



Spatial and Seasonal Assessment of Water Quality in the Tigris River, Baghdad, Using Benthic Macroinvertebrate-Based Biotic Indices

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Abstract

This study aimed to evaluate the water quality of the Tigris River in Baghdad using benthic invertebrate communities as biological indicators. A total of 5722 individuals representing 12 taxa were collected including Chironomidae, Gammaridae, Thiaridae, Physidae, Lemnaceae, Nematoda, Tubificidae, Rotifera, Planariidae, and Naididae. Chironomidae was the less abundant group accounting for 27% of the total community followed by *Gammarus* spp. (25%), while *Potamothenis* spp. showed the lowest abundance (0.16%). Species richness index (D) values were relatively similar among the studied sites recording 3.25 at S1, 3.30 at S2, 3.16 at S3, and 3.24 at S4. Shannon–Wiener diversity index values ranged from 1.3 to 1.78 with the highest diversity observed at site S3 and the lowest at site S1. The Hilsenhoff Biotic Index (HBI) values ranged from 4.98 to 6.90 indicating low to moderate organic pollution at S1 and moderate to high pollution levels at the other sites. The Biological Monitoring Working Party (BMWP) index recorded its highest value at site S1 (21) while the remaining sites showed lower values (15). Correspondingly ASPT values ranged from 2.62 at S1 to 2.14 at the other sites reflecting varying degrees of environmental stress. Relative abundance analysis revealed the dominance of three major taxa: Chironomidae, *Gammarus* spp. and *Melanoides* spp. which together constituted more than 60% of the benthic community. Jaccard similarity index showed the highest similarity between sites S1 and S2 (91%) and the lowest between S1 and S4 (75%). Cluster analysis supported these patterns highlighting site S1 as the most distinct among the studied locations. Overall, the results demonstrate the effectiveness of benthic invertebrates as bio indicators for assessing water quality in the Tigris River and reveal clear spatial variability in environmental conditions associated with different human activities along the river course.

Keywords: Benthic Invertebrates, Biodiversity, Bio indicators, Tigris River.

1. Introduction

Rivers are considered one of the most important freshwater resources in natural ecosystems as they play a central role in supporting biodiversity and providing water for agricultural, industrial, and domestic purposes in addition to contributing to maintaining environmental balance^{1,2}. However, these water systems are currently facing increasing pressures especially in urban and semi-urban areas due to urban expansion, industrial and agricultural activities which negatively affect water quality and limit the efficiency of rivers in performing their environmental functions³. In Iraq, the Tigris River is among the most impacted by human activities within the Capital Baghdad. Untreated sewage disposal, industrial waste and agricultural runoff flowing into the river causing water quality to deteriorate at various points along its path. Within the city, local research has shown a pronounced north-south spatial gradient of declining water quality in

relation to increasing organic loads and human input⁴. Although physical and chemical indicators are important in assessing water quality, they reflect only the current state and do not adequately express the cumulative and long-term effects of pollution. Therefore, relying on biological indicators particularly benthic invertebrates has become an essential element in the integrated environmental assessment of river systems⁵. These organisms are characterized by their close association with sediments limited mobility and varying tolerance levels to pollutants making them sensitive indicators of environmental changes and ecological disturbances. The composition of benthic communities in the Tigris River changes significantly depending on the intensity of human impacts, with noticeable differences observed in species richness density and biotic index values between sites affected by sewage discharges and those less affected⁶. Other results also demonstrated a positive relationship between the increased abundance of certain pollution-tolerant groups such as oligochaete worms and Chironomidae larvae and higher organic content in sediments as well as declines in dissolved oxygen values⁷. Accordingly, the use of benthic invertebrates supported by diversity and density indices is considered an effective tool for assessing the environmental status of the Tigris River within the local context. This study aims to evaluate the water quality at selected sites along the Tigris River within the Baghdad Capital based on biological indicators contributing to the identification of pollution areas and supporting monitoring programs and sustainable environmental management⁸.

2. Materials and Methods

2.1. Study Area:

Tigris River flows through Baghdad for a distance of 110 Km⁹ Four sites were chosen for sample collection, as shown in **Table 1**.

Table 1. Study site's geographic Coordinates (GPS) along the Tigris River, Baghdad (Coordinates were recorded by the authors during field sampling using GPS)

All Stations	X-Coordinate
S1 Muthanna Bridge	345'' E °.428'' N,44°33
S2 Abassli Resort	347''E°.389''N,44°33
S3 Shawaka	387''E°.337''N,44°33
S4 Dora Thermal Power Station	374''E°.260''N,44°33

Site One (S1) represents an agricultural activity area; (S2) is a tourism activity area; (S3) is a commercial activity area; (S4) is an industrial activity area (**Figure 1**)

