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Water quality, diatoms, pollution and Shannon diversity indices for the Euphrates river

Abdul-Nasir A M Al-Tamimi and Meysaa M Braak.

Department of Biology, Education College For Women, Anbar University - Iraq[1]

ABSTRACT

Al-Tamimi AAM., Braak MM., Water quality, diatom, pollution and Shannon diversity indices from the Euphrates river, Onl J Vet Res., 23 (2):161-, 2019. Authors report biological and water quality indices from the Euphrates river between Ramadi and Fallujah in Western Iraq from November 2017 to July 2018. We assessed water quality index (NSF-WQI), Trophic Diatoms (TDI), Pollution Tolerance (PTI) and Shannon Diversity Indexes (H). Most of the biological indices reflected water quality low to moderately polluted, oligotrophic to mesotrophic, with moderate biodiversity by diatoms and medium to good water quality. The water quality index (NSF-WQI) showed some consistency with the values of some physical and chemical parameters. The comparison between the biological indices and the water quality index showed no clear pattern between the water quality index and the PTI, but some showed compatibility between *H*, PTI and NSF-WQI .

Keywords : Diatom, Water Quality Index, Biological Indices, Physical and Chemical

INTRODUCTION

Precipitation, surface runoff, ground water flow, interception and abstraction affect discharge and contamination in rivers [1, 2]. River biotic indices are based on periphytons, diatoms, non-diatomic algae, including cyanobacteria, macro algae and phytes [2]. Diatoms rapidly respond to environmental changes, deterioration of water quality, nutrients, acidification and metals are thus used to monitor ecological status of rivers [3]. Shape, size and pattern of silica frustules are used to identify diatoms and recent studies reveal that diatom based indices vary according to ionic composition and organic pollution in rivers [4, 5]. Diatoms are being used to assess ecological status of water in Iraq. [6, 7, 8, 9] and have become valuable elements in large scale national and international assessment programs of the United States and Europe [14, 15]. Authors report diatom indices and NSF-Water quality indices from 5 sites of the Euphrates River over 9 months.

MATERIALS AND METHODS

The study area lies at 15° 43' to 42° 43' E longitude and 21° 33' to 28° 33' latitude with an expanse of 444 sq Km as depicted in Figure 1 below. The River Euphrates measures 2940 Km and is the fortieth longest river [16].

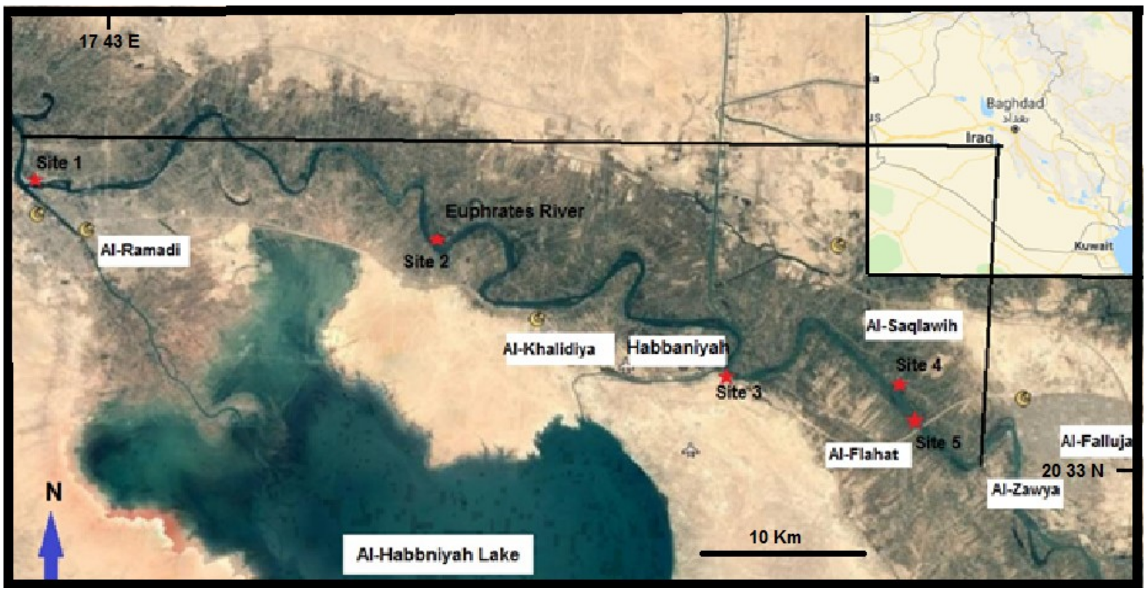

Figure 1. Studied area and sampling points (Google Earth)

