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Evaluation of Tigris River Water Quality using Biological Indicators

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Abstract

With the industrialization of societies, population growth, climate change, and increased exploitation of surface waters, environmental pollutants have increased, leading to a decrease in the quality of existing water resources. Therefore, examining the quality of river pollution is of great importance for agricultural and environmental programs. In order to investigate the water quality of the Tigris River using 4 biological indicators, sampling was carried out from April 2021 to March 2022 and the above indicators were calculated based on the data obtained. After identifying and determining sampling stations, biological indicators were calculated to determine the level of pollution in this river. The results showed that the average NAFWQI index indicated poor water quality, the BMWP index indicated moderate and poor water quality, the ASPT index indicated suspected pollution and pollution with medium levels, and the Helsonhof index indicated relatively poor and poor water quality. Based on the results of this study, most of the examined indicators show that Tigris River's water quality is in a low to moderate category.

Keywords

Tigris River, Water Quality, Biological Indicators, ASPT, BMWP.

Introduction

Rivers have always been essential and important to human societies, and cities and industrial and agricultural centers are usually built near rivers to take advantage of water resources. This

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not only meets vital needs but also helps meet agricultural and transportation needs. The increasing demand for water, rising living standards, and pollution of water resources due to the development of agricultural, urban, and industrial activities have created unfavorable environmental conditions and intensified water pollution, making rational management very difficult and complex. Quantifying the quantity and quality of pollutants, determining the quality status, and providing a suitable model for studying spatial and temporal changes in pollutants are among the most important components of water quality studies (Rahbari & colleagues, 2006).

Surface waters have a high potential for pollution. These waters have long been threatened by urban communities and industrial centers (Afghani and Erfanmanesh, 2012). Increased water consumption, depletion of natural water resources, environmental pollution, and increased water demand for human activities have made the evaluation of water quality one of the important issues in recent years (Khalaji et al., 2016).

Determining the qualitative characteristics of running waters is possible using hydrobiological studies. These studies are generally conducted in three sections: physicochemical, bacteriological, and biological. Among these, biological studies are of particular importance because they can provide a logical and reasonable judgment of an ecosystem with the help of other studies (Ahmadi and Nafisi, 2001)

Kefzian meetings reflect the general state of aquatic environments over a long period of time and are therefore among suitable indicators for evaluating aquatic ecosystems (Ebrahimi et al., 2004). On the other hand, changes in physical and chemical parameters of water can also affect kefzian communities, so exceeding these parameters can be life-limiting for some kefzians (James & JOEL, 2003).

One of the indicators of water quality is the National Sanitation Foundation Water Quality Index (NSFWQI) of the National Health Organization in America. This index is one of the simplest and most widely used methods for evaluating water quality, which is calculated using 9 water quality parameters (Landwehr & Deininger, 1976).

Biological indices are numerical expressions that combine quantitative measures of species diversity with qualitative information about the ecological sensitivities of each taxon relative to others (Czerniawsks-Kusza, 2005). A score is assigned to classify pollution intensity based on the tolerance levels of indicator species to pollutants. The most commonly used biological index is BMWP (Biological Monitoring Working Party), which was first proposed by the Biological Monitoring Working Party of the UK Environmental Agency in 1978 (Wally &

Hawkws, 1997). The average score per taxon (ASPT) is also a widely used biological index, which was proposed by Armitage et al. in 1983 and was accepted as a more reliable index for assessing river water quality compared to the total BMWP score (Czerniawska-Kusza, 2005). The Hilsenhoff Biological Family Index (HFBI) is one of the best and most cost-effective methods used in America and Europe today (Huang et al., 1982). This index provides an assessment of water quality changes for each station by demonstrating pollution caused by nutrients using the resistance level of each taxon to pollution (Hilsenhoff, 1988). Sanchez et al. (2006) used water quality and dissolved oxygen deficiency as a simple index for assessing water pollution. They concluded that the water quality index was useful for classifying water monitoring and there was a linear relationship between the water quality index and dissolved oxygen deficiency (Ravera, 2001).