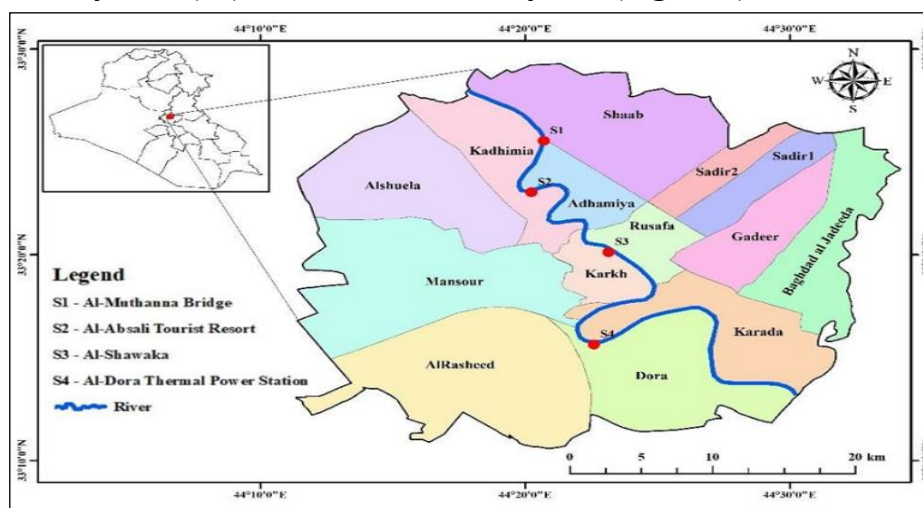


Figure 1. Tigris River within Stations designed by the authors using the sampling site coordinates obtained during field surveys.

2.2. Sample collection

Samples were collected monthly from the study areas, with three replicates each time, for the period from January to September 2025. The samples included water, plant (*Ceratophyllum demersum*) and sediments from the bottom, collected in 8-liter polyethylene containers and transported to the laboratory for examination.

2.3. Benthic organisms Isolation

The benthic samples were taking the laboratory for Isolation using Dissecting microscope (Novel) with magnification of (4,10,40 and 100) X Assistance with Classification key¹⁰, The sample were sorted and some were fixed to temporary, permanent slides for examination in laboratory

2.4. The Biological Indicators

A set of biological indicators was used to assess the ecosystem status of the four sites, in order to provide a comprehensive view of the human impacts on water quality and benthic communities¹¹ (Table 2).

Table 2. Description of biological indices used in the study

Indices	Equation	Classes	Description
BMWP (Biological Monitoring Working Party)	BMWP = $\sum$ Score Score = Tolerance score assigned to each family of benthic invertebrates recorded in the sample	> 100 71–100 41–70 11–40 ≤ 10	Very clean water Good Intermediate Polluted Very polluted
ASPT (Average Score Per Taxon)	ASPT = BMWP/N BMWP = Total scores of the BMWP index for the families recorded at the site, N = Number of families (Taxa / Families) recorded in the sample.	> 6 5 – 6 4 – 5 3 – 4 < 3	Very good water Good Intermediate Polluted Very polluted
The Shannon-Wiener index (H')	$H' = -\sum (n_i/N) \ln(n_i/N)$ n_i = number of individuals of a single species at the site , N = the total number of individuals in the same location	$H < 1$ $H > 1$	Little variety High diversity
Hilsenhoff Biotic Index (HBI)	$HBI = \sum (n_i * a_i) / N$ n_i : Number of individuals in the taxonomic unit , a_i : The unit's tolerance value. N: Number of individuals in the taxonomic unit.	< 4.0 4.0 – 5.5 5.6 – 6.5 6.6 – 7.5 > 7.5	Clean water Light pollution Moderate pollution High pollution Severe pollution
Species richness index (S)	$D = (S-1)/\log N$ S = Number of species , N = total number of individuals ,	< 2 2 – 4 4 – 6 > 6	Poor Moderate Good Very good
Relative Abundance Index (RA)	$Ra = N/N_s * 100$ N = Number of individuals per categorical unit in the sample, N _s = the total number of individuals in the sample.	70% < Ra 40 %-70 % 10%-40 % < %10Ra	Dominant species Abundance species Less Abundance species Rare species
Jaccard similarity index	$J = C/(A+B-C) * 100$ A = the total number of species at the site (1) B = the total number of species at the site (2) C = the total number of species common between sites (1) and (2)	0– 0.25 0.26– 0.50 0.51– 0.75 0.76 – 1	Very low similarity Low similarity Moderate similarity High similarity

2.4.1. BMWP (Biological Monitoring Working Party)

Used to estimate the intensity of organic pollution by monitoring the composition of benthic invertebrate families and giving points to each family according to its tolerance to pollution¹².

2.4.2. ASPT (Average Score Per Taxon)

Was used to measure the average sensitivity level for each discovered family it is an indicator considered a complement to BMWP, as it expresses small environmental impacts more accurately¹³.

2.4.3. The Shannon-Wiener index (H')

Was used to measure species diversity within each benthic community allowing for a better understanding of ecological balance and how the community responds to pollution¹⁴.

