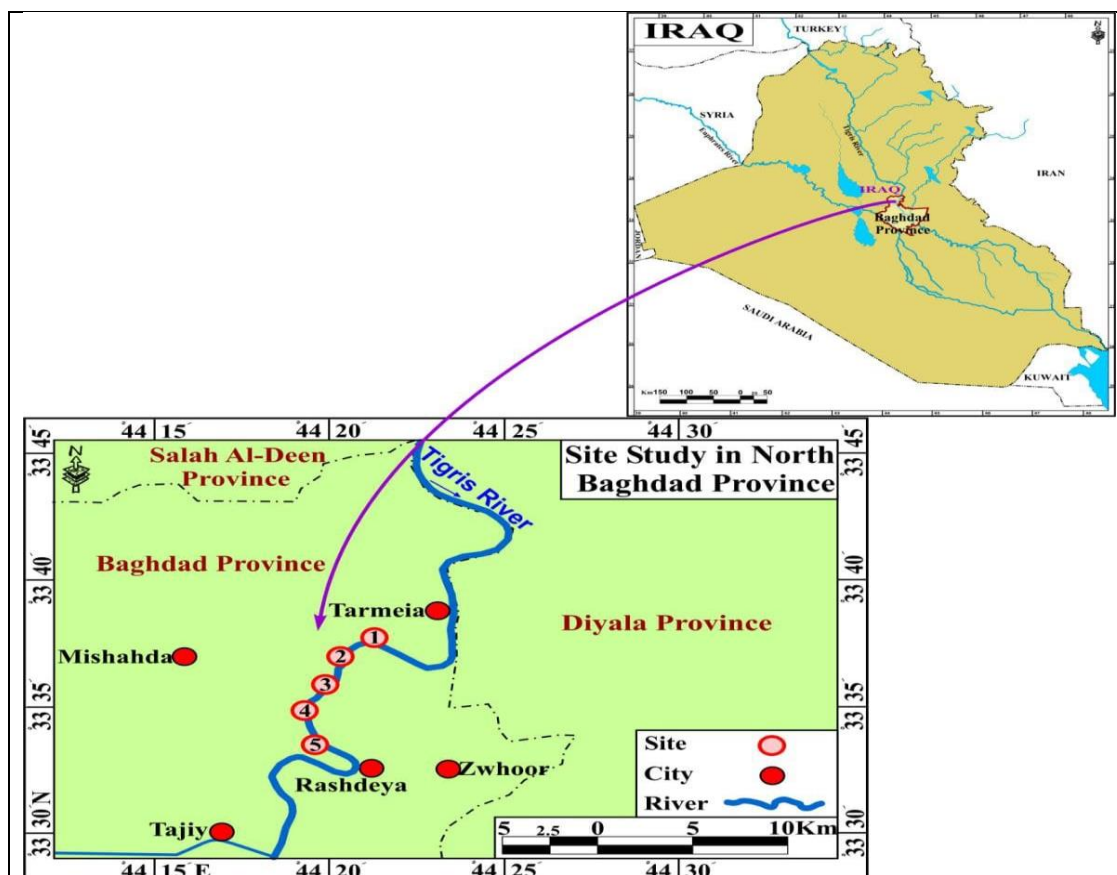


Figure 1-Map of Tigris River with locations of the studied sites Northern of Baghdad Province .

2.1 Samples Collection and Analysis

The samples were collected monthly from the five sites between October 2019 and September 2020. Eleven physical and chemical parameters were measured; these were: Temperature, Turbidity, Conductivity, pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD₅),

Total Hardness, Sulphate, Total Dissolved Solids (TDS), Nitrates, and Phosphates, in accordance with the methods outlined in previous reports [16-21].

Rotifers samples were collected also monthly from each site, by filtration of water through a Hydro-Bios net with a mesh size of 55 μ. The specimens were preserved in 4% formaldehyde. The species were identified according to the diagnostic keys described earlier [22-25]. The results are expressed as individual/m³.

2.2 Calculating the Value of the Water Quality Index

The CWQI for Overall, Drinking and Aquatic live computed by select a different set of parameters for each of them based on both importance and availability of data[10]

The CCME WQI was developed to be used as a tool for simplifying and interpreting water quality data. Three measures were selected to calculate the CWQI [2].