Monthly water samples through nine months were taken from 5 sites along the Euphrates River between Al-Ramadi and Al-Fallujah from November 2017 to July 2018 as shown in Figure 1. Water temperature and pH were measured by portable electronic meters (Wilheim, model pH90). Dissolved oxygen (DO) and demand (BOD) were measured with an oxymeter (YOI model IS-D). Nitrate (NO3), Phosphate (PO4) and total dissolved solid (TDS) were measured as described by APHA (2007) [17]. Turbidity was determined by Lenntech turbidimeter (LT 550) . Fecal Coliform population was analyzed by MPN/100 ml method grown on M-FC medium at 44.5 C° ± 1 C° counted after 48hrs as described by WHO [18].

Qualitative diatom determinations were done as described by Germain (1981) [19] and Patrick and Reimer (1975) [20] and quantitative diatoms by the hemocytometer method described by Martinez *et al.*, (1975)[21]. For water quality, weighed factors (conditions) shown in Table 1 are used to calculate a sub-index value using a conversion curve as described by Basin (2002) [22]. The water quality index was calculated from:

NSF-WQI = ∑ WI [ref. 22]

Where W = weight of factors affecting water quality and I = sub-index of water quality parameter obtained from conversion curve (Table 1).

Table 1. Weighted factors of NSF-WQI .

Parameters	Weight
Turbidity	0.08
BOD	0.11
DO	0.17
Fecal Coliform	0.16
NO3	0.1
pH	0.11
Temperature	0.1
TSS	0.07
PO4	0.1

The index has a value between 0 to 100 as shown in Table 2 below.

Table 2. Water quality index classification according to NSF-WQI .

Water Quality	Index
Excellent	91-100
Good	71-90
Medium	51-70
Unsuitable	26-50
Very Unsuitable	0-25

Trophic diatom index (TDI) [23] was calculated from

$$WMS = \sum asv / \sum av$$

Where WMS=weighted mean sensitivity of taxa in the sample, a = abundance or proportional values of each taxa in sample, s = pollution sensitivity (1 – 5) of taxon and v = indicator value for each taxa (1 – 3) as described by Kelly and Whitton (1995) [23].

TDI is WMS expressed on a scale from 0 to 100 calculated from:

$$TDI = (WMS \times 25) - 25$$ [23]

Pollution Tolerance Index (PTI) [24] from

$$PTI = \sum (nt)/N$$

Where n = is the relative abundance of each taxon (n/N), t = is tolerance value for each taxon and N = total number of taxa in each site. Taxa were categorized as tolerant (1) or sensitive (4) with milder categories of 2 or 3 as described by Lowi (1974) [25] with PTI value classed in Table 3.

Table (3) Water quality pollution index (PTI) .

Water Quality	PTI
Most Polluted	1
Moderately Polluted	2 – 3
Least Polluted	4

Shannon Weaver Diversity Index (*H*) was determined as described by Shannon and Weaver (1949) [26] from:

$$D = \sum Pi * \ln (Pi)/H\ max$$
$$H\ max : \ln (N)$$

Where D = Diversity Index, Pi = number of individual species/total number of sample, ln = natural logarithm, H max = maximum diversity possible, N = number of species in sample.

RESULTS AND DISCUSSION

Physical and chemical properties of river water samples are listed in Table 4 below.

Table (4) Mean $\pm$ SD physical and chemical properties of Euphrates river water . n=9