2.4.4. Hilsenhoff Biotic Index (HBI): To estimate the severity of organic pollution by assessing the sensitivity of species to pollutants especially organic substances¹⁵.

2.4.5. Species richness index (S) Used to measure the number of species present at each site directly reflecting the level of biodiversity in the area¹⁵.

2.4.6. Relative Abundance Index (RA) To determine the relative abundance of each species within benthic communities, contributing to the understanding of species composition and environmental changes¹⁶.

2.4.7. Jaccard similarity index It is used to determine the degree of similarity between benthic communities at different sites, which helps in assessing the impact of human activities on species distribution¹⁶. Using these indicators together allows for an accurate comparison between the less polluted northern sites and the southern sites affected by urban and industrial activities, and is considered a global standard approach compatible with local studies in the Tigris River¹⁷.

3. Results

The result showed that total number of registered individuals reached 5,902 belonging to 12 main taxonomic groups representing benthic invertebrates found in the Tigris River during the study period from January to September 2025.

3.1. Distribution of benthic organisms (Community composition)

The results showed that the most prevalent group was Chironomidae, with 1,605 individuals accounting for 27% followed by *Gammarus* spp. with 1,510 individuals accounting for 25% then *Melanoides* spp. with 640 individuals accounting for 10.8%. The least abundant was *Potamothenix* spp. with only 10 individuals accounting for 0.2%.

3.2. Seasonal effects on the benthic invertebrate community

The total abundance of aquatic invertebrates was 5,722 individuals, peaking in June (1,461) and declining to 278 in September. Chironomidae was the most abundant taxon (1,605), followed by *Gammarus* spp. (1,510). Most taxa showed significant monthly differences ($P \leq 0.05$), whereas *Potamothenix* spp., *Rotifera*, and *Planaria* spp. showed no significant differences (**Table 3**).

Table 3. Seasonal Effects on the Benthic Invertebrate Community

Taxon	Jan.	Feb.	March	April	May	Jun.	July	Aug.	Sep.	Total	L.S.D.
Chironomidae	0	0	150	250	350	350	250	205	50	1605	22.38 *
<i>Tubifex</i> spp.	38	40	36	32	11	7	5	0	2	171	19.55 *
<i>Nais</i> spp.	3	3	4	2	3	2	2	0	1	20	13.44 *
<i>Potamothenix</i> spp.	2	4	2	1	0	0	0	0	1	10	9.74 NS
<i>Melanoides</i> spp.	0	0	0	64	56	20	150	106	64	460	17.02 *
<i>Physa</i> spp.	0	0	0	60	90	150	120	101	60	581	18.53 *
<i>Pallmayeria</i> spp.	0	0	0	48	62	130	110	82	48	480	14.29 *
<i>Lemnaea</i> spp.	0	0	0	35	70	80	85	73	47	390	20.62 *
<i>Gammarus</i> spp.	0	0	0	0	0	484	516	510	0	1510	34.57 *
<i>Nematodes</i> spp.	27	53	33	44	45	45	50	55	61	413	17.85 *
<i>Rotifera</i>	1	7	6	4	3	12	14	8	5	60	6.25 NS
<i>Planaria</i> spp.	0	0	1	4	3	5	5	2	2	22	2.107 NS
Total	81	113	211	524	674	1461	1305	1178	278	5722	
L.S.D.	12.53 *	10.76 *	16.58 *	21.84 *	19.77 *	28.43 *	24.68 *	18.77 *	14.60 *		

* ($P \leq 0.05$).

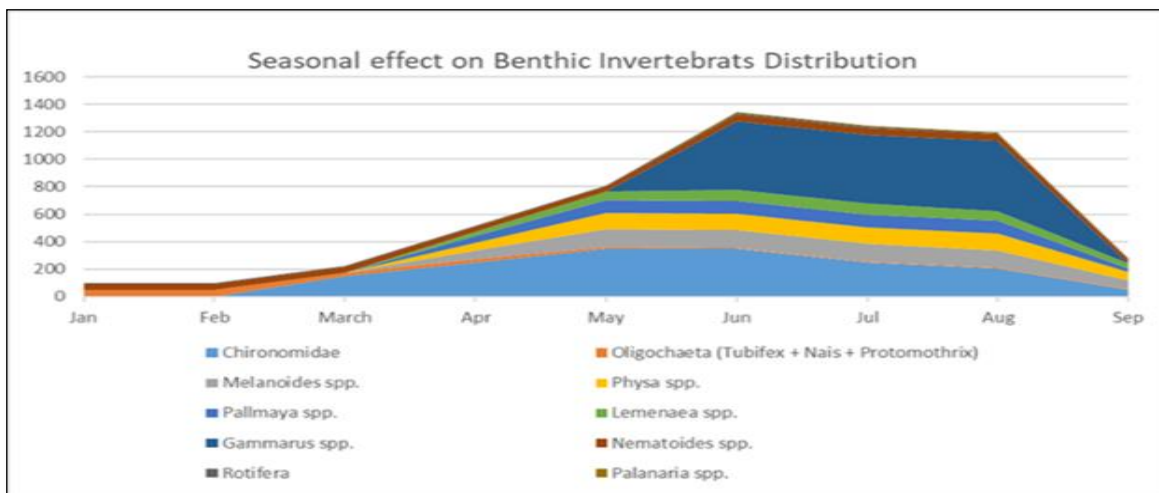


Figure 2. Seasonal Effects on the Benthic Invertebrate Community

3.3. Total abundance and distribution of species among sites

Table 4 shows the distribution of the species recorded at each site, with a total of 5,902 individuals distributed across 12 the groups.