The examination of biological indicators and environmental factors demonstrated the impact of human activities on river habitats and confirmed that an increase in human activities leads to spatial and temporal changes in river habitats, resulting in alterations in the diversity and abundance of benthic organisms (Wang et al., 2006).

Studies conducted on the Tigris River, by dividing the large population of benthic macroinvertebrates into 6 trophic groups including collector-gathering, collector-filtering, predator, scraper-collector, and scraper, have shown that the Tigris River has become more polluted from upstream to downstream due to stressful factors such as agricultural runoff, aquaculture farms, pollution caused by ecotourism and recreation. These factors have caused changes in the communities of macroinvertebrates and their population structure in a specific spatial range. In this study of aquatic insect larvae, the dominant group of benthic organisms in the Tigris River was found to be composed of collector-gatherers (Sharifinia et al., 2012). Similar results have been reported from the Chafrood River (Ghane Sasan Sarayi, 2003) and the Lasem River (Kamali and Esmaeili, 2009). This study was designed and conducted to evaluate the water quality of the Tigris River and classify it using the NSFWQI quality index and biological indices such as Bmwp, ASPT, and Hilsenhoff.

Materials and methods of work

Introducing the area:

The Tigris River is a vital source of water for domestic and economic activities in Iraq. The assessment of water quality in Iraq has become a vital issue in recent years, especially due to concerns that fresh water will become scarce in the future and will always be at risk of pollution. The Tigris River is the second longest river in West Asia, with a length of 1850 kilometers, originating from eastern Turkey and entering Baghdad as part of the alluvial plain with an average flow rate of 540 cubic meters per second for the period 2005-2020. Sampling: Water sampling was carried out in four stages and seasonally (in the middle of each season) at each station with three repetitions in an area where water mixing was fully done. Sediment sampling from the bedload of the river was carried out in 12 stages with a frequency of once every 30 days (from April 2011 to March 2012) using a Surber sampler (dimensions 34 × 34 cm and mesh size of 300 microns) with three repetitions along a transverse profile perpendicular to the riverbank at both sides and middle part of the river. The collected sediment samples were transferred to special containers after separating unwanted materials on standard sieves with a mesh size of 60 microns, fixed with formalin solution (4%), and transferred to the laboratory. The location of sampling stations is shown on Figure 1, and their geographical coordinates are given in Table 1 .

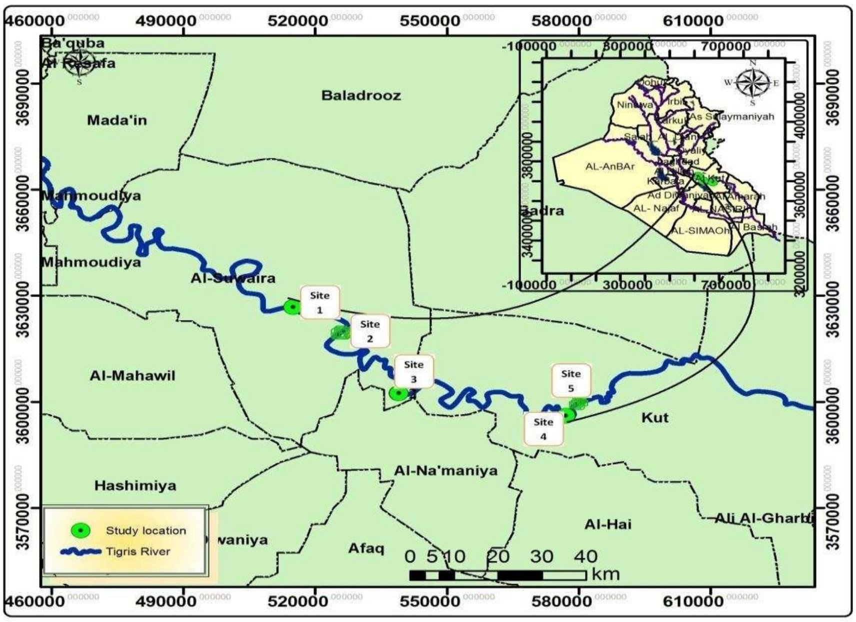

Figure 1: Map of the Tigris River and the study area (Used Arc-GIS Map program).

