



APPLICATION OF DIATOMIC INDICES IN LOTIC ECOSYSTEM, IRAQ

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ABSTRACT

Fifteen indices were applied to the lotic ecosystem in Iraq to evaluate the water quality. The Al - Shamiya river was selected for this study as a lotic ecosystem. The river physicochemical characteristics were studied in period March, 2013 to February, 2014. These indices (pollution, trophic and diversity) included: Saprobic Index (S), Pollution Tolerance (PTI), Palmer Pollution Index, Percent Sensitive Species (%SS), Simpson Index, Trophic State Index, Trophic diatom Index (TDI), Diatomic Index (Id),)Generic Diatoms Index (GDI), Index of Pollution Sensitivity (IPS), Biological water Quality (BWQI), Richness Index (D), Shannon-Weaver Index (H), Evenness Index (E), McIntoch Diversity Index (Mc).. In addition to physicochemical characterized features of the river. The results revealed that the water quality of the river ranged between less polluted water to moderate polluted water. The existing of some diatomic species indicated the trophic status of the river and this result conformed by using diatomic indices in this study.

KEY WORDS: Lotic Ecosystems, Biological Indices, Water Quality, Water Pollution, Diatoms, Phytoplankton.

INTRODUCTION

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 [1,2]. Many organisms can be used as indicators of water quality as well as the pollutants that may lead to sudden death, or indicates the presence of a toxic substance in the environment. This makes them highly valuable as indicators of environmental health [3]. Dokulil^[4] explained the principle of algal bio-indications in different aquatic ecosystems. The algae have been well known as bio-monitors in the mid 19th century. Algae have responded to environmental alteration by means of different growth rates and physiological changes, hence used as bio-indication for pollution in an aquatic ecosystem [5]. Diatoms are predominant phytoplankton in most aquatic ecosystems, these algae has the ability to resist alteration in the environment, also these algae are sensitive to low concentration of pollutants compared with other algal groups [6, 7, 8, 9]. In polluted aquatic ecosystems will predominate by a specific organism (tolerant species), while its conversely in unpolluted aquatic systems a few

Predominant organisms^[10]. The qualitative and quantitative of diatoms depend on the trophic status of an aquatic ecosystem [11]. These algae used as diagnostic tools in biological monitoring and as bio-indicators [12, 13]. Other organism can be used as bio-indicators by means of their density and types which are evidence of environmental health or deteriorating water quality [3]. Many authors revealed that diatoms composition reflected the water quality of lotic ecosystems in Iraq and dominancy of diatoms [14, 15, 16, 17]. The present study aimed to apply the fifteen indices in the lotic ecosystems (Al-Shamiyah River) to evaluate their water quality and to use these indices tool for monitoring in Iraqi aquatic systems.

MATERIALS & METHODS

The Al-Shamiyah River was selected for application indices. Monthly sampling was taken from four sites along Al-Shamiya river during the period from March, 2013 to February, 2014 (Fig. 1). All physicochemical parameters were determined follow APHA^[18], nitrite, nitrate, phosphate and silicate^[19] and total organic carbon^[20].

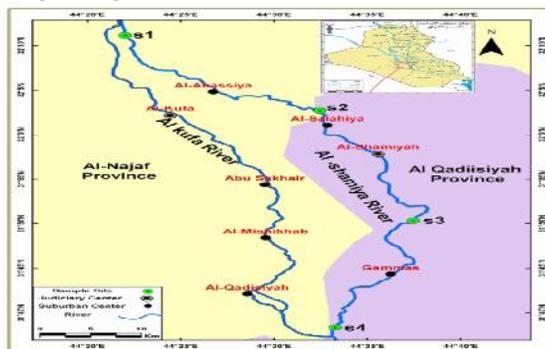


FIGURE 1: Location of sites on Al-Shamiyah River (Followed Hassan and Shawaait^[8]).