Table 4. Shows the distribution of the species recorded and L.S.D. for at each site

Taxon	S1	S2	S3	S4	Total	L.S.D.
Chironomidae	321	321	482	481	1605	83.56 *
Gammarus spp.	1510	0	0	0	1510	107.44 *
Melanoides spp.	64	128	192	256	460	57.96 *
Physa spp.	145	174	145	117	581	52.30 *
Pallmayera spp.	120	144	120	96	480	46.95 *
Lymnaea spp.	137	117	78	58	390	29.36 *
Nematodes spp.	62	83	124	144	413	36.78 *
Tubifex spp.	9	17	68	77	171	19.55 *
Rotifera	25	20	10	5	60	16.48 *
Planaria spp.	8	6	4	4	22	13.07 *
Nais spp.	6	4	7	3	20	13.44 *
Potamothenix spp.	5	0	4	1	10	9.74 NS
Total No.	2410	1019	1234	1229	5722	176.54 *
L.S.D.	97.45 *	71.33 *	16.58 *	38.91 *	19.77 *	----

* ($P \leq 0.05$).

3.4. Biodiversity Indexes (Diversity Indices)

The BMWP index was highest at S1 (21), while S2–S4 recorded 15. ASPT values ranged from 2.14 to 2.62. The HBI was highest at S3 (6.9), whereas the Shannon–Wiener index was highest at S2 (1.8), indicating differences in water quality and biodiversity among sites.

Table 5. The biodiversity Indexes for each sites

Indexes	S1	S2	S3	S4
BMWP	21	15	15	15
ASPT	2.62	2.14	2.14	2.14
HBI	4.98	6.35	6.9	6.26
Species abundance(s)	3.25	3.3	3.16	3.24
Shannon-Weiner Index(H)	1.3	1.8	1.78	1.74

3.4.1 BMWP, ASPT Index

The results showed that site S1 achieved the highest BMWP index value of 21 compared to the other sites which recorded 15 namely sites S2, S3, and S4. Site S1 also recorded the highest value reaching 2.62 while the values remained constant at 2.14 at the other sites.

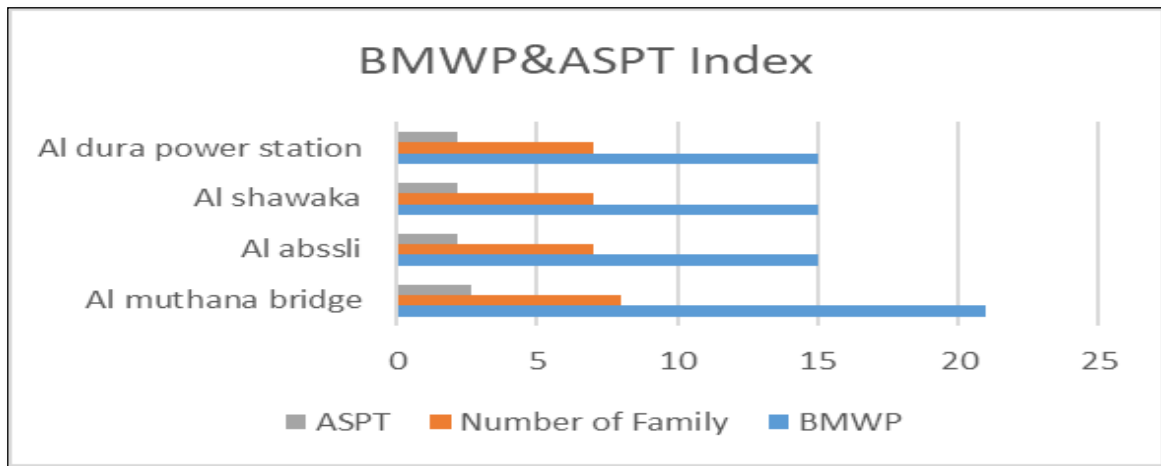


Figure 3. BMWP&ASPT Index

3.4.2 Hilsenhoff Biotic Index (HBI)

The results of the Hilsenhoff Biotic Index showed clear differences between the four study Stations with values ranging from 4.98 to 6.9 (Figure 4).