Table 1. The geographical positions (GPS) of the five study sites.

Sites	Longitude (eastwards	Latitudes (northward)
S1: Al-Aziziyah	°.9818′35	55°.9050′
S2: Zubaidiyah	55°.9799′	55°.8850′
S3: Numaniyah	55°.9111′	75°.7080′

S4: Before Kut dam	51°.1551′	10°.5520′
S5: After Kut dam	51°.1595′	10°.1105′

Identification of large invertebrate samples: After transferring the samples to the laboratory and washing them to separate any extraneous materials, the samples were identified using a loop and, if necessary, a microscope. The available identification keys were used to identify the specimens at the family level, and their numbers were counted.

Measurement of physical and chemical water parameters: Physicochemical parameters of water including temperature, dissolved oxygen, pH, EC, and turbidity at the station were measured using portable devices. Temperature was measured using a mercury thermometer with an accuracy of 1% Celsius degree, and dissolved oxygen was measured using a WTW-OXI 196 oxygen meter made in Germany. pH meter and EC meter were measured using digital meters model CORNING and CIBA made in America respectively. Turbidity was measured using a DRT-15CE turbidity meter. BOD5 and COD were measured by measuring the remaining oxygen after 5 days using an oxygen meter and digestion by reflux distillation method respectively, followed by colorimetric measurement. Nitrate ions were measured by spectrophotometry using a colorimeter method. TDS was measured by filtering and using an electrical conductivity meter, while soluble phosphate was measured by colorimetry using a JENWAY 6400 spectrophotometer model. Fecal coliforms were also measured by MPN 9-tube method with a dilution factor of 1 to 100 by Ghaemshahr Water and Wastewater Laboratory (APHA,1992).

Indices under investigation

ASPT and BMWP indices: all benthic macroinvertebrates collected at the family level (and some at the order level) were identified. Based on the scores assigned to each family in the modified BMWP scoring system in 1996 and 1997, a numerical score was assigned to each family (Wally & Hawkes, 1997). Finally, the scores of the families present in the sample were added together to obtain the BMWP score for that station. The ASPT index was calculated using equation 1 and water quality class based on tables 2 and 3.

Equation (1):

Number of taxa present in the sample / ASPT = BMWP.

Table 2: Water quality classification based on the BMWP index (Hawkes,1997)

Overall index score	Quality class	water quality
0 -10	very bad	Severe pollution
11 - 40	Bad	Contaminated or affected by contamination
41 - 70	medium	Moderately affected
71 - 100	Good	Clean, slightly affected

Table 3: Water quality classification based on the ASPT index (Armitage et al., 1983

water quality	ASPT
More than 6	Clean waters
5 - 6	Quality waters suspected of contamination
4 - 5	Waters with medium pollution probability
Less than 4	Highly polluted waters

Hilsenhoff index

The Helsinhoff index was estimated using equation 2 and to evaluate the water quality, the resulting values were compared with the data in Table 4 (Hilsenhoff, 1988).

Relationship (2)

$$HFBI = \sum Vt \times n / N$$

N: total number of samples in all families

n: total number of samples in each family

Vt: the bearing value of each family

Table 4: Water quality classification based on Hilsenhoff index (Hilsenhoff, 1988)

HFBI	water quality	Degree of contamination with organic matter
3/75 – 0/00	Excellent	No pollution
3/76 – 4/25	very good	Very little pollution
4/26 – 5/00	Good	Low pollution
5/1 – 5/75	medium	Moderate pollution
5/76 – 6/50	weak	A lot of pollution
6/51 – 7/25	Bad	Too much pollution

7/26- 10/00	very bad	Very heavy organic pollution

NSFWQI index

is calculated using quality measurement parameters including pH, BOD5, COD, nitrate, phosphate, temperature variations, turbidity, dissolved solids and fecal coliform in different stations during each season. The quality classification of water is determined using Table 5.

