Water Quality assessment by Diatoms in Tigris River / Iraq

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Abstract:
Pollution of freshwater resources has become one of the most important problems of humanity and as it is known, continuous monitoring of the quality of aquatic ecosystems is one of the best protection techniques. The present study is conducted to assess the environmental status of the Tigris River by applying diatomic indices (epipelic diatom). Nine diatomic indices were used in this study. Nine indices were used in this study for the period from June 2015 to May 2016. The results revealed that the water quality of the river ranged from moderate to good pollution, oligotrophic to mesotrophic and high diversity of diatoms.

Keywords: Biological Indices, Tigris River, Water Quality, Water Pollution, Epipelic Diatoms.

Introduction
River ecosystems are under threat from various human activities across the globe leading to considerable changes in sediment delivery and flow patterns, declining water quality and loss of biodiversity (Vörösmarty et al., 2010). The aquatic organisms were used as bio-indicators for pollution, also as bio-monitors to understand the interaction between organism's responses to environmental alteration and their legal effect (Markert & Zechmeister, 2003). The benthic algae community has a rapid response to disturbance in the water, as the water affected by pollution often changes the composition of species or diversity, which vary from one watercourse to another. Because of this feature, the benthic diatom community is useful and an important tool in the detection of human-induced effects of the aquatic environment. Diatoms are a large part of benthic habitats (often 90-95%) and have become an important part of water quality control. The most important feature is that they can be present in all surface waters, anytime, samples collected from them can be maintained for a long period of time (Acs et al., 2004). The benthic diatoms are used as ecological indicators and regarded as valuable in water quality assessment and monitoring (Round, 1991). Some researchers studied on epipelic algae in Tigris River as reversed the importance of their study of running water such as (Al-Tamimi, 2012; Hassan & Al-Bdulameer, 2014; Al-Hassany & Hindi, 2016).

Diatoms have been recognized as good indicators of water quality (Stevenson, 2014), several diatom indices have been implemented around the world, examples include IPS (CEMAGREF, 1982), Trophic Diatom Index (TDI) (Kelly & Whitton, 1995) and the Diatom Biological Index (IBD) (Coste et al., 2009), which are based on a weighting average equation. Maznah and Omar (2010) revealed that the use of algae as bioindicators is important to identify the alteration of water quality in the freshwater ecosystems. In addition, Cosgrovea et al. (2004) has used periphyton as bio-indicators for water quality.
The present study selected epipelic diatoms because these diatoms reflected the environmental status of the study area. The present study is aimed to apply the nine indices in the Tigris River to evaluate their water quality and to use these indices tool for monitoring in Iraqi aquatic systems.

Materials and Methods
The Tigris River was selected for application indices. Monthly sampling was taken from five sites along Tigris River during the period from July 2015 to May 2016 and the results presented seasonally (Fig. 1, Table1). All physicochemical parameters were determined follow APHA (2005) nitrite, nitrate and phosphate (Strickland & Parsons, 1972) and silicate (Parsons et al., 1984), Chlorophyll-a and phaeophytin-a of epipelic algae were estimated according to Eaton and Moss (1966) and total organic carbon (Ryan et al., 2003). Nine biological indices were used for this study of water quality. These indices have been calculated according to references marked in front of each index (Table 2).

![Figure 1: Map of the Tigris River and the study area (Used Arc-GIS Map program).](image-url)
Table 1. The geographical positions (GPS) of the five study sites

<table>
<thead>
<tr>
<th>Sites</th>
<th>Longitude (eastwards)</th>
<th>Latitudes (northward)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1: Al-Aziziyah</td>
<td>98°18'35</td>
<td>54°9050'</td>
</tr>
<tr>
<td>S2: Zubaidiyah</td>
<td>35°9799'</td>
<td>55°8840'</td>
</tr>
<tr>
<td>S3: Numaniyah</td>
<td>35°9611'</td>
<td>57°7080'</td>
</tr>
<tr>
<td>S4: Before Kut dam</td>
<td>36°1336'</td>
<td>60°5320'</td>
</tr>
<tr>
<td>S5: After Kut dam</td>
<td>36°1395'</td>
<td>60°6604'</td>
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</tbody>
</table>