Fifteen biological indices were used for this study of water quality. These indices have been calculated according to references marked in front of each index. The indices were

as follows (*= pollution Indices**= Trophic Indices***= Diversity Indices^[21]):

Index	Reference
1 Saprobic index (S)*	Pantle and Buck ^[22]
2 Pollution Tolerance Index (P.T.I)	Lang-Bertalot ^[23]
3 Palmer Pollution Index *	Palmer ^[24]
4 Index of Pollution Sensitivity (IPS) *	Prygiel and Coste ^[25]
5 Biological Water Quality Index (BWQI) *	Wegl ^[26]
6 Percent Sensitive Species (SS%) **	Metzmeier ^[27]
7 Trophic diatom index (TDI) **	Kelly and Whitton ^[28]
8 Diatomic Index (Id) **	Descy ^[29]
9 Generic Diatom Index (GDI) **	Lecoite <i>et al.</i> ^[30]
10 Simpson Index ***	Simpson ^[31]
11 Trophic State Index ***	Nygaard ^[32]
12 Richness index (D) ***	Stiling ^[33]
13 Shannon-Weaver index (H') ***	Shannon and Weaver ^[34]
14 Evenness index (E) ***	Neves <i>et al.</i> ^[35]
15 McIntoch Diversity Index (Mc) ***	McIntoch ^[36]

The qualitative studies of diatoms were followed the identification references as follows: Germain^[37]; Hassan *et al.*^[38]; Al- Hassany and Hassan^[39]. The quantitative study calculated by the micro transects method^[40]. Statistical Package for the Social Science (SPSS) used for statistical analysis.

RESULTS & DISCUSSION

The physicochemical parameter was already discussed by authors^[8]. The results revealed that the river was alkaline

and oligohaline according to criteria proposed by Reid^[41]. Dissolved oxygen concentration recorded above 7 mg/l in all study period while biochemical oxygen demand (BOD₅) ranged from 1.37 mg/l to 1.85mg/l, these values of BOD₅ were less than permissible limit (5 mg/l) proposed by WHO^[42]. The average Chlorophyll-a concentration ranged from 2.40 to 3.37 µg l⁻¹ that means the river was I -oligotrophic according to trophic classification^[43]. Table 1 illustrated the range of the studied physicochemical parameters.

TABLE1: Range of mean values of Physicochemical Parameters in Al-Shamiyah River during the study period.

Parameter	Mean
Air temp. (°C)	24.63 – 28.06
Water temp. (°C)	21.67 – 24.50
Water flow (m/min)	33.22 – 39.11
Turbidity (NTU)	12.87 – 16.87
Light penetration (cm)	31.33 – 45.54
Electric C conductivity (µs/cm)	1189 – 1314
Salinity ‰	0.76 – 0.84
Total dissolved solids (mg/l)	761 – 841
Total suspended solids (mg/l)	25.53 – 34.35
pH	7.93 – 7.99
Dissolved oxygen mg/l	7.62 – 8.98
Biochemical oxygen demand mg/l	1.37 – 1.85
Alkalinity mg CaCO ₃ /l	128.30 – 137.50
Hardness mg CaCO ₃ /l	382.64 – 465.00
Calcium mg/l	104.27 – 110.68
Magnesium mg/l	32.91 – 48.28
Nitrite µg/l	1.22 – 1.54
Nitrate µg/l	57.00 – 73.00
Phosphate µg/l	0.01 – 0.12
Silicate µg/l	120.25 – 140.73
Total organic carbon mg/l	0.54 – 0.94

Authors^[8] studied the composition of phytoplankton in Al-Shamiyah River and a total of 144 diatom taxa were recorded. The phytoplanktons were predominated with pennate diatoms. Different Saprobic index (S) was

recorded among the study sites. The mean values were ranged from 1.78 in site 1 to 1.94 in site 2. While its values in site 3 and 4 were 1.84 and 1.88, respectively (Table 2 and fig. 2A). These values indicated that Al-Shamiyah

River is slightly oligosaprobic to moderate (Beta-mesosaprobic) according to Lowe [44]. In oligosaprobic pollution all material and biodegradable compounds will be fully oxidative while in the mesosaprobic pollution the organic load will be continuous oxidation[45]. This result might be due to leak organic material and sewage from

nearby farmland and domestic into the river this load will be less effective during increased water discharge [45]. The quality and quantity of diatoms will be affected by this index so some of the diatoms existed as common or predominant according to their tolerance to pollution [46].