Relationship (3)

$$NSFWQI = \sum_{i=1}^{n} WiQi$$

Qi: sub-index of each parameter

Wi: weighting factor of each parameter

Table 5: The overall ranking of the NSFWQI Index (Landwehr & Deininger, 1976)

Numerical value of index	**Water quality feature**
0 -25	so bad
25 -50	Bad
50 - 70	medium
70 - 90	Good
91 - 100	great

Statistical analysis: Statistical analyses were performed using SPSS18 software (Zar, 1999). Firstly, the normality of the data was checked using the Kolmogorov-Smirnov test and the uniformity of variances was examined using the Levene test. One-way ANOVA was used to compare differences between stations and different sampling stages. The Duncan method was used for mean comparison at a %90 confidence level. Pearson correlation was used to examine the correlation between water quality indicators and parameters (Kotani et al., 2015) due to the normal distribution of data. Finally, Box and Whisker plots were drawn using Statgraphics software to investigate spatial and temporal changes in data and obtain an overall view of their variations in the Tigris River.

Results:

Based on the results of this study, a total of 9 families of the large unfeathered birds belonging to 7 orders and 3 classes were identified in the marshes of the Tigris River. The identified samples along with their presence in different stations are reported in Table 6.

Table 6: List of Macroinvertebrates identified in four stations of Tigris River in 2022

Category	right	Family	1	2	3	4
Insecta	Ephemeroptera	Baetidae	+	+	+	+
		Caenidae	+	+	+	+
	Plecoptera	Nemouridae	+	+	+	+
	Trichoptera	Hydropsychidae	+	+	+	+
	Diptera	Chironomidae	+	+	+	+
Gastropoda	Pulmonata	Physidae	+	+	+	+
	Porosobranchiata	Valvatidae	+	+	+	
Oligochaeta	Tubificida	Tubificidae	+	+	+	+
		Naididae		+	+	+

Changes in BMWP index at different stations and sampling times are shown in Figure 2. As observed, the comparison of means did not show a significant difference (P=%402) in the values of this index between different stations. The highest and lowest values of this index, which actually indicate the number of identified benthic families, were observed in stations 1 and 4, respectively.

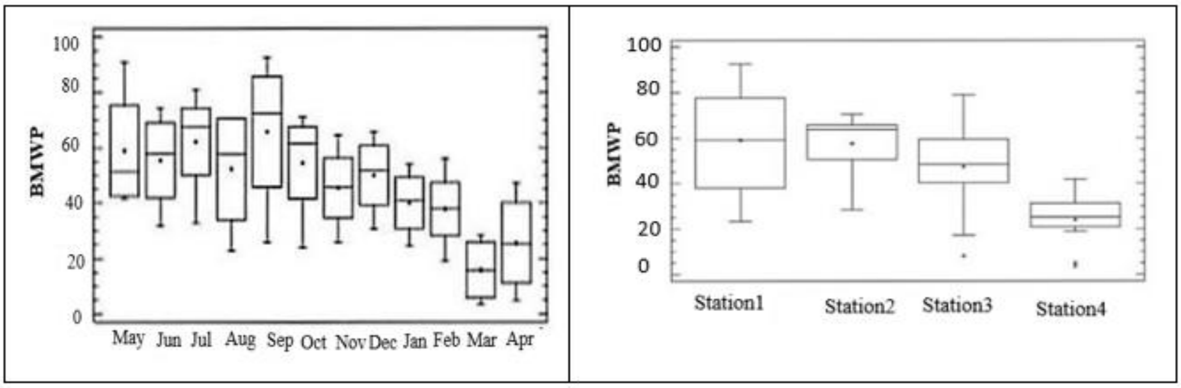

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Figure 2: Changes in the BMWP index at stations (A) and sampling times (b) in Tigris River 2022

Also, no significant difference (P=%465) was observed between different stages of sampling (Figure 2-b). In this graph, a decrease in the number of large families of benthic invertebrates was observed in the cold months of the year. The trend of ASPT index changes in the sampling stations is shown in Figure (3a). As can be seen, there is a significant difference ($p < 0.05$) in the average level of ASPT index between the studied stations. The highest value of this index was estimated at stations 1 and 2 and the lowest at station 4.