F₁ (Scope)

$$F_1 = \left[\frac{\text{Number of Failed Variables}}{\text{Total Number of Variables}} \right] \times 100$$

F₂ (Frequency)

$$F_2 = \left[\frac{\text{Number of Failed Tests}}{\text{Total Numbers of Tests}} \right] \times 100$$

F₃ (Amplitude): the number of exceeded tests were calculated in three steps

The first step: calculation of excursion. Excursion: is the number of times by which an individual concentration doesn't meet the objective, and is expressed as follows.

When the test value must not exceed the objective:

$$\text{Excursion} = \left[\frac{\text{Failed test value}}{\text{Objective}} \right] - 1$$

When the test value must not fall below the objective:

$$\text{Excursion} = \left[\frac{\text{Objective}}{\text{Failed test value}} \right] - 1$$

The second step: calculation

of Normalized Sum of Excursions (nse). Calculated as flow.

$$nse = \frac{\sum_{i=1}^n \text{excursion}}{\text{number of tests}}$$

The third step: calculation of Amplitude, F₃ is calculated by flow formula.

$$F_3 = \left[\frac{nse}{0.01 nse + 0.01} \right]$$

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

The final equation produces a value between 0 and 100 and gives a numerical value to the state of water quality. Note that a zero (0) value indicates a very poor water quality, whereas a value close to 100 indicates excellent water quality.

The water quality is ranked in the following 5 categories (Table 1) [2]:

Table 1- The five water quality ranks [2].

Rank	CCME WQI values
Excellent	95- 100
Good	80- 94
Fair	60- 79
Marginal	45- 59
Poor	0- 44

3. Results and Discussion

Twenty-five species that belong to 8 different families of rotifers were recorded, 11 of which were Brachionidae, 2 species of Euchlanidae, one species of Gastropodidae, 5 species of Lecanidae, 2 species of Lapadellidae, one species of Notomanatidae, 2 species of Synchoetidae, and one species of the family Trichotoidae (Table 2).

Table 2- List of rotifera species recorded during the study period.

Family	Genus	Species 1	Species 2	Species 3	Species 4	Species5	Species 6
Brachionidae	<i>Brachionus</i>	<i>B. angularis</i> Gosse, 1851 Site: 1,2,3,4,5.	<i>B. calyciflorus</i> Pallas, 1766 Site: 1,2,4,5.	<i>B. falcatus</i> Zacharias, 1898 Site: 2,3.	<i>B. plicatilis</i> Müller, 1786 Site: 1, 2, 3.	<i>B. quadridentatus</i> Hermann, 1783 Site: 1, 2,3,4,5.	<i>B. rubens</i> Ehrenberg, 1838 Site: 1,2 ,5.
		<i>K. cochlearis</i> (Gosse, 1851) Site: 1, 2,3,4,5.	<i>K. quadrata</i> (Müller, 1786) Site: 1, 2,3,4,5.	<i>K. tropica</i> (Apstein, 1907) Site: 1, 2,3,4,5.	<i>K. valga</i> (Ehrenberg, 1834) Site: 1, 2,3,4,5.	<i>K. tecta</i> (Gosse, 1851) Site: 2, 3.	
Euchlanidae	<i>Euchlanis</i>	<i>E. dilatata</i> Ehrenberg, 1832 Site: 1, 2,3,4,5.	<i>E. deflexa</i> (Gosse, 1851) Site: 2, 4.				
Lecanidae	<i>Lecane</i>	<i>L. bulla</i> (Gosse, 1851) Site: 1, 2,3,4,5.	<i>L. closterocerca</i> (Schmarda, 1859) Site: 1, 2,3,4,5.	<i>L. hamata</i> (Stokes, 1896) Site: 2, 4.	<i>L. lunaris</i> (Ehrenberg, 1832) Site: 1, 3.	<i>L. luna</i> (Müller, 1776) Site: 1, 2,3,4,5.	
Lepadellidae	<i>Colurella</i>	<i>C. adriatica</i> Ehrenberg, 1831 Site: 2,3,4,5.	<i>C. obtusa</i> (Gosse, 1886) Site: 2, 3.				
Synchaetidae	<i>Polyarthra</i>	<i>P. dolichoptera</i> Idelson, 1925 Site: 1, 2.	<i>P. vulgaris</i> Carlin, 1943 Site: 1, 3, 4.				
Gastropodidae	<i>Ascomorpha</i>	<i>Ascomorpha</i> sp. Site: 1.					
Notommatidae	<i>Cephalodella</i>	<i>C. gibba</i> (Ehrenberg, 1832) Site: 1, 2,3,4,5.					
Trichotriidae	<i>Trichotria</i>	<i>T. tetractis</i> (Ehrenberg, 1830) Site: 1,3,4,5.					