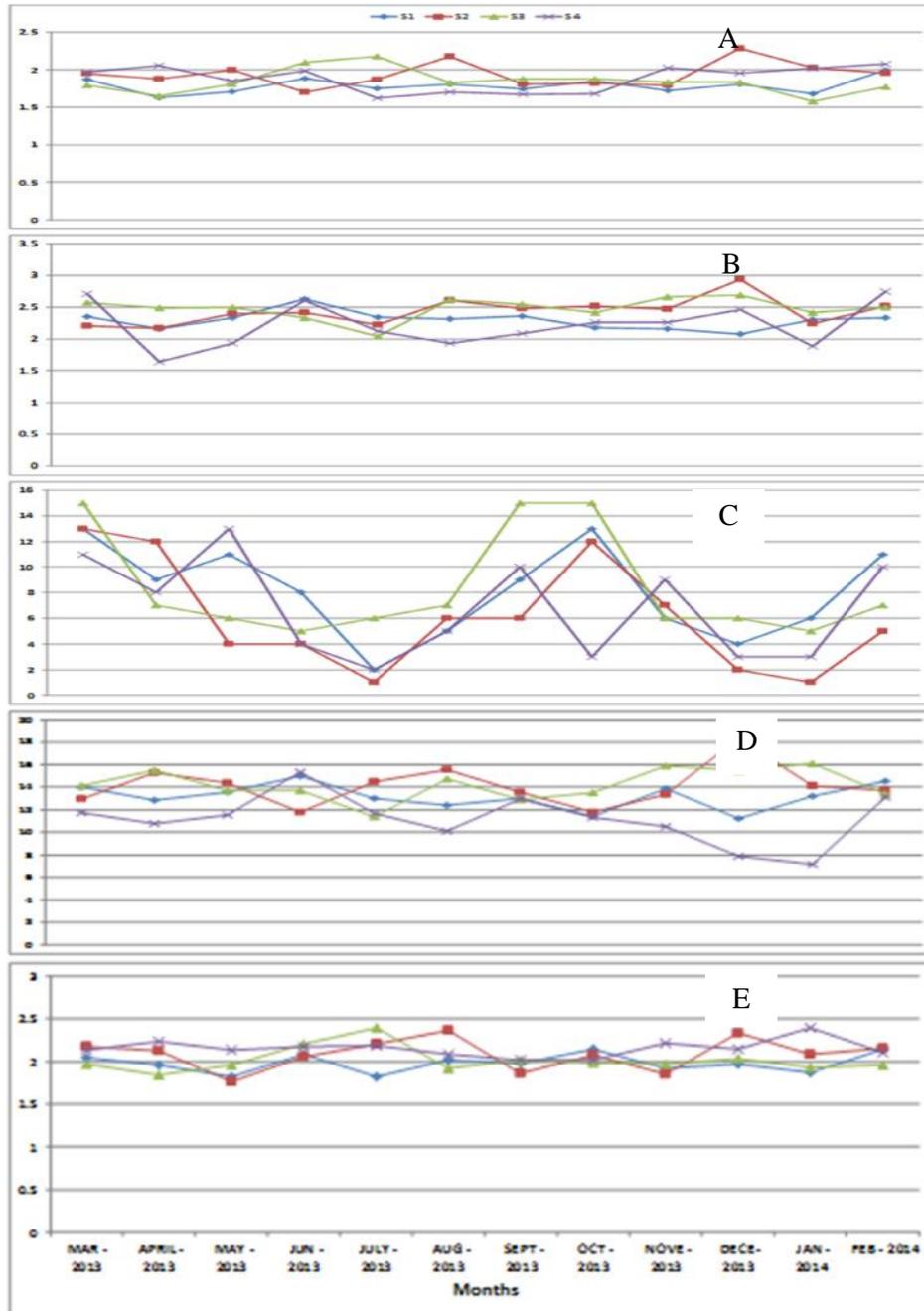


FIGURE 2: Monthly variation in the studied indices: A: Saprobic Index; B: Pollution tolerance Index; C: Palmer Pollution Index; D: Index of Pollution Sensitivity, E: Biological Water Quality Index, in Al-Shamiyah River during the study period.