Table 2: The biological indices used in this study

<table>
<thead>
<tr>
<th>Index</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pollution indices</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Palmer Pollution Index</td>
</tr>
<tr>
<td>2</td>
<td>Index of Pollution Sensitivity (IPS)</td>
</tr>
<tr>
<td>3</td>
<td>Biological Water Quality Index (BWQI)</td>
</tr>
<tr>
<td><strong>Trophic indices</strong></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Trophic diatom index (TDI) **</td>
</tr>
<tr>
<td>5</td>
<td>Diatomic Index (Id)</td>
</tr>
<tr>
<td>6</td>
<td>Generic Diatom Index (GDI)</td>
</tr>
<tr>
<td><strong>Diversity indices</strong></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Richness index (D)</td>
</tr>
<tr>
<td>8</td>
<td>Shannon-Weaver index (H')</td>
</tr>
<tr>
<td>9</td>
<td>Evenness index (E)</td>
</tr>
</tbody>
</table>

The studies of epipelic diatoms were isolated from sediment according to Eaton and Moss (1966). The identification of diatoms were done followed the references: Hadi * et al.; 1984, Wehr & Sheath, 2003; Lavoie * et al., 2008 ; Blanco * et al., 2011 and Al-Hassany and Hassan, 2014.

Statistical Analysis

The results of the study were analyzed using the Statistical Package for the Social Science SPSS 19.0 program (Steel & Torrie, 1980).

Results and Discussion

In the present study, the measured physico-chemical parameters are shown in Table 3. Water and air temperature ranged 11–51 C° and 12-34 °C respectively (Table 2). This variation is known in lotic system relation between water and air temperature (Wetzel, 2001). Temperature is very important to water quality, and affects the solubility of gases and salts in water and effected on the behavior, physiological and distribution of aquatic organisms (Hoosier, 2000; Shehata * et al., 2009).
pH of water samples were slightly alkaline, They ranged from 6.5 to 8.4, many studies in Iraqi inland water was recorded the buffer capacity of water such as (Al-Saadi et al., 2000; Hassan et al. 2008; Hassan et al. 2010; Salman et al., 2013). Water salinity ranged 0.412-0.726 g.L⁻¹ at site 5, this results revealed that the river was alkaline and oligohaline according to the classification of Reid (1961). Dissolved oxygen concentration recorded between 5.2 mg.L⁻¹ -11.6 mg.L⁻¹ while biochemical oxygen demand (BOD₅) ranged from 0.3 mg.L⁻¹ to 2.5mg.L⁻¹, these values of BOD₅ were less than permissible limit (5 mg.L⁻¹) proposed by WHO (1996). Nitrogen and Phosphorous are two major nutrients required for algae growth,
the third one, Silica, is necessary for diatom growth (AL-Gahwari, 2003). During the study period, values of nitrate and phosphate elevated at all sites, this interpreted by increased human activity in agriculture and sewage wastes discharging into study sites. While silicate, Iraq waters are characterized by high concentrations of silicate. This is due to the geological nature of land in which Tigris and Euphrates Rivers flow. The results of the present study ranged 11.36-39.28 mg.L⁻¹ at sites 1 and 5 in June 2015 and May 2016 respectively.

Total organic carbon has effect on many chemical and biological processes in sediment, in spite of the importance of organic carbon as a source of feeding for different organisms, on other hand increase their quantity lead to anoxic condition that will be harmful for many organisms including algae (Folger, 1972). The results of the study showed that the values of TOC in the sediments ranged between the low concentration 0.425 % at site 4 in June 2015 and the high concentration 0.65 % at site 1 in October 2015, December 2015 and February 2016. The statistical analysis showed significant temporal differences (p≤ 0.05) in all months of the study sites, and no significant spatial differences in the sites of the study. The results also showed a fluctuation in TOC values during the study, which increased due to the influence of various environmental factors such as temperature, biology activity of organic matter in sediments (Al-Fatlawi, 2011). The average Chlorophyll-a concentration ranged from 0.05 μg.cm⁻² to 5.26μg .cm⁻² at sites 2 and 3 in December 2015 and June 2015 respectively, and the concentration of phaeophytin-a was 0.02μg.cm⁻² in sites 1, 2 and 4 in December 2015 and January 2016 and the highest 1.78 μg.cm⁻² at site 1 respectively that means the river was oligotrophic according to trophic classification (Schmitt, 1998).The difference in the concentration of chlorophyll can be attributed to the concentrations of nutrients and other physical factors that affect the concentration of chlorophyll and the growth of epipelic algae (Guts et al., 2009). Table 2 illustrated the range of the studied physicochemical parameters.