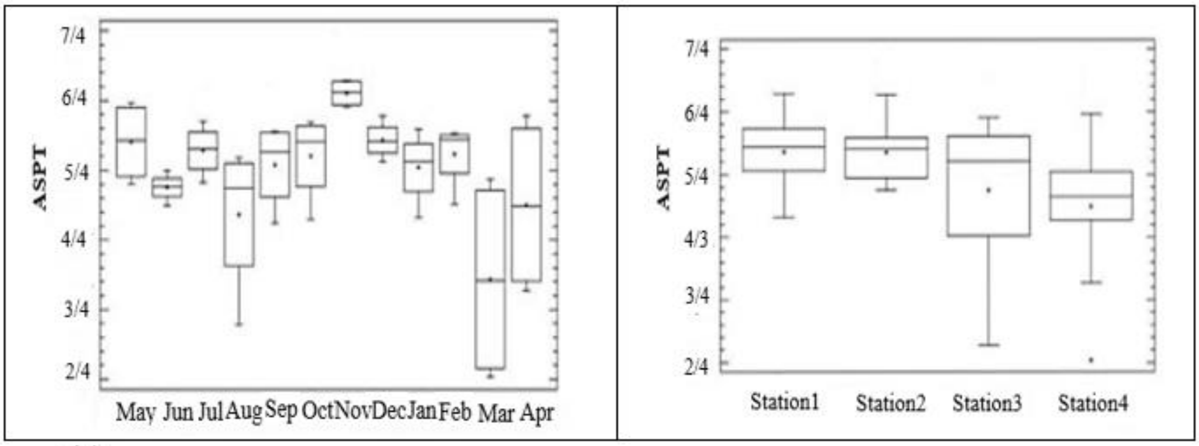

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Figure 3: The changes of the ASPT index in stations (A) and sampling times (b) in the Tigris River in 2022

Changes in the ASPT index during sampling times in figure (3b) indicate a significant difference ($p<0.05$) between sampling times. Based on the results, the highest amount of this index was calculated in November and the lowest in December. Changes in the Helson-Hubbard biological index at stations and sampling times are shown in figure 4. As observed, there is a significant difference ($p<0.001$) between stations (4a). The lowest average value of this index was recorded at station 1 and the highest at station 4.

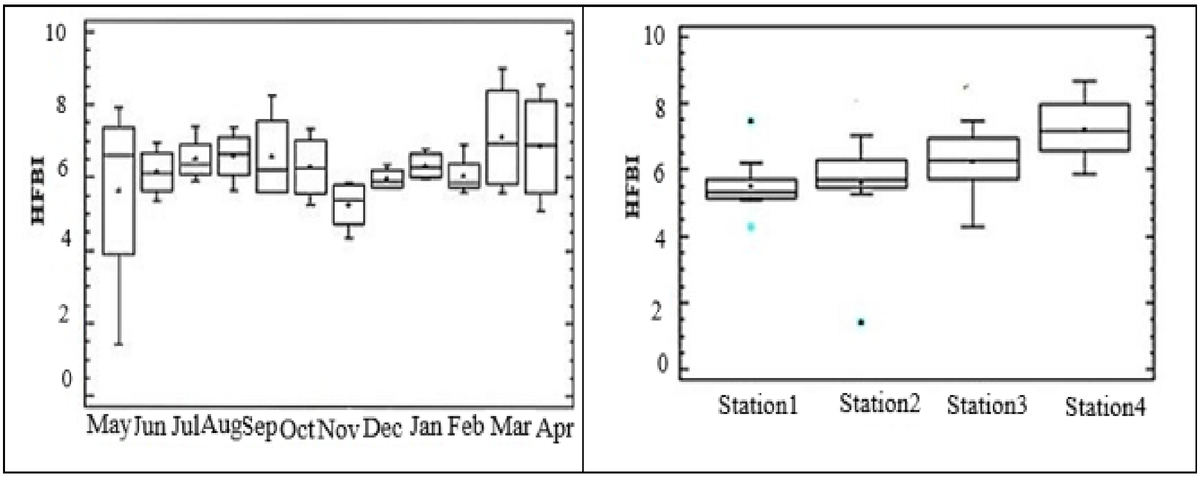

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Figure 4: Changes in the HFBI index in stations (a) and sampling times (b) in Tigris River 2022

The changes in this index during the sampling months are shown in figure (4b). The values of this index, like the BMWP index, did not show a significant difference between different months statistically (p = 0.452).