On the other hand, a clear variation was observed in the value of the overall water quality index. The values recorded had the range of 42-65, which classified the water to have poor-

fair categories (Table 3). During summer, the poor value, due to the depletion in the dissolved oxygen concentration, resulted in the increase of organic matter with an increase in water temperature [26].

However, it might also be caused by the decrease in water levels caused by evaporation, which consequently would lead to the increase in salinity, conductivity, turbidity, hardness, and biological oxygen demand.

As for spring, a relative increase in this value was recorded, which might be attributed to the relative improvement in some of the factors, such as conductivity, turbidity, biological oxygen demand, and total hardness. The values of these factors have experienced a decrease due to water dilution because of rainfall during the winter that came before spring, accompanied with the increase of water levels, as well as the graduate increase of the dissolved oxygen and decrease in temperature [27].

The severe decline in the quality of the Tigris water was reflected in poor drinking water quality in all seasons, except spring which showed a marginal value ranging from 39 to 56. Therefore, river water needs various treatment steps to become acceptable for drinking.

The low values of the water quality index were a result of the deviation in most of physical and chemical standard values for drinking water. They might be associated with the decrease of water levels and the increase in evaporation rates due to the high temperature during summer. All these factors have led the values of most variables to exceed the acceptable limits, except for dissolved oxygen and pH values that were within the acceptable drinking standards. This may be due to the speed of water current that provides a good mixing or the presence of green plants and phytoplankton. However, the study recorded a slight improvement in the quality of water during spring. This improvement could be attributed to rainfall during the winter that came before spring and the graduate decrease in temperature that has led to an increase in the dissolved oxygen value.

Table 3- Seasonal variation of water quality index in Tigris River sites.

	Data Summary	Overall	Drinking	Aquatic
Winter	CWQI	47	41	69
	Categorization	Marginal	Poor	Fair
	F1 (Scope)	33	33	50
	F2 (Frequency)	23	33	20
	F3 (Amplitude)	81	90	3
Spring	CWQI	65	56	67
	Categorization	Fair	Marginal	Fair
	F1 (Scope)	33	33	50
	F2 (Frequency)	26	33	27
	F3 (Amplitude)	44	60	12
Summer	CWQI	42	39	60
	Categorization	Poor	Poor	Marginal
	F1 (Scope)	33	33	50
	F2 (Frequency)	32	33	47
	F3 (Amplitude)	89	94	12
Autumn	CWQI	43	40	56
	Categorization	Poor	Poor	Marginal
	F1 (Scope)	33	33	50
	F2 (Frequency)	33	33	50
	F3 (Amplitude)	87	93	30

Meanwhile, the values of water quality index for the protection of aquatic organism life appeared in two categories, namely Marginal and Fair, as the values ranged between 56 and 69 during the study period (Table 3). This case is possibly related to anthropogenic activities [28].

Rotifers were affected by water quality of Tigris River, as noticed by rotifers density which was increased significantly during spring and winter (Table 3 and Figure 2). During these two seasons, the water quality was rated Fair, which could be accredited to the stability of the environmental circumstances that are suitable for high rotifers density [29]. Furthermore, the moderate temperature during these seasons is perfect for their reproduction [30], in addition to the availability of nutrients resulting from the moderate temperature that could have increased the primary productivity and nutrient levels [31].