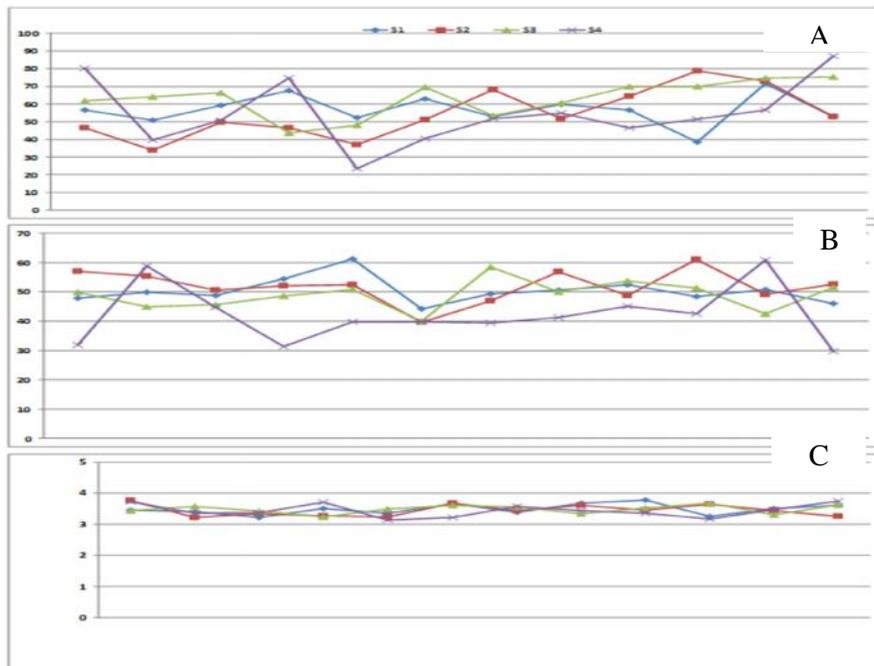
Pollution Tolerance index (PTI) determines the pollution by using diatoms to assess the health of aquatic ecosystems such as rivers [47]. This index value ranged from 1.64 at site 4 in April 2013 to 2.94 at site 2 in December 2013 (fig. 2B). These results indicated that the river was least polluted to moderately polluted water

according to classification of water pollution by Lange-Bertalot [48]. This classification revealed that values of PTI were ranged from 1 to 4, the 1 indicated Most Polluted Water while the 2, 3 and 4 numbers indicated Moderately Polluted Water and Least Polluted Water, respectively.. Hence PTI results of the Al - Shamiyah river

agreed with Saprobic index. Palmer index values for diatoms (Phytoplankton) ranged from 1.0 at site 2 in July 2013 and January 2014 to 15 at site 3 in March, September and November 2013 (Fig. 2C). The values of the Palmer index less than 15 were considered as drift in slowly eutrophic status [24, 49]. Similar results were also observed in two water bodies in India [50]. The palmer index values confirmed the TPI and Saprobic index results. The results of the index of Pollution Sensitivity (IPS) of diatoms (Phytoplankton) showed that Al-Shamiyah river was moderate to good according to IPS values. These mean values ranged from 11.18 at site 4 to 14.21 at site 3 (Fig. 2D). Both the low (in January 2014) and high (in December 2013) values were recorded in the cold months. Results of Biological Water Quality Index (BWQI) showed that the studied river was moderate to heavily pollute and mostly moderate polluted according to Lobo *et al.* [51] 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 2.8-4.0 (very pollution). The mean values of BWQI ranged from 1.98 at site 1 to 2.16 at site 4. The lowest values recorded in May 2013 and the highest value was in July 2013 (fig. 2E). The following changes in the diatoms composition and its ratio in aquatic system might be used to evaluate the water quality by Percent sensitive Species (diatoms) index This index ranged from 23.47% in July 2013 to 87.22% in February 2014 in site 4 for both percents (Fig. 3A). The low results of this index indicated that pollution might be due to waste disposal into the river and lead to reduce the Percent Sensitive Species of diatoms. The percent more than 50 % indicated moderately polluted or b-mesosabropic and less than 50% was critically polluted (b-a- mesosabropic. The results of this index indicated that the Al-Shamiyah river ranged from good to moderately polluted according to Lange-Bertalot [23] and the spatial and temporal variation in this index related to different

load of pollution, predators and availability of nutrients [52,53]. Trophic diatom index (TDI) is a good tool for monitoring river, diatom community are liable to alter of factors that not related to nutrients [28]. (The present study results of TDI mean values ranged from 42.14 at site 4 to 51.87 at site 2 (Figure 3B). The lowest value was recorded in early spring (February 2014) while the high value was in the summer (July 2013). According to this index the Al-Shamiyah River was tended to be oligotrophic to mesotrophic, this might be confirmed by existence of *A. minutissima* at all study sites. This species found in oligo-mesotrophic River [28].