The number of epipelic diatoms recorded during the present study on the Tigris River in the five sites was 161 species belonging to 34 genera. Palmer index values for epipelic diatoms ranged from 4.30 at site 2 in summer 2016 to 11.02 at site 1 in spring 2016 (Fig. 2A). The results of the statistical analysis showed significant differences (P ≤0.05). The values of the Palmer index less than 15 were considered as drift in slowly eutrophic status (Palmer, 1969; Parvatesam & Mishra, 1993). The results of the Palmer Manual showed that the Tigris River of study sites (with no high organic pollution) is consistent with the organic pollution manual, which shows that the water ranges from low pollution to moderate pollution.

The results of the index of Pollution Sensitivity (IPS) of epipelic diatoms showed that Tigris River was moderate to good according to IPS values. These mean values ranged from 9.49 at site 4 to 16.31 at site 3 (Fig. 2B). The results of the statistical analysis showed significant temporal and spatial differences (P ≤0.05) of the study sites. The water quality of the Tigris River depending on the index that they range from low-Eutrophication to Moderate and this is consistent with the obtained General Diatomic Index result. It is consistent with the Palmer Pollution Index, which showed that the water of the Tigris River has no high organic pollution. These study sites are agriculture area, so the effects of agricultural human pollutants that are put into the river increase the nutrient levels, affecting the water quality and the presence diatoms. It also changes the water chemistry of the rivers, thus changing the numbers and species of habitats, including the diatoms, and varies the amount of pollutants that are thrown into the surface and which affect the physical, chemical and biological properties (Giller &
Malmquist, 1998). Results of Biological Water Quality Index (BWQI) showed that the studied river was moderate to heavily polluted and mostly moderate polluted according to Lobo et al. (2002) scale. This scale has varied from 1 to 4 as follows: 0.0-0.9 (pollution absent), 1.0-1.4 (low pollution), 1.5-2.0 (moderate pollution), 2.1-2.7 (heavy pollution) and 2.8-40 (very pollution). This results reversed the Palmer pollution index results which obtained the river has no high organic pollution. The mean values of BWQI ranged from 1.76 at site 2 in autumn 2015 to 2.17 at site 1 in spring 2016 (Fig. 2C). The results of the statistical analysis showed significant temporal

![Graphs showing seasonal variation in indices](image)

**Figure 2:** Seasonal variation in the studied indices: A: Palmer Pollution Index; B: Index of Pollution Sensitivity; C: Biological Water Quality Index; D: Trophic diatom index in Tigris River during the study period
differences (P≤0.05), and no spatial differences of the study sites. Trophic diatom index (TDI) is a good tool for monitoring river, diatom community are liable to alter of factors that not related to nutrients (Kelly & Whitton, 1995). The present study results of TDI mean values ranged from 33.70 at site 2 to 62.70 at site 1 (Fig. 2C). The lowest value was recorded in winter2016 while the high value was in the winter2016. The results of the statistical analysis showed significant temporal and spatial differences (P≤0.05). According to this index the Tigris River was tended to be oligotrophic to mesotrophic, the average level of water is moderate to the water quality in the Tigris river. The genus of D. vulgare was recorded during the present study, which is an indicator of water quality ranging from Mesotrophic to Eutrophic (Taylor et al., 2005). The species N. palea is present in the highly food-rich waters (Tapia, 2008) and water quality index with the degree of organic pollution (Polysabropic) and G. Parvulum with high tolerant of water rich in nutrients and poor oxygen content (Potapova & Charles, 2003). The following species have been identified as F. capucina, which is highly tolerant to pollution and nutritional enrichment, but has been demonstrated in the present study because this type of diatom, which has a wide range of endurance where it exists in water ranging from the nutritional level between Oligotrophic to Eutrophic (VanDam et al., 1994).