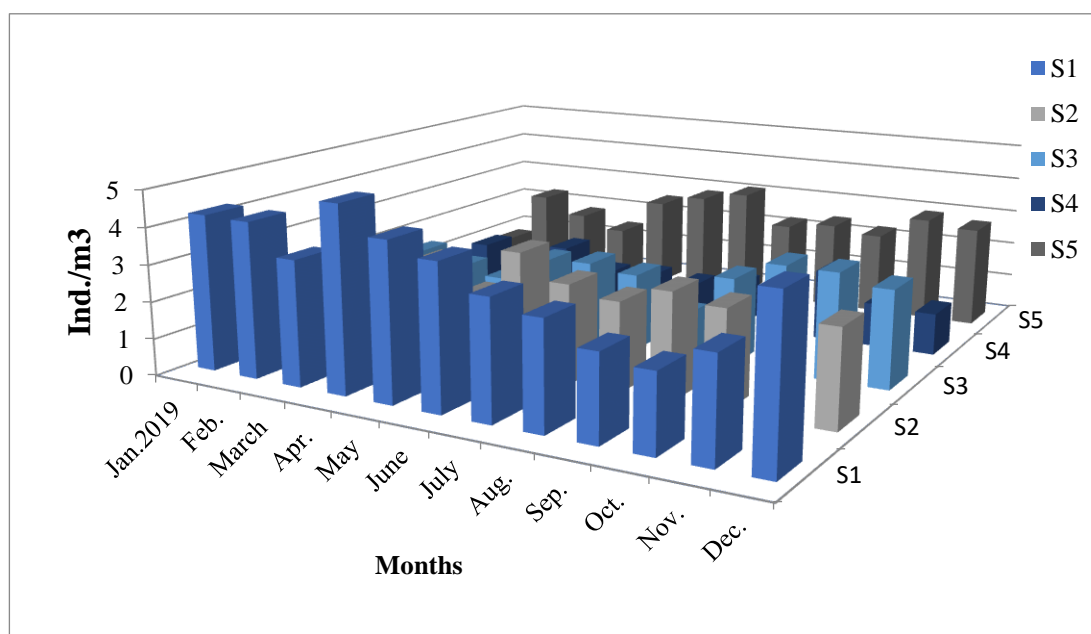


Figure 2- Seasonal variation of rotifera density during the period of study.

However, in summer and autumn, the water quality was classified as Marginal due to the floodplain period during 2019, which led to the increase in water levels and dilution of nutrients [32]. Hence, a significant decline in rotifers density was noticed during these seasons (Table 3 and Figure 2). As an alternative explanation, it might be attributed to the lower temperature and light transmittance and higher water flow, which lead to the change of surface zooplankton [33]. Also, higher agitation of sediments could have caused high density of suspended solid particles which have effects on light transmittance.

The values of overall water quality index varied between sites, ranging 40-45. Thus, the water was classified as Poor to Marginal. The highest value (45) was recorded at the second site, while it was Poor category at all other sites (Table 4). This indicates that the water quality is threatened in the river which is always exposed to polluted sources because it is located near residential communities and receives large quantities of pollutants resulting from the direct disposal of domestic sewage and agricultural and industrial wastes into the river water.

Nonetheless, the values of WQI for drinking water assessment were Poor in all sites and ranged 31-40. The highest recorded value was 40, which was recorded in all the sites, while the lowest was 31, being recorded in the fourth site (Table 4). These findings suggest that the Tigris water is not suitable for human consumption, unless it is treated. The reason for these results might be the untreated domestic sewage water and industrial and agricultural waste

that are disposed directly to the river [34], as well as the decrease in the water levels that would concentrate the pollutants in the untreated wastewater [35].

Table 4- Annual variation of water quality index at each site.

Site 1			
Data Summary	Overall	Drinking	Aquatic
CWQI	44	40	66
Categorization	Poor	Poor	Fair
F1 (Scope)	33	33	50
F2 (Frequency)	26	33	29
F3 (Amplitude)	87	93	13
Site 2			
Data Summary	Overall	Drinking	Aquatic
CWQI	45	40	62
Categorization	Marginal	Poor	Marginal
F1 (Scope)	33	33	50
F2 (Frequency)	31	33	42
F3 (Amplitude)	85	92	13
Site 3			
Data Summary	Overall	Drinking	Aquatic
CWQI	44	40	64
Categorization	Poor	Poor	Marginal
F1 (Scope)	33	33	50
F2 (Frequency)	29	33	38
F3 (Amplitude)	85	92	7
Site 4			
Data Summary	Overall	Drinking	Aquatic
CWQI	40	31	36
Categorization	Poor	Poor	Poor
F1 (Scope)	50	67	100
F2 (Frequency)	32	36	46
F3 (Amplitude)	86	93	11
Site 5			
Data Summary	Overall	Drinking	Aquatic
CWQI	44	40	60
Categorization	Poor	Poor	Marginal
F1 (Scope)	33	33	50
F2 (Frequency)	32	33	46
F3 (Amplitude)	85	92	13