The results of Diatomic index (Id) showed temporal variation. The lowest value recorded in summer (in July 2013) and higher value was in Autumn (in November 2013). Its mean values ranged from 3.44 at sites 2 and 4 to 3.49 at site 1 (Fig. 3C). According to Id values mentioned in Descy [29] the present water quality data ranged between moderate to good. This may be emphasized by the slight change in diatoms (phytoplankton) communities noted by Hassan and Shawaait [8] study during the same period. The mean values of the Generic Diatoms Index (GDI) ranged from 12.31 at site 4 to 15.06 at site3 (Fig. 3D). Both the low (January 2014) and high (December 2013) values of GDI recorded in the cold months. The higher values of GDI indicated good water quality with low or absent pollution [54]. The lowest values of GDI indicate deterioration in water quality of an aquatic system. The study area ranged from moderate to good. Some genera or species of diatoms were sensitive and other tolerant to pollution that diatoms were considered as bioindicator [55]. 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 [56, 57, 58].



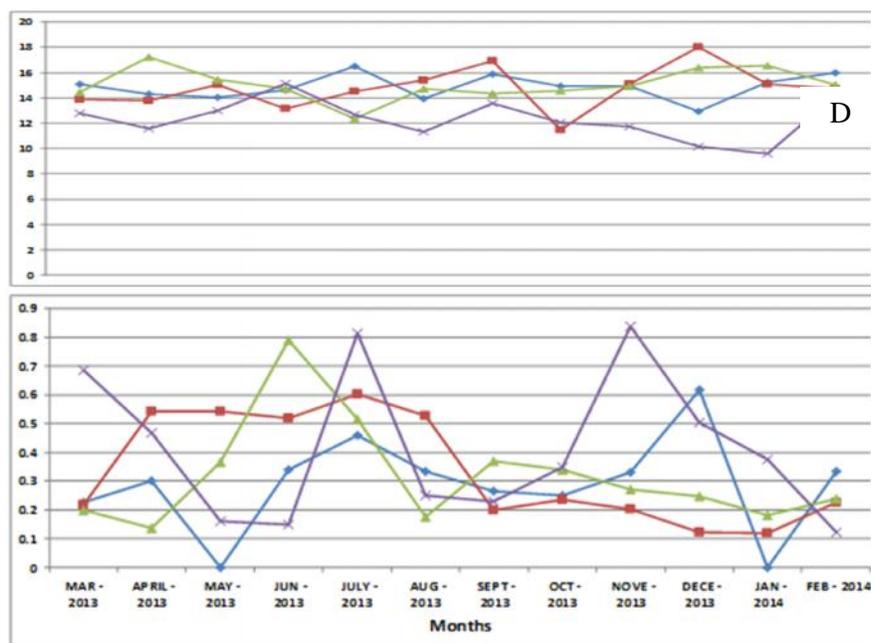


FIGURE 3: Monthly variation in the studied indices: A: Percent Sensitive Species; B: Trophic Diatom Index; C: Diatomic Index; D: Generic Diatoms Index; E: trophic State Index, in Al-Shamiyah River during the study period.

