Epipelic Diatoms as Bioindicators to Assess the Water Quality Status of Baghdad Tourist Island Lake -Iraq

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Abstract
The study aims to assess the water quality of the Baghdad Island Lake Tourist Lake by epipelic diatoms for the period from October 2021 to May 2022. Three sites were chosen in the lake waters located within the Baghdad governorate sector. A group of physical and chemical factors and a qualitative and quantitative study of epipelic diatoms were studied. Four biological indices were carried out to assess water quality, namely, the Saprobic index (SI), the Palmer pollution index (PPI), the pollution tolerance index (PTI), and the Trophic diatomic index (TDI). As well as conducting the Canadian Water Quality Index for Living Aquatic Life. The results of the current study showed that the water quality of the Baghdad island lake for tourism is mesosaprobic to polysaprobic and mesotrophic. In contrast, the lake water quality was described as marginal and threatening to the livelihood of aquatic organisms, with the agreement of the results of biological indices With the results of physical and chemical tests for the quality of the lake water.
Keywords: Epipelic Diatom, Bioindicators, Water Quality Index, Baghdad Island Tourist Lake

1. Introduction

Organisms are primarily used to describe the state of an ecosystem. These organisms have been recognized as biomonitoring or bioindicators, And both can differ greatly (Lilian, 2009; Offem *et al.*, 2011). Where biomonitoring is based on bioindicators, it can serve as an early warning of high levels of trace elements in aquatic ecosystems due to trophic interactions (Bonanno and Di Martino, 2017). When studying ecosystems, their health status, and the quality of the changes made, bioindicators can determine them. In contrast, quantitative information about the ecosystem's state is obtained using biomonitors. It is also data collected regarding previous cases and the effect of different variables in biological systems (Gaston, 2000). Benthic algae refer to the habitat type of the algae, and these algae are usually found on rocks, mud, organic plant and animal waste (Addy and Green, 1966). Benthic algae are different groups of algae in aquatic ecosystems, such as rivers, lakes, and swamps. These algae are affected by the geography and appearance of aquatic ecosystems and human activities affecting them (Rimet, 2009). Algae play a vital role in all aquatic ecosystems by providing food and energy for all organisms living in lakes, ponds, streams, and rivers (Kolayli and Baysal, 1998). Benthic algae perform a range of functions for ecosystem stability, including sediment biotic stability, regulation of the benthic and pelagic nutrient cycle, and primary production (Poulić Kova *et al.*, 2008). The role of benthic algae in ecosystem production has received little attention compared to studies of food web surfactants for phytoplankton production (Nozaki *et al.*, 2003). The current study is one of the pioneering studies in evaluating Lake Baghdad Island tourism waters using the epipelic algae, where some studies were conducted and dealt with other aspects. The study by Ismail (1989) dealt with the physical and chemical properties of the lake and Tigris river waters and the quantitative and qualitative phytoplankton therein. Another study was conducted on the lake's water (Kazim, 2021) that dealt with physical and chemical factors and heavy metals, as well as conducting a qualitative and quantitative study of phytoplankton. The study by Obaid (2021) dealt with assessing the lake water quality by using epiphytic algae on two aquatic plants. The current study aims to employ the qualitative and quantitative of epipelic algae to assess the quality of lake water using bioindicators indices of water pollution and the Canadian Water Quality Index, suitable for living aquatic organisms.

2. Material and Methods

Table 1: Geographical coordinates of the sampling sites in the lake of Baghdad Island touristic (Google map)

Geographical coordinates		Sites
Longitude (East)	Latitudes (North)	
33° 27' 00"	44° 20' 34"	Site 1
33° 26' 37"	44° 27' 00"	Site 2
33° 26' 13"	44° 20' 47"	Site 3

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Three sites were selected within the lake, where water samples and epipelic diatoms were collected from October 2021 to May 2022. All physical and chemical factors were performed according to APHA (2017) and Welch (1952) except for biological oxygen demand (BOD) and phosphates (PO_4) according to Eaton *et al.* (2005) and Murphy & Riley (1962) respectively (Table 2). Epipelic algae samples were collected according to Eaton and Moss (1966), the algae were identified in the laboratory according to the following Patrick and Riemer (1966) and Germain (1981), while the micro transects method was used to conduct the quantitative study of epipelic algae and was calculated according to Hadi (1981).