Moreover, the values of this index for aquatic organism life ranged 36-66, thus classified to be within the two categories of Poor to Fair. The first site recorded the highest value of 66, while the lowest value was observed in the fourth site (36). Rotifers density values coincided with the values of this index, as the highest density of the rotifers assembly was recorded in the first site and the lowest was in the fourth site (Table 4 and Figure 2). This relation might be due to the nature of the physical and chemical factors that control biodiversity, species abundance, and zooplankton density [36].

However, the lower density found in the fourth site might be caused by the pollution resulting from dumping domestic sewage waste directly into the river and, as a result, of its decomposition that leads to higher consumption of dissolved oxygen in the water [6]. It might also be due to the fact that most variables have exceeded the acceptable limits of the Iraqi standards [37], as well as the Canadian standards for the protection of aquatic organism life [38].

Biological oxygen demand (BOD₅) recorded high levels, ranging from 1.3 mg/L in the second site to 8.1 mg/L in the fourth, which is a negatively determining effect on zooplankton [39]. This implies that the river water is questionable in its cleanliness.

Moreover, the Tigris River is considered as very hard according to the total hardness values, which ranged 10- 548 mg/L (Table 5).

Table 5- Water quality parameters and rotifers density at the study sites on Tigris River.

Site	1		2		3		4		5	
Parameter	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
W.T	12-30	21.72	30-12	21.93	13-29.3	21.80	13.5-30.5	22.15	13.6-30	22.34
Tur. (NTU)	5.1-61	27.70	2.15-58	22.58	4.1-69	29.69	4.2-120	34.42	5.45-101	36.91
EC (µs/cm)	400-1175	748.75	810-1030	930.33	810-1175	^{946.83} ₃	510-1175	912.75	850-1185	949.916
pH	6.7-8.5	7.308	6.8-8.4	7.508	7.1-8.4	7.533	7-8.5	7.625	7.1-8.4	7.666
DO (mg/L)	5.8-10.5	8.083	5.2-11	7.658	3.9-10.6	7.558	5-10.8	7.916	6-11.6	8.716
BOD ₅ (mg/L)	2.7-6.6	4.458	1.5-8.1	4.216	1.7-6.1	3.61	1.3-7.8	4.041	2.4-7.1	4.441
TH (mg/L)	320-520	408.3	310-468	398.55	320-520	405.55	320-548	392.2	320-503	391.66
SO ⁺⁴ (mg/L)	45-120	91.88	40-155	99.66	45-1130	83.4	50-150	96.13	50-150	91.66
TDS (mg/L)	330-520	358	440-540	466	400-620	481	400-570	470	420-560	490
NO ₃ ⁻² (mg/L)	0.940-2.515	1.52	0.823-1.998	1.33	0.91-1.844	1.41	0.883-1.888	1.36	0.796-1.822	1.33
PO ₄ ⁻² (mg/L)	0.012-0.051	0.033	0.018-0.052	0.039	0.018-0.061	0.041	0.016-0.084	0.041	0.015-0.063	0.032
Rotifera (Ind./m ³)	1.044-1200	479.755	111-1800	^{660.66} ₆	1.454-680	^{351.80} ₅	1.26-650	284.793	3.355-880	324.279

While the nitrates recorded values lower than the acceptable limits, ranging 0.796 -2.515 mg/L. Meanwhile, increased levels of total dissolved solids were recorded, ranging 330-620 mg/L (Table 5), which exceeds the internationally acceptable limit of 500 mg/l. This increase in WQI value might be associated with the overall low values of TDS.

Turbidity as well exceeded the level of 5 NTU, which is regarded as the acceptable limit, and recorded 2.15-120 NTU, due to the pollution of organic matter and suspended particles that are drifted from the soil during rainfall.

The current study concluded that the water of the Tigris passing through Mishahda City is considered to be highly contaminated and not suitable for human consumption unless the necessary treatment is applied. It was also noticed that the population density of the rotifers community was affected by the river water quality; therefore, they can be used as a bio-indicator for water quality.

However, despite the presence of environmental pressures, the rotifers continued to reproduce and conserve.

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