According to the Helson's index, the water quality of the river is suitable in November, weak in December and January, and relatively weak in other months. Figure 5 shows the changes in NSFWQI index values at the examined stations. As observed, water quality of the river showed a decreasing trend from upstream to downstream. This decrease is more apparent at station 2. Although the variance analysis test did not show a significant difference between different stations (p = 0.866)

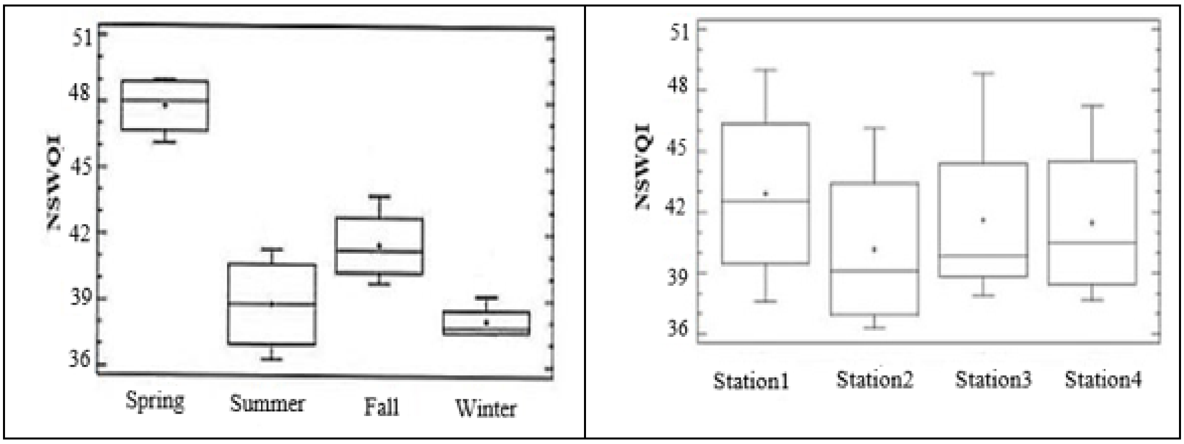

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Figure 5: Changes in NSFWQI index in stations (A) and seasons (b) Sampling in Tigris River 2022

On the other hand, changes in NSFWQI index in different seasons showed a statistically significant difference (p > 0.05) between different seasons of the year (Figure 5-b). According to this index, the river water quality in the studied area is bad in the spring season and very bad in other seasons. The correlation coefficients of the calculated indicators and quality parameters of Tigris River water in this study are reported in Table 7.

Table 7: Correlation coefficients of calculated indices and water quality parameters of Tigris river in 2022

Quality parameters of water	BMWP	ASPT	NSFWQI	HFBI
COD	0/514	-0/046	-0/305	0/372

BOD5	0/547	-0/059	-0/242	0/417
Nitrate	-0/125	0/074	-0/769**	-0/247
Phosphate	0/437	-0/166	-0/334	0/475
TDS	-0/908**	-0/331	-0/621*	-0/236
pH	-0/655*	-0/067	-0/328	-0/331
EC	-0/760**	-0/010	-0/392	-0/528
temperature	0/600*	0/224	-0/200	0/096
DO	0/192	0/475	0/788**	-0/406
Turbidity	-0/895**	-0/257	-0/537	-0/316
Faecal coliform	-0/912**	-0/348	-0/569	-0/231

*** meaningful on the surface 0/05**

**** meaningful on the surface 0/01**

In contrast to the changes in the NSFWQI index in different seasons, a significant statistical difference ($p < 0.05$) was shown between different seasons of the year (Figure 5-b). Based on this index, river water quality in the study area was poor in spring and very poor in other seasons of the year. The correlation coefficients of the calculated indices and parameters of Tigris River water quality in this study are reported in Table 7.