Baghdad Island Tourist Lake is located on the right side of the Tigris River, north of Baghdad, with a total capacity of 370,000 m^3 of elongated crescent shape, 1,600 m long and 125 m wide (Fig. 1).

Fig. 1: A map showing the locations of sample collection (Google Earth)

Four bioindicators were conducted to assess water quality, the saprobic index (SI) according to Pantle & Buck (1955), the Palmer pollution index (PPI) according to Palmer (1969), the pollution tolerance index (PTI) according to Lange–Bertalot (1979) and the trophic diatomic index (TDI) according to Lange–Bertalot (1979). And the achievement of the Canadian Water Quality Index based on (CCME, 2007).

3. Results and Discussion

Environmental condition: The results (Table 2) indicate a group of physical and chemical factors conducted during the current study in three Baghdad Island Tourist Lake water sites. The differences in air temperature between the months of the study and the dryness of the Iraqi climate are characterized by a large variation in temperatures during the year (Abdul-Jabbar, 2020). The water temperature varies daily and seasonally according to the air temperature (UNEP, 2008). The alkalinity rates higher than 100 mg $CaCO_3$/l in all seasons and locations exceeded the permissible values (WHO, 2004), so the lake water is described as having medium alkalinity, the pH values ranged between 7.2–8.3, which confirms that the lake water has a high Buffering Capacity Because the Iraqi soil is rich in carbonate and bicarbonate compounds (Al-Tamimi and Al-Obeedi, 2021). The Electrical conductivity (EC) values exceeded the permissible limits, with the highest rate of 1057 µ.s/cm recorded in site 3 (WHO, 1998). The highest recorded rate of total dissolved solids was about 812 mg/l in site 2, so the lake water is considered to have exceeded the permissible limits, while the highest rate of turbidity values was recorded at 8.45 NTU, with limits that exceeded the permissible values (CCME, 2007; WHO, 1998).

The values of the total hardness recorded the highest rate of 540 mg $CaCO_3$/ l and did not exceed the permissible limits; its water is considered hard to very hard because the lake is affected by the water of the Tigris River, the main source of the lake water (Hassan *et al.*, 2018). (The lake water is well aerated, as the dissolved oxygen values exceeded 5 mg /l, and no critical values were recorded for the biological oxygen demand, where the highest rate of 3.32 mg/l where the lake water is considered to have moderate organic pollution (Lkr and Singh, 2020). Nitrates and nitrites did not exceed the permissible values, where the highest rates were recorded at 6.05 mg/l and 1.80 mg/l, respectively. The decreased nitrite values in lake water may be attributed to the high dissolved oxygen content (Sraddha *et al.*, 2011). Phosphate concentrations exceeded the permissible limits. The highest rate was recorded at 3.49 mg/l in Site 1, which may be due to the pollution in the Tigris River due to the anthropogenic dumping of untreated sewage water containing detergents and agricultural fertilizer residues (Obeid, 2021).

Table 2: The physical and chemical factors of Baghdad Island tourist lake in sampling sites from November 2021 to May 2022

Site			Parameters
3	2	1	
20 – 37 29 ± 37	19 -36 27 ± 8.33	19 – 40 28 ± 8.7	Air Temperature (°C)
16.4 – 30.6 20.1 ± 7.0	15.7 – 31.4 20.05 ± 7.58	15.3 - 30.8 19.8 ± 7.38	Water Temperature (°C)
7.5 – 8.3 7.90 ± 0.4	7.2 – 8.2 7.77 ± 0.46	7.3 – 8.1 7.67 ± 0.38	pH
130 – 160 142 ± 12.5	100 – 170 135 ± 31.09	90 – 148 124 ± 24.5	Total Alkalinity (mg $CaCO_3$/l)
757 -1683 1057 ± 429	756 -1350 963 ± 276	737 – 1085 933 ± 167	Electrical Conductivity (µ.s/cm)
372 – 1010 595 ± 290	372 – 1890 812 ± 723	362 – 651 488 ± 141	Total Dissolved Solid (mg/l)
4.4 – 18.5 8.43 ± 6.8	2.4 – 8.9 6.35 ± 2.8	2.2 – 19.7 8.45 ± 7.7	Turbidity (NTU)
310 – 860 483 ±253	300 – 1116 540 ± 385	280 – 432 355 ± 66.5	Total Hardness (mg $CaCO_3$/l)
6.19 – 7.03 6.36 ± 0.36	6.09 – 7.05 6.53 ±0.53	6.23 – 6.79 6.53 ± 0.29	Dissolved Oxygen (mg/l)
2.01 – 3.41 2.98 ± 0.65	3.08 – 3.62 3.28 ± 0.25	3.22 – 3.43 3.32 ± 0.09	Biological Oxygen Demand (mg/l)
2.0 – 10.0 6.05 ± 3.51	2.5 – 10.0 5.43 ± 3.49	2.2 – 10.0 6.05 ± 3.76	Nitrate (mg/ l)
0.5 – 3.01.80 ± 1.06	0.5 – 2.1 1.33 ± 0.67	0.5 – 2.8 1.78 ± 3.98	Nitrite (mg/l)
0.0 – 5.05 2.73 ± 2.35	0.0- 5.09 2.94 ± 2.54	0.0 – 5.09 3.49 ± 2.34	Phosphate (mg/l)