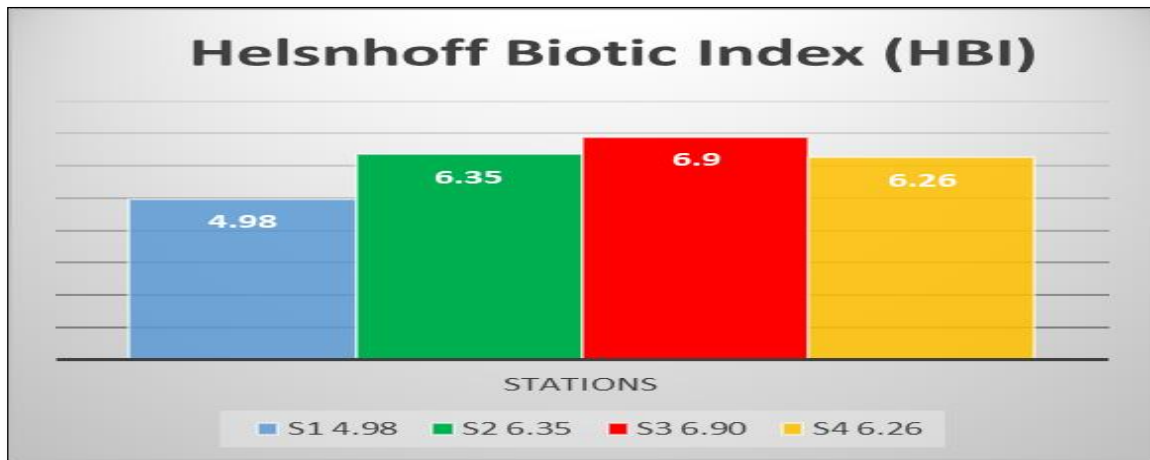


Figure 4. HBI Index Values for the Studied Stations

3.4.3. Species Richness Index (S)

The results of the species richness index showed slight differences between the sites with values ranging from 3.16 to 3.3. (Figure 5).

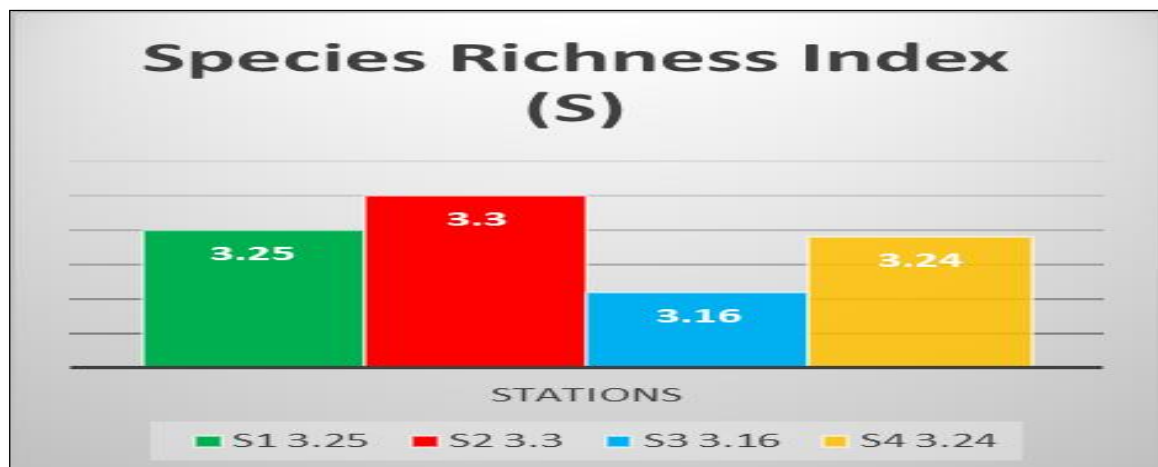


Figure 5. Distribution of species richness index values

3.4.4. Relative Abundance (RA)

The results of the numerical analysis of the benthic invertebrate distribution showed that the Chironomidae group was the most dominant at 27%, while the *Potamothenix* spp. genus from the Naididae group was the least dominant at 0.16%. (**Table 6**).

Table 6. Relative Abundance for all taxa

Taxon	Number of Individuals	Relative Abundance (%)
Chironomidae	1605	27.20%
<i>Gammarus</i> spp.	1510	25.50%
<i>Melanoides</i> spp.	640	10.80%
<i>Physa</i> spp.	581	9.80%
<i>Pallmayer</i> spp.	480	8.10%
<i>Lemnaea</i> spp.	390	6.60%
<i>Nematodes</i> spp.	413	6.90%
<i>Tubifex</i> spp.	171	2.80%
Rotifera	60	1.01%
<i>Planaria</i> spp.	22	0.30%
<i>Nais</i> spp.	20	0.30%
<i>Potamothenix</i> spp.	10	0.16%
Total	5902	100%