The results of Diatomic index (Id) showed temporal variation. The lowest value recorded 2.75 in site 1 in winter2016 and higher value was 4.11 in sites3 in spring2016 (Fig.3A). According to Id values mentioned in Descy (1979) the present water quality data ranged between moderate to good. Water quality is normal with little change in diatom community. The species of resistance are predominant and the number or disappearance of sensitive species is very high, between medium qualities to good quality this is adequate with the result of the water quality index used to assess the water quality of the Tigris River. When comparing the results obtained by using the GDI with the ideal values for this index (Hungary Ministry of Environment and water, 2005) and the values obtained during the study, the quality of the Tigris River from moderate to good. The higher the values of GDI indicator the water quality tend to the water is good or pollution is low.

The mean values of the Generic Diatoms Index (GDI) ranged from 11.12 was in site3 in winter2016 to 16.51 in site3 in spring 2016 (Fig. 3B). The higher values of GDI indicated good water quality with low or absent pollution (Hungary Ministry of Environment and water, 2005). The lowest values of GDI indicate deterioration in water quality of an aquatic system. The study sites ranged from moderate to good depending on the value ranges. Some genera or species of diatoms were sensitive and other tolerant to pollution that diatoms were considered as bioindicatior (Armstrong & Brasier, 2005). The balance of existing sensitive species and tolerant species depend on alteration in water quality due to different pollutant disposal into an aquatic ecosystem which effect physicochemical and biological features (Giller & Malmqoist, 1998; Szabo, et al., 2005).

The high values of diversity in Tigris River were emphasized by its water quality. Mean values of the Richness index (D) for epipelic diatoms in this study ranged from 8.34 at site4 in spring2016 to 20.21 at site3 in winter2016 (Fig. 3C). The results of the statistical analysis showed significant temporal and spatial differences (P≤0.05) of the study sites. The recorded D values in Tigris River indicated its high diversity of diatoms that may be due to less pollution
Figure 3: Seasonal variation in the studied indices: A: Diatomic Index; B: Generic Diatoms Index; C: Richness index; 
D: Shannon-Weaver index; E: Evenness index in Tigris River during the study period and less grazing activities by zooplankton (Ghosh et al., 2012). The high values of D were remarkable to healthy diatom communities and this index will cover any alteration in communities in the aquatic systems (Barbour et al., 1999). In the present study the Shannon-Weaver index ($H'$) recorded values above 1 in the study period. $H$ values ranged from 1.86 at...
site 1 in winter 2016 to 3.57 at site 2 in autumn 2015 (Fig. 3D). The results of the statistical analysis showed significant temporal and spatial differences between (P ≤ 0.05). These findings confirmed the D index results which emphasize that the Tigris River has high biodiversity (diatoms) and also meant that non-dominance for certain species of diatoms in the study river, while the few values (less than 1) indicate dominance of certain species of epipelic on the appropriateness of environmental conditions from physical and chemical factors in the study sites that assist in the growth and diversity (Jonge, 1995). The results of Evenness index (E) confirmed the homogenization of species in the present studied river where more than 0.5 values recorded in most seasons and months of the study. This is agreed with Green (1993) revealed that low values of Evenness index indicated emergence of few species with high densities which is an indication of the existence of environmental stress. The values of E index ranged from 0.51 in site 1 in summer 2016 to 0.82 in sites 2 and 3 in spring 2016 and winter 2016 respectively (Fig. 4E). The results of the statistical analysis showed significant differences between among sites (P ≤ 0.05).

Conclusions
It can be concluded that most of the studied indices reflected the status of the water quality of Tigris River which was low to moderately pollute. The results showed diatomic indices revealed that Tigris River was ranged between moderate to good pollution, Oligotrophic to Mesotrophic and high diversity of diatoms, and it’s suitable for living of many species of organisms. This is confirmed by Evennes index. These studies demonstrate the applicability of Trophic diatom index and can help in establishing a database in Tigris River.

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References