Biodiversity of epipelic diatom flora: 137 species classified in the current study belong to 33 genera, and 8 species of the order Centrales belong to 5 genera. In comparison, the order of Pennales belonged to 129 species belonging to 28 genera. Table (3) indicates the numbers of species and genera of epipelic diatom diagnosed in the current study according to the studied sites in the lake of Baghdad Island tourism, where Site 1 recorded the largest number of diagnosed species, including 108 species belonging to 26 genera, the high number of species in this site is an indicator On the high diversity and also an indicator of the presence of small percentages of pollution (Al-Hasoo and Al-Tamimi, 2022). The total number of epipelic diatom cells showed clear seasonal and locational variations. The highest total number was 216 x 10^3 cells/cm^2 in summer (Site 1), while the lowest total number was 63 x 10^3 cells/cm2 in summer (Fig. 2). The increase in the number of epipelic diatoms cells in Site 1 may be due to the abundance of plant nutrients processed from the site of water entry to the lake from the Tigris River due to domestic and agricultural waste (Al-Hamdani, 2010; Ali et al., 2017), as well as high summer temperatures and decomposition of organic matter, which leads to supplying algae with important nutrients, and this, in turn, leads to increased growth. A decrease in the total number of epipelic diatoms cells in Site 3 may be due to the effect of this Human activities cause the site and pollution from the mooring of boats from the waste of maintenance of the boats from the waste of fuel and other organic compounds, which leads to damage to the growth of epipelic diatoms (Obeid, 2021).

Table 3: Number of species and genera diagnosed in the study sites

Taxa	Site 1		Site 2		Site 3	
	G	sp	G	sp	G	sp
BACILLARIOPHYCEAE (CENTRALES)	1	6	1	6	4	4
BACILLARIOPHYCEAE (PENNALES)	25	102	24	89	24	91
Total	26	108	25	95	28	95

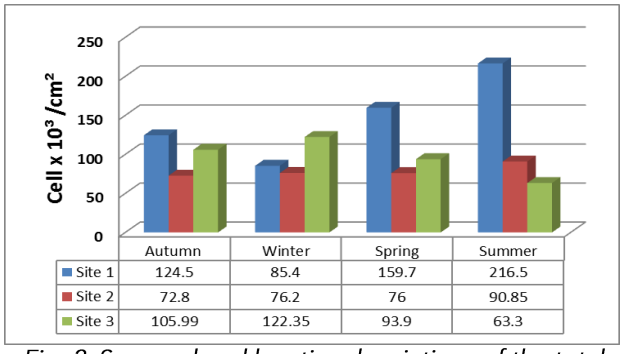


Fig. 2: Seasonal and locational variations of the total number of Epipelic diatoms cells during the current study

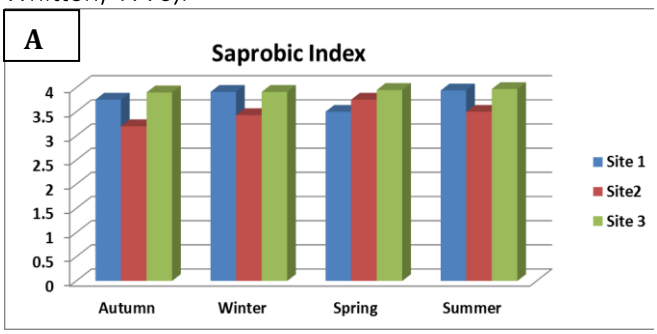
Bioindicators Indices: The highest rate of the saprobic index (SI) was recorded at 3.93 in site 3 because the lake water was affected by human activities and the movement of vacationer's boats in this site, as well as the influence by the water entering the lake from the Tigris River (Obeid, 2021), and the lowest recorded rate was 3.20 in Site 2. The highest values were recorded in the summer at 3.97 in Site 3. The high values of the SI in the summer may be due to the rise in temperatures, which leads to an increase in the number of aquatic organisms and their decomposition after their death, leaving large amounts of organic matter as well as what is added to the lake water from the surrounding areas (Al-Obaidi, 2021 (Table 4, Fig. 3). According to the results of the current study of the SI, the lake water is considered ą –Mesosaprobic to Polysaprobic organic pollution.