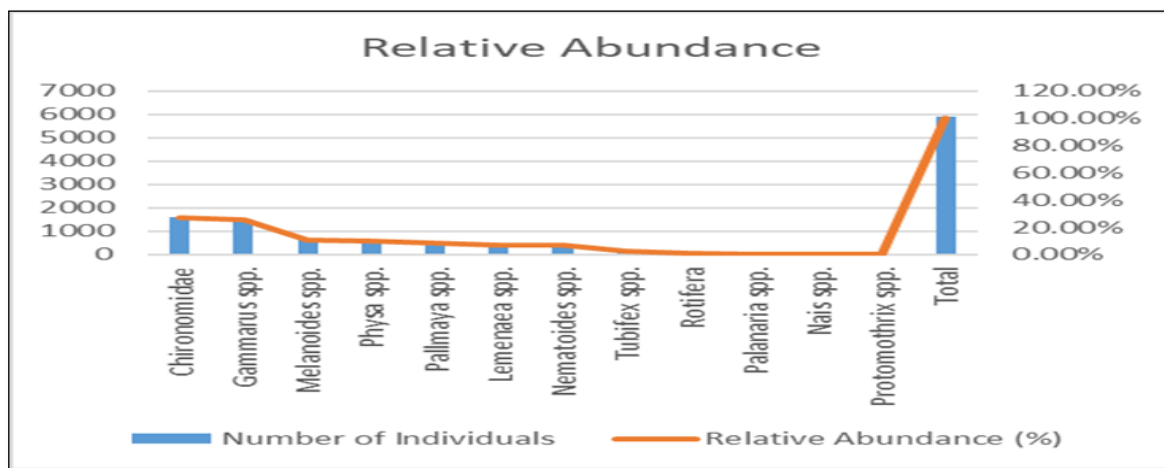


Figure 6. Relative Abundance for all genus.

3.4.5. Shannon–Weiner Index (H')

The sites showed a clear variation in Shannon-Wiener index values, with S2 recording the highest value of 1.8 bits/individual whereas the lowest value was observed at S1 with 1.3 bits/individual. (**Figure 7**) showed Shannon Wiener Index.

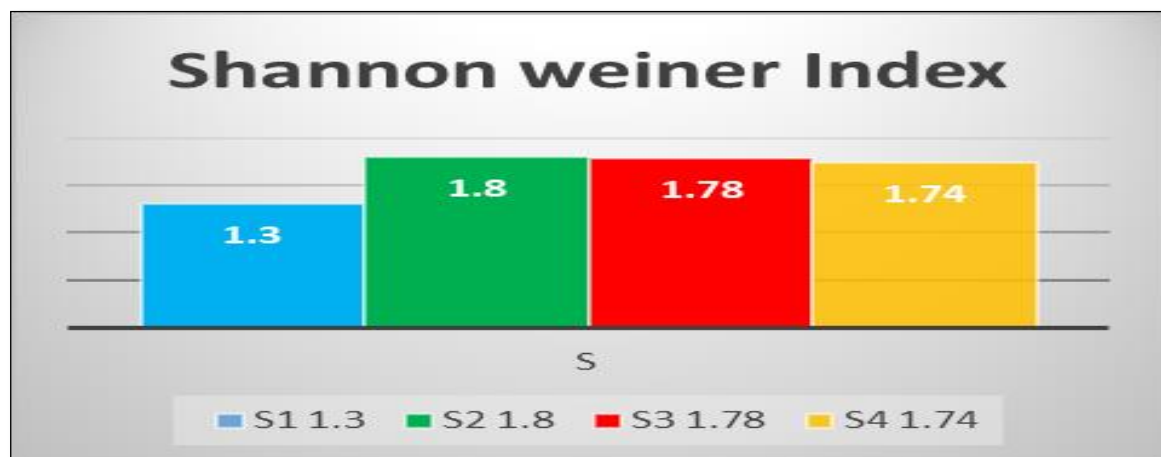


Figure 7. Shannon Winner Index

3.4.6. Jaccard Index

The results of the Jaccard similarity index showed the S2, S3, and S4 shared the presence of 11 species, except for the S1, which was distinguished by the presence of 12 species and the value ranged from 0.9 to 1, Which appear very high similarity among stations (**Figure 8**).