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5
Turbidity (NTU)	21.0 ± 13.0 7.2 – 41.0	8.0 ± 4.2 4.0 – 17.0	6.1 ± 2.2 3.2 – 10.0	13.7 ± 17.7 2.6 – 58.0	7.7 ± 3.1 2.1 – 11.2
BOD (mg/l)	0.24 ± 0.14 0.1 – 0.5	0.75 ± 0.54 0.2 – 1.6	0.57 ± 0.15 1.4 – 0.9	0.69 ± 0.45 0.1 – 1.3	0.33 ± 0.17 0.1 – 0.6
DO (mg/l)	7.5 ± 1.0 5.8 – 8.9	8.7 ± 0.6 7.9 – 9.8	7.8 ± 4.3 7.0 – 8.3	7.9 ± 0.7 6.7 – 8.8	8.1 ± 0.6 7.0 – 9.0
Fecal coliform (MPN/100 ml)	7110 ± 790 200 - 21200	2890 ± 270 300- 9300	7850 ± 210 3300 – 11000	4830 ± 130 1500 – 6400	3310 ± 180 1500 – 7100
NO3 (mg/l)	2.30 ± 0.50 1.5 – 3.1	2.30 ± 0.76 1.2 – 3.4	2.80 ± 0.22 1.9 – 3.4	2.84 ± 0.74 1.8 – 4.3	2.72 ± 0.40 2.1 – 3.3
pH	7.9 ± 0.49 6.5 – 8.0	7.7 ± 0.32 7.0 – 8.1	7.6 ± 0.75 7.2 – 9.2	7.7 ± 0.76 7.3 – 9.7	7.5 ± 0.46 6.8 – 8.1
Temperature (C °)	20.1 ± 6.5 8 - 20	21.7 ± 4.4 17 – 27	22.3 ± 4.2 17 – 28	20.3 ± 6.5 9 – 28	22 ± 4.2 17 – 29
Dissolved solid (mg/l)	671 ± 101 494 - 776	649 ± 106 475 – 769	656 ± 136 481 – 867	713 ± 167 455 – 969	646 ± 159 343 – 825
PO4 (mg/l)	0.03 ± 0.02 0.0 - 0.07	0.03 ± 0.03 0.0 – 0.08	0.04 ± 0.02 0.0 – 0.07	0.02 ± 0.03 0.0 – 0.07	0.02 ± 0.02 0.0 – 0.06

BOD = Biochemical oxygen demand, DO = dissolved oxygen.

As shown in Table 1 above, water temperature ranged 8 – 29 C° affecting its quality, solubility of gases and salt which in turn affects behavior, physiology and distribution of aquatic organisms [27, 28]. pH was slightly alkaline ranging 7.5 – 7.9 confirming previous findings in Iraq rivers [6, 7, 8]. pH values at all sites suggests that the river has high buffer capacity as described by Reid (1961)[29]. We found DO of 7.5mg/l to 8.7 mg/l and a BOD of 0.24 mg/l to 0.75 mg/l which was below permissible limit of 5mg/l as published by the WHO in 1996 [18]. Nitrate (NO_3) and phosphate (PO_4) are nutrients required for algae growth but we detected very low levels at all sites, possibly due to dilution and/or wide surface area of the river as reported by Al-Tamimi and Al-Mersomy (2018) [6]. The quality standard for drinking water turbidity is < 5 NTU [30]. We detected turbidity of 6.1 NTU to 21.0 NTU, low values which would encourage growth of phytoplankton . The site 1 (

Ramadi) showed a high value of the turbidity due to the proximity of this site from the Ramadi Dam where the water is disturbed leading to mixing in the components of the basin. Dissolved solids were higher than permissible at all with a highest value of 713 mg/l at site 4 (Azreqiah). These high values may be due to discharge from agricultural areas, sewage and/or industrial water, especially in residential areas at sites 1 (Ramadi), 2 (Khalidiya) and 5 (Fallujah) [7].

Coliform bacteria may not cause a particular disease directly, but its presence in drinking water indicates a low level of sanitation as contamination is linked with presence of other pathogenic bacteria that normally live in the human and animal waste [30]. We found (results not shown) mean fecal coliforms (E. coli) of 78500 MPN/100ml at site 3 but a much lower 2890 MPN/100 ml at site 2 probably due to domestic sewage effluent from domestic wate, garbage dumped into river or washing and/or effluent human/animal stools.

Diatoms isolated are shown in Table 5 below. We found 95 species with highest numbers at site 2 and 3, probably due to agricultural spills and/or domestic and waste water effleunts [6] . Water quality exerts a selective action on the flora and fauna which constitute a living population of water and the effects produced in them can be used establish biological indices of water quality [31]. Diatoms are classified by tolerance to pollution most tolerant are *Nitzschia palea and Amhpora veneta (1)* whereas *Achanthes lanceolata , Cocconeis phacentula , Cyclotella meneghiniana , Navicullа lanceolata , Nitzschia acicularis and N. linearis* middle tolerance and *Fragillaria pinnata , Amphora ovalis , Cocconeis placentulla , C. pediculus , Rhoicosphenia curvata , Cymbella cistula , C. tumida , Fragilaria capusina , and Nitzschia sigmoidea are very sensitive (4)* [24]. Our findings suggested low to moderate pollution in the Euphrates river sampled [6] .