For example *A. minutissima* and *Nitzschia* spp were predominant in polluted water. Both species considered as tolerant to different pollution^[59]. Diatoms were considered as sensitive organisms to environmental alteration in water bodies such as nutrient availability in which that related to the trophic status of an aquatic system^[60]. The mean value for trophic state index (TSI) in this study ranged from 0.29 at site 1 and 0.41 at site 4. Low value recorded in May 2013 and high value in November 2013 (Fig. 3E). Nygaard^[32] revealed that value of this index ranged from 0.00 to 0.30 indicated as oligotrophic while if an aquatic system ranged from 0.00-1.75 was Eutrophic. The lowest value of the Simpson index for diatoms was 0.023 at site 1 in September 2013 and the higher value was 0.33 at site 4 in June 2013 (Fig. 4A). Mean values of the Simpson index ranged from 0.05 to 0.16 in the same above sites, respectively. These results indicated that Al-Shamiyah river was tending to be of high diversity and low or moderately polluted water. This result was evidence that polluted material released into river varied spatially and temporally which affects dominance of some species against another. This finding was also observed by Kassim et al.^[61] on the polluted Diyala and Tigris rivers, in general the highly polluted water body is usually characterized by low diversity and also, the alteration in algal diversity was an indication to change in water quality^[62, 63]. The high values of diversity in Al-Shamiyah river was emphasized by its water quality. Mean values of the Richness index (D) for diatoms in this study ranged from 3.46 at site 2 to 4.23 at site 3 (Fig. 4B). The lowest value was recorded in January 2014 (coolest month) and the highest value was in September 2013 (early autumn). The recorded D values in Al-Shamiya river indicated its high diversity of diatoms that may be due to less pollution and less grazing activities by zooplankton^[64]. The high values of D were remarkable to healthy diatom communities and this index will cover any alteration in communities in the

aquatic systems^[47]. In the present study the Shannon-Weaver index (H') recorded values above 1 in the study period. H values ranged from 2.43 at site 4 to 3.23 at site 1 (Fig. 4C). Both low and high values were recorded in spring (February 2014 (for low value) and Autumn (September 2013 (for high value), respectively). These findings confirmed the D index results which emphasize that the Al-Shamiyah River has high biodiversity (diatoms) and also meant that no dominance for certain species of diatoms in the study river. Moreover, there was a similar species composition at all studied sites with some differences due to the nature of each site and type of macrophytes in each on the bank of river such as *Phragmites australis*, *Typhah domingensis* and *Ceratophyllum demersum*. These macrophytes lead to suitable condition of algal growth^[65, 66]. High values of H index were recorded in the blooming period (spring and autumn). This result agreed with other studies on rivers^[15, 67, 68]. The high values of H' index indicative of good water quality of Al-Shamiyah river^[60]. The results of Evenness index (E) confirmed the homogenization of species in the present studied river where more than 0.5 values recorded in the study period^[69]. Green^[69] revealed that low values of Evenness index indicated emergence of few species with high densities and an indication of environmental stress. The values of E index ranged from 0.76 at site 4 to 0.94 at site 1 (Fig. 4D). The low and high values were recorded in February 2014 and December 2013, respectively. McIntosh Diversity Index (Mc) for diatoms mean values ranged from 0.64 at site 4 to 0.80 at site 1 (Fig. 4E). All recorded values tended to be close to 1 and this evidence that the river was characterized by high biodiversity of diatoms due to a suitable condition to growth of diatoms and less effect of pollution, also it may be difficult to explain the lowest values because of overlapping environmental factors that organizing diatom community in lotic ecosystems^[60, 70, 71]. Statistical analysis

showed significant differences between the studied indices (table 3). A Statistical analysis showed positive correlation between pollution indices (S with BWQI and PTI with SS %) while palmer index did not record any correlation with other indices of pollution. But there were a positive correlation between the Palmer index with Shannon – weaver index (diversity index), SS% with Id (water quality index) and IPS with GDI (water quality index). Only one index of water quality recorded positive correlation with H (diversity index). A positive correlation noticed between H and MI and E and MI.

Authors in the same period of this study published the qualitative and quantitative study of phytoplankton in Al-Shamiyah river^[8]. They explained that some species such as *Aulacoseria granulata*, *Cocconeis placentula*, *Cymbella* spp., *Fragilaria capucina*, *Gomphonies olivaceum*, *Diatoma elongatum*, *Navicula radiosa* and *Syndra ulna* were indicative to trophic status of aquatic ecosystems between oligotrophic to eutrophic^[72]. This is agreement with other results of indices presented in this study (TDI, S, Palmer index and Simpson Index).

CONCLUSION

It can be concluded that most of the studied indices reflected the status of the water quality of Al-Shamiyah River which was low to moderately polluted. The results showed an alteration of water quality from upstream (Site 1) to downstream (site 4) which may be due to discharge of organic and other pollutant being dumped into the river during river passing in Al-Shamiya city and other small villages located on river banks.

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