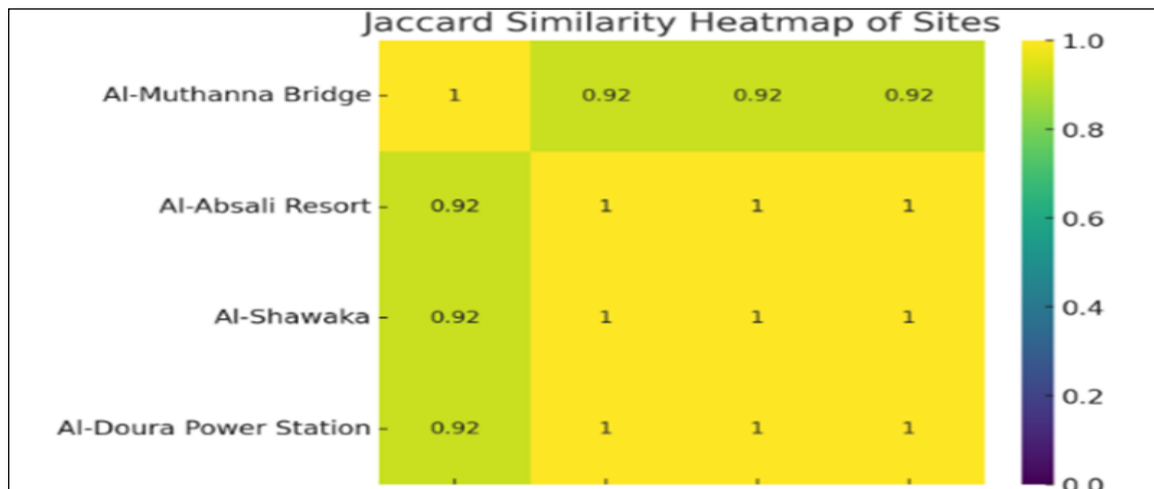


Figure 8. Heatmap showing Jaccard Similarity Indexes among study stations

4. Discussion

4.1. Seasonal Effects on the Benthic Invertebrate Community

The different numbers of benthic organisms showed variability among the four recorded sites with the family Chironomidae representing the highest proportion in all benthic community sites despite its decrease during the wet seasons¹⁸. Conversely, Oligochaetae such as *Tubifex spp.*, *Nais spp.*, and *Potamothenix spp.* recorded higher proportions during the wet season, especially in the southern sites, his is Conversely, Oligochaeta such as *Tubifex spp.*, *Nais spp.*, and *Potamothenix spp.* recorded higher proportions during the wet season, especially at the southern sites. This increase may be attributed to the accumulation of organic matter in sediments resulting from seasonal runoff and the availability of suitable feeding resources. In addition, lower temperatures and improved dissolved oxygen conditions during the wet season may contribute to creating more favorable environmental conditions for these organisms. which enhance sediment stability during this season¹⁹ Mollusca such as *Melanoides spp.*, *Physa spp.*, and *Pallmayera spp.* were almost absent during the wet season while their numbers increased during the dry season to reach between 20-30% particularly at site four due to Mollusca are ectothermic organisms meaning their metabolic and reproductive activity increases with rising temperatures in addition to the abundance of food resulting from algae growth and biofilm formation as well as the relative stability of the sediments²⁰, On the other hand nematode worms (Nematoda) maintained their presence across all sites with their proportions ranging between 5-12% in each During the two dry and wet seasons their numbers slightly increased during the dry season due to their ability to adapt to temperature changes indicating their environmental resilience compared to other groups that are more affected by seasonal changes^{21,22}

4.2. Total abundance and distribution of species among stations

The results of the analysis of variance and LSD test show that the spatial distribution of aquatic invertebrates at the study stations (S1–S4) is significantly affected by environmental differences between the sites Species with high abundance at certain sites such as *Gammarus spp.* at S1 and Chironomidae at other sites reflect biological responses to variations in water quality current sediment and the presence of organic matter in the water and sediment Some species such as *Potamothenix spp.* did not show significant differences indicating relative environmental stability of their habitat across the sites. These results confirm that spatial environmental factors form the fundamental basis for interpreting the different distributions of aquatic assemblage²³

4.2.1. BMWP, ASPT Index

The analysis results showed a clear variation in the values of the BMWP and ASPT indices with S1 recording the highest values. The analysis results showed clear variation in BMWP and ASPT values among the study sites, with S1 recording the highest values. Although all ASPT values indicated a very polluted condition according to the adopted classification system the relatively higher values observed at S1 suggest a comparatively better ecological status than the other sites. This may be related to the occurrence of *Gammarus spp.*²⁴, which are generally associated with relatively well-oxygenated habitats. Nevertheless, the ASPT values indicate that all sites were subjected to considerable organic pollution during the study period at this site likely due to the presence of taxa sensitive to organic pollution particularly *Gammarus spp.* which are known to inhabit well-oxygenated and well-ventilated waters. The high BMWP and ASPT values suggest that the benthic community at S1 is dominated by pollution-sensitive organisms reflecting better ecological conditions²⁵. These findings are consistent with the study which also reported higher BMWP and ASPT scores in less polluted river sites. In contrast other sites showed lower BMWP and ASPT values which can be attributed to the dominance of pollution-tolerant organisms such as Chironomidae and Tubificidae are generally considered tolerant of organic pollution and are frequently associated with sediments rich in organic matter²⁶. Therefore the variation in BMWP and ASPT indices across sites reflects the gradient of organic pollution in the river and confirms the usefulness of these indices for assessing ecological water quality²⁷.