The values of the Palmer Pollution Index (PPI) did not show clear seasonal and locational variations, and they were characterized by the convergence of their values, which exceeded all of their values in the sampling sites from the 20, so the lake water is considered to have high organic content (Palmer, 1969). The highest rate of PPI values was 28.75 in site 3 in the south of the lake and at the end of the water exit to the river, where it is more feet than the water of site 1, whose source is from the river water and is renewable (Obeid, 2021), while the lowest rate was recorded at 26.75 in site 2. The highest PPI value of 30 (Site 3) was recorded in winter. The lowest values were recorded at 24 (site 2) in the fall (Table 4, Fig. 3). Recording the high values of PPI values may be due to the amount of human and agricultural activities of the Tigris River feeding the lake water (Al-Makdami, 2016).

The location and seasonal variations of the pollution tolerance index (PTI) values did not show a noticeable variation, as the highest average of the PTI values was 2.66 in Site 1, the lowest was 2.37 in the second location, and the highest values were 2.87 (Site 3) in the fall season. In contrast, the lowest values were recorded at 1.89 (Site 2) in the fall (Table 4, Fig. 3). According to the results of the PTI values, the lake water is moderately polluted (Lang-Bertalot, 1979). The convergence of the PTI values gives an impression of homogeneity in the lake water (Al-Hasso and Al-Tamimi, 2022). Many epipelic diatoms with medium tolerance to the surrounding environmental conditions in the water medium polluted were recorded, Including Synedra ulna, Surirella tenera, Nitzschia amphibian, Navicula cryptocephala, Stigonema smithii, Gyrosigma spencerii, Gomphonema acuminatum, Cymbella affinis, Cyclotella meneghiniana, Bacillaria paradoxa, Amphora ovalis, Achnanthes lanceolata (Moscio, 2002).

The seasonal and locational variations showed a

significant variation in the Trophic diatomic Index (TDI), where the highest rate of TDI values was 57.82 at Site 1. In contrast, the lowest rate was recorded at 51.58 at Site 2. The highest values of the TDI, 66.45 (Site 2), were recorded in the winter season. In contrast, the lowest values were recorded at 41.15 (Site 2) in the spring (Table 4, Fig. 3). According to the results of the TDI, the waters of the lake are classified as mesotrophic (Kelly, 1995). The recording of a group of genera for the class of epipelic diatoms that tolerate the mesotrophic water was reflected in the determination of the lake's water quality, which are Achnanthes, Gomphonema, Navicula, Nitzschia, Surirella, Synedra. In contrast, a group of species was recorded for the epipelic diatoms that tolerate the mesotrophic water: Bacillaria paradoxa, Cocconeis pediculus, Cocconeis placentula, Synedra ulna (Kelly Whitton, 1995).