Discuss

Reduced rainfall, uncontrolled harvesting in highland areas, resulting in reduced river flow and warming of the air in summer, as well as the entry of urban, agricultural and industrial wastewater into rivers, pose a major threat to the downstream river ecosystem. All these factors cause extensive changes in the physical and chemical properties of water, including reduced oxygen, increased TDS, BODS, COD and TDS (Jorjani et al., 1999; Hosseinpour, 1995; Seather, 1962; Simeonov et al., 2002). The BMWP index (Figure 2) classified the quality of the Diyala River water as moderate during the study period. Among the stations surveyed, station 4 was classified as poor in terms of this index. The reason for the decrease in this index at station 4 is due to the presence of pollution-resistant benthic organisms, especially oligochaetes and chironomids, which have resulted from increased pollution load due to the entry of dissolved nutrients and suspended solids from domestic, agricultural and industrial wastewater. An increase in pollution-resistant species such as oligochaetes and chironomids due to environmental pollutants has been proven in similar studies (Jorjani et al., 1999; Silva et al., 1999).

On the other hand, the decrease in BMWP index during the cold months (Figure 2-b) is due to the sensitivity of this index to the number of families of benthic organisms, which can be due to the decrease in water temperature for oligochaetes and due to their life cycle for chironomids. Based on this index, water quality of the river was evaluated as average from April to December and poor in other months of sampling. Also, considering the significant and highly significant correlation between BMWP index and parameters such as pH, temperature, fecal coliforms, turbidity, EC and TDS that play an important role in estimating water quality index (NSFWQI) (Table 7), it can be concluded that it is possible to evaluate the water quality of Dez River using this index. In similar studies, Azrina et al. (2005) reported Langat River in Malaysia as having 4 classes of good, moderate, poor and very poor using BMWP index. Namati (2007) evaluated the biological status of Zayandehrud River using a large-scale study of benthic macroinvertebrates and physical and chemical factors. The results showed that BMWP index was a suitable tool for assessing the water quality status of Zayandehrud River and classified the study area into three classes: suspiciously polluted, moderately polluted and severely polluted. The ASPT index (Figure 3) classified Dez River water quality along its flow path generally into two classes: suspiciously polluted and moderately polluted. The imprecise delimitation of the assessed quality range is due to some biological indices calculated at family level having some weaknesses and problems in distinguishing between taxa or different times (Azrina et al., 2005).

In addition, due to the life cycle of large benthic macroinvertebrates (approximately 1 to 5.1 years) and their duration in aquatic habitats, it is not possible to accurately comment on the trend of changes in biological indicators with one-year monitoring. Overall, the Aspt index, like the BMWP index, showed a decrease in water quality towards downstream stations and estimated its ecological conditions as undesirable. This is while the river water quality during the study period (Figure 3b and Table 3) was classified into four categories: suspicious pollution, severe pollution, moderate pollution, and clean. These fluctuations indicate the severe impact of environmental factors, especially different human land uses on the water quality of the Tigris River. Additionally, it seems that the ASPT index has been more sensitive than the BMWP index and has better demonstrated changes in river water quality. Armitage et al. (1983) confirmed this conclusion by stating that regarding environmental factors, ASPT index shows better results than BMWP index.

The range of changes in the Helmholtz index is different from other indices, and the smaller the number, the better the water quality. Based on the data in Table 4 and Figure 4-b, stations