4.2.2. Hilsenhoff Biotic Index (HBI) Indicator

The (HBI) index showed a gradient in levels of organic pollution with site S1 recording the lowest value (4.98) indicating low to moderate pollution and the presence of a balanced biological community while site S3 recorded a higher value for organic pollution (6.9) indicating moderate to high organic pollution and the dominance of resistant groups such as Oligochaeta and Chironomidae, which aligns with the impact of urban activities in central Baghdad²⁸. Additionally, site S4 showed values similar to S3 reflecting its exposure to multiple sources of organic pollution including thermal emissions²⁹.

4.2.3. Species Richness Index (D)

The values of species richness (S) showed a general similarity between the sites. S2 had the highest abundance value due to habitat diversity and increased riverine vegetation cover which are factors known to support biodiversity³⁰. As for sites S1 and S4 they showed similar values reflecting the influence of the river's general hydrological characteristics. Local studies indicate that the presence of habitats and river flow affect diversity more than pollution levels alone³¹.

4.2.4. Relative Abundance (RA)

The study results showed that Chironomidae family was the most abundant taxon accounting for 27% of the total relative abundance of the relative abundance a phenomenon commonly observed in urban rivers exposed to varying levels of organic loads. This family is considered highly tolerant characterized by its significant ability to adapt to conditions of low oxygen and increased organic matter. This prevalence serves as an indicator of environmental impacts ranging from moderate to high levels³². The genus *Gammarus spp.* recorded a high percentage of 25% indicating the availability of suitable environmental conditions in some sites particularly at S1. This genus is considered relatively sensitive to organic pollution as it requires good levels of aeration and water movement. Its abundant presence is considered a positive indicator reflecting the improvement of water quality in the sites where it was observed³³. The average abundance ratios of *Melanoides spp.* and *Physa spp.* (10.8% and 9.8%, respectively) reflect an environmental condition that combines limited organic influences with the presence of suitable habitats for benthic mollusca. Local studies indicate that these species show a notable response to changes in benthic substrates and pollution levels where their high density may be associated with increased organic matter or slow water flow³⁴. Species with low abundance such as *Tubifex*

spp., *Nais spp.* and *Potamothrix spp.* although some are associated with polluted environments like *Tubifex spp.* their low numbers may reflect an uneven distribution of organic matter or strong competition from more widespread species, In addition low numbers of Rotifera may indicate weak primary production in some areas³⁵. The patterns of relative abundance generally highlight the existence of a clear environmental gradient between different sites reflecting differences in flow rates the impact of human activities and the amount of organic matter reaching the river³⁶.

4.2.5. Shannon–Wiener Index (H')

The results of the guide showed a noticeable variation in the level of diversity among the studied sites, with a value of 1.3 recorded at stations S1 due to the dominance of *Gammarus spp.*, this genus is sensitive to organic pollution and lives in high dissolved oxygen levels, indicating improved aeration and hydrological conditions of the river water at that site. Mean while sites S2, S3, and S4 showed higher values (1.84, 1.78, 1.74) respectively, indicating a balanced distribution of species and environmental conditions that allow the coexistence of sensitive and resistant species This does not necessarily indicate better water quality than the first site, S1³⁷. These results are consistent with the study by which suggested a strong relationship between biodiversity values and physical and chemical variables. Additionally, the study by emphasized the necessity of using benthic invertebrates to interpret the level of sediment pollution and the impact of human activity³⁸.

4.2.6. Jaccard Index

The Jaccard index showed a significant similarity among the four study sites with a similarity value of (1) for stations (S2, S3, S4) This pattern indicates a similarity in the occurrence of the recorded species, whereas the first site had a value of (0.9) This is due to the presence of the genus *Gammarus spp.* which is sensitive to organic pollution and is found in waters with dissolved oxygen and good aeration highlighting the distinct hydrological characteristics of the first site compared to the other study sites³⁹.

5. Conclusion

The present study demonstrated that benthic macroinvertebrate communities are effective bioindicators for assessing environmental conditions in the Tigris River, Spatial variations among sampling sites reflected differences in environmental quality and the degree of anthropogenic influence, with Site S1 exhibiting relatively better ecological conditions, whereas Site S4 showed signs of environmental stress associated with human and industrial activities, Seasonal fluctuations in the abundance and composition of benthic invertebrates further highlighted the influence of environmental factors, particularly temperature and organic matter availability, on community structure, The dominance of tolerant taxa such as Chironomidae and Oligochaeta in some locations indicates the impact of environmental pressures, while the presence of relatively sensitive taxa such as *Gammarus spp.* reflects favorable habitat conditions in certain sections of the river, These findings confirm the usefulness of benthic macroinvertebrates as reliable tools for long-term biomonitoring of river ecosystems, It is recommended that regular monitoring programs incorporating benthic macroinvertebrate assemblages be implemented to assess water quality in the Tigris River, In addition efforts should be directed toward reducing untreated domestic and industrial discharges and minimizing anthropogenic impacts to preserve ecological integrity and improve river health.

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Conflict of Interest

There is no conflict of Interest

Funding

No Funding

Ethical Clearance

The research does not require Ethical Clearance

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