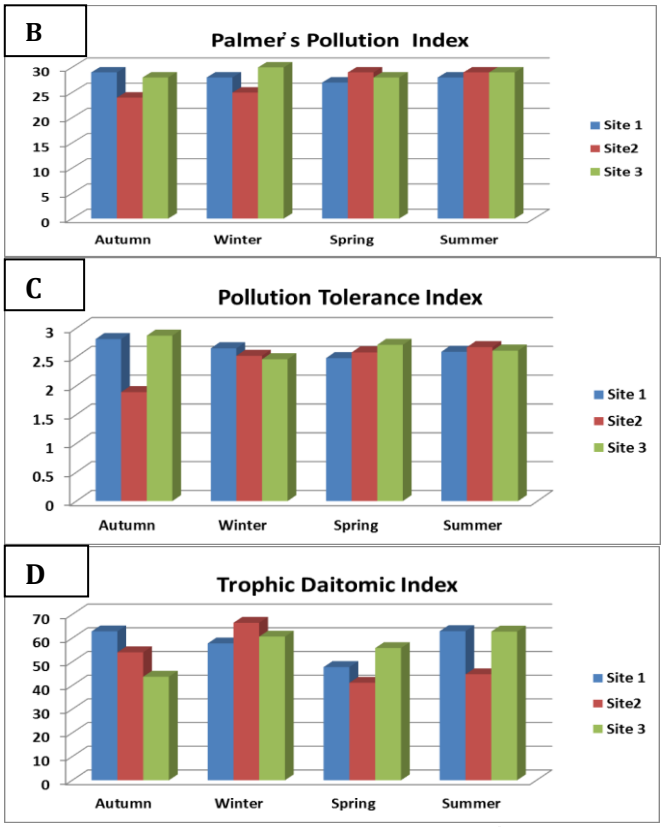


Fig. 3: Seasonal and locational variations of biological indicators values at sampling sites during the current study period (A = SI, B = PPI, C = TDI, D = TDI)

Table 4: Range, mean, and water quality state of biological indicators and water quality index in the sampling sites during the current study period

Site 3	Site 2	Site 1		Bioindicators Indices
3.90 – 3.97	3.20 – 3.75	3.50 – 3.94	Range	Saprobic Index (SI)
3.93	3.47	3.78	Mean	
Polysaprobic	ą –Mesosaprobic	Polysaprobic	Water quality status	
28 - 30	24 - 29	27 - 29	Range	Palmer's Pollution Index (PPI)
28.75	26.75	28.00	Mean	
High Organic Pollution	High Organic Pollution	High Organic Pollution	Water quality status	
2.46 – 2.87	1.89 – 2.67	2.48 – 2.81	Range	Pollution Tolerance Index (PTI)
2.66	2.37	2.63	Mean	
Moderate Polluted Water	Moderate Polluted Water	Moderate Polluted Water	Water quality status	
43.70 – 62.75	41.15 – 66.45	47.78 – 62.92	Range	Trophic Diatomic Index (TDI)
55.7	51.6	57.8	Mean	
Mesotrophic	Mesotrophic	Mesotrophic	Water quality status	
58.44	55.26	49.63	Values	CCM Water Quality Index
Marginal	Marginal	Marginal	Water quality status	

Water Quality Index: The Canadian water quality Index (CCME-WQI) values converged for the living of aquatic organisms in the sampling sites, where the highest value was 58.44 in Site 3, and the lowest values were recorded at 49.63 in Site 1 (Table 4, Fig. 4). According to the results of the CCMW-WQI, the lake water quality is described as marginal and threatening to aquatic life. The convergence of the CCME-WQI values for the sampling sites may be due to the small area of the lake as well as the similarity of the nature of the sites (Al-Hasoo & Al-Tamimi, 2022). A group of physical and chemical properties led to a decrease in the value of the CCME-WQI, which is the temperature of the water, Na and NO2, and the rest of the other factors were compatible and within the permissible limits. In general, the low values of the CCMW-WQI in the lake water may be due to the water nourishing the lake by the Tigris River being polluted by sewage waste, agricultural operations, and fish farm cages (Al-Makdami, 2017; Abdullah et al., 2019).

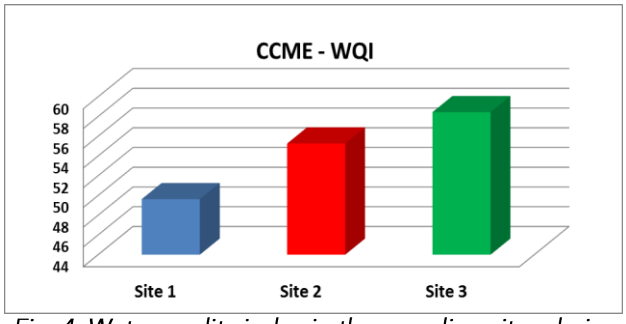


Fig. 4: Water quality index in the sampling sites during the current study

4. Conclusion

The study of biological indices using epipelic diatoms to estimate the water quality of Lake Baghdad Island tourism revealed that it is

mesosaprobic to polysaprobic and mesotrophic. In contrast, the lake water quality was described as marginal and threatening to the livelihood of aquatic organisms, with the agreement of the results of biological indices With the results of physical and chemical tests for the quality of the lake water.

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