1, 2, and 3 have relatively poor quality, while station 4 has poor quality. The results of examining the Helmholtz index showed that this river generally had a low quality index at the studied stations, with an estimated average Helmholtz index between 5.76 and 7.20. This index was higher compared to measurements in other rivers flowing into the Caspian Sea (Kamali et al., 2009; Ghaeni Sarayi, 2003), indicating a higher volume of organic matter and severe pollution in this river. Karimian et al. (2009) and Naderi Jaloudar et al. (2011) used this index to evaluate water quality in rivers and found that because it is related to the range of organism tolerance, it is more accurate than other indices. In their study on the mountainous part of the Diyala River, they estimated the Helmholtz index between 4.29 and 5.75. The main reason for lower values of this index and consequently better water quality in their research was due to the studied stations being located in mountainous areas with less human activity affecting them. According to Figure 5, Station 2 showed the lowest value of NSFWQI index. This station is located in the urban area and is affected by both urban sewage and wastewater discharge. Therefore, the NSFWQI index showed the lowest value at this station. In terms of this index, all stations were classified as poor quality. In this area, Station 2 had a relatively better situation with the lowest value of the index. On the other hand, significant statistical differences were observed in NSFWQI index changes in different seasons ($p < 0.05$) (Figure 5-b). As mentioned before, this index is influenced by nine parameters that decrease along the river due to high levels of nitrates and phosphates, increased turbidity, and fecal coliforms. Mehrdadi et al. (2003) also attributed the high levels of nitrates in summer to increased agricultural activity and discharge of urban and industrial wastewater in Dejleh River. Sohrabian et al. (2009) also attributed the high levels of this index in Kalam Ilam River to an increase in some water quality parameters such as nitrates, phosphates, and BOD5. The excessive entry of organic matter from domestic, agricultural, and industrial wastewater into aquatic ecosystems affects turbidity, pH, BOD5, COD and accumulates decomposable organic matter that changes the quality of the substrate. All these factors affect the quality quantity of biological communities. If these substances enter aquatic environments within a limited range, they can create favorable nutritional conditions for some benthic organisms by increasing organic matter load. In this case, new habitats are provided for biological communities through changes in substrate structure and possibly increasing opportunities for aquatic plant emergence and development.

On the other hand, if organic matter levels exceed a certain limit (highly polluted environments), it limits biological communities' growth and negative correlations between physical and chemical parameters above and biological indices will be observed. This conclusion has also been confirmed in other studies (Sharifi Nia et al., 2012). Based on the table, the BMWP index showed a negative correlation at a %1 level with TDS, EC, turbidity, and fecal coliform factors, and a positive correlation at a %5 level with temperature and saturation factors. The pH factor also showed a negative correlation at a %5 level. All physical and chemical parameters of water affect benthic communities and changes in their family numbers affect the BMWP index. Other researchers have also shown that the BMWP index has a negative correlation with fecal coliform, TDS, EC, and BOD5 parameters and a positive correlation at a %1 level with oxygen saturation percentage and pH (Namati, 2007). The ASPT index also showed a positive correlation at a %5 level with saturation. Some researchers have stated in their studies that the ASPT index has a negative correlation with water chemical parameters and a positive correlation with physical factors such as slope, height, and discharge (Camen et al.,1995). The Helminth index also had a positive correlation with BOD5 and COD but did not show significant correlations. The NSFWQI index had negative correlations at a %1 level with nitrate and at a %5 level with TDS. In confirmation of these findings, other researchers have shown that the NSFWQIm index has negative correlations with parameters such as fecal coliform, EC, TDS, phosphate, nitrate, and BOD5 and positive correlations with oxygen saturation percentage and pH (Namati, 2007). Overall, the findings of this study evaluated the water quality of the Diyala River in the study area as average to poor. Therefore, the downstream area of the river (station 4) had the lowest water quality both spatially and in winter season.

Along with the general agreement among indicators in evaluating the quality of the Tigris River, limitations were identified in using biological indicators to interpret temporal changes in water quality. The reasons for these limitations can be attributed to factors such as changes in the riverbed during the study period, short study duration relative to the life cycle and presence of large populations of benthic macroinvertebrates in the riverbed, inaccurate compatibility of indicators with Iraqi conditions due to lack of fundamental studies in this area, and other ecological factors that can affect the structure of benthic macroinvertebrate communities.

Overall, the results of this qualitative study indicate that the water quality of the Tigris River is classified as moderate to poor based on the BMWP index, suspected pollution to moderate pollution based on the ASPT index, and relatively poor to poor quality based on the Helson index. Additionally, the NSFWQI index placed all stations in the bad quality category. These findings suggest that the Tigris River is increasingly affected by human activities and, due to its low flow rate, excessive use for agricultural purposes, receiving agricultural wastewater, discharging domestic and industrial sewage, has undergone a gradual deterioration in water quality. If proper management is not implemented to regulate and maintain its quality, it will face a high risk of severe pollution in the near future and its biodiversity will be threatened with extinction.

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