Table (4) Diversity and classification of diatoms (-) none, (+) <1%, (α) 1-10%, (x) 10–100%

Taxon	Diatom frequency for sites				
	1	2	3	4	5
BACILARIOPHYCEAE					
CENTRALES					
Bidduiphia laevis Ehrenbecg	_	_	+	_	_
Coscinodiscus lacustris Grunow	+	α	+	_	_
Cyclotella bodanica Eulenst	_	_	_	+	_
Cyclotella comta (Ehr.)Kuetzing	_	_	_	_	+
C.kutzingiana Thwaites	+	_	_	_	+
C. meneghiniana keutzing	α	+	+	+	_
C.meduanae Germain	+	_	_	_	_
C. pseudostelligera Hustedt	_	_	_	+	_
Cyclotella sp.	+	_	+	_	+
Melosira dikii Kutz.	+	_	_	_	_
M.roseana Rabenhorst	_	_	_	_	α
Stephanodiscus dubius (Fricke)Hustedt	+	+	_	+	_
Stephanodiscus sp.	_	x	α	x	x
Thalassiosira fluviatilis Hustedt	_	_	+	+	_
PENNALES					
Achnanthes affinis Grunow	_	_	+	_	α
A. flexella Kutz.	+	+	_	_	_
*A. lanceolata (*Breb.) Grunow	_	_	+	_	_
A. microcephala (Ktz.) Grunow	_	_	_	+	_
Amphiprora paludosa W. Smith	+	_	_	_	_
Amphora normannii Rab.	+	_	_	_	_
A.ovalis Kuetzing	+	_	_	_	_

A. lineolata Ehernerg	α	_	_	_	_
A. veneta(Ktz.)	+	_	_	_	_
Bacillaria paxillifer (Muell.) Hendey	+	+	_	+	+
Caloneis amphisbaena (Bory) Cleve	+	+	_	_	_
Campylodiscus biengulatus Grev.	_	_	_	_	+
Campylodiscus sp.	_	_	_	_	+
Caloneis bacillum (Grun.) Cleve	-	α	_	_	_
Cocconeis pediculus Ehrenberg	+	_	_	_	_
Cocconeis placentula(Ehr.)	+	+	+	+	_
Cymatopleura elliptica (Breb.) W.Smith	_	_	+	_	_
Cymatopleura solea (Breb)W.smith	+	_	_	_	_
Cymbella affinis (Kuetzing)	α	_	_	_	_
C. aspera (Ehr.) H. paragallo	_	_	_	+	+
C.cistula (Ehr.) Kirchn.	_	_	_	+	_
C. lanceolata (Ehr.)	+	_	_	_	_
C. tumida (Breb.) van. Heurck	_	_	_	+	_
C. turgida (Greg.) Cleve	+	_	_	_	_
C. ventricosa Kuetzing	_	_	_	_	+
Denticula elegens Kuetz	+	_	_	+	_
Diatoma elongatum (Lyngb.) Agardh	+	_	_	+	+
D. elongatum var. minor Grun	_	_	_	_	+
D.vulgare Bory	+	_	_	_	_
Diatomella hustedii Manguin	x	α	x	_	x
Epithemia turgida (Ehr.) Kuetzing	+	_	+	_	+
E. sorex Kuetzing	_	_	+	_	_
Eunotia pectenalis Kuetzing	_	+	_	_	_
Fragilaria capucina Desmazieres	+	_	_	_	_
Fragilaria constuens (Ehr.) Grunow	_	_	+	+	_
F. intermedia Grunow	_	_	_	_	+
F. pinnata (Ehr.)	+	_	_	_	_
F.virescens Ralfis	_	α	_	_	_
Gomphoneis herculaeana (Ehr.) Cleve	_	+	_	_	_
G. olivaceum Langby	_	+	_	_	+
Gomphonema tergestinum (Grun.)	+	_	_	_	_
Gyrosigma acuminatum (Ktz.) Rabenhorst	_	+	_	_	_
G. attenuatum (Ktz.) Rabenhorst	_	_	+	_	_
Hannaea arcus (Ehr.) Patrick	_	_	_	+	_
Mastogloia apiculata W.Smith	_	_	_	+	+
Navicula contenta Arn.	_	_	α	_	_
N .cuspidata (Ktz.) Kuetzing	_	α	_	+	_
*N. follis (*Ehr.)	α	_	_	_	_
N.fragilariodes Krasska	x	α	α	_	x
N.humerosa de Brebisson	+	_	_	_	_
*N. lanceolata (*Ag.) Kuetzing	α	_	x	_	_
N. pusilla W.Smith	+	_	_	_	_
N.rhynchocephala Kuetzing	_	_	_	_	x
N. stagnorum Rahb.	+	_	_	_	_
Naviculla sp.	x	α	α	x	α
Nitzschia acicularis W. Smith	_	_	α	+	+
N. acuta Hantzsch	_	+	_	_	_
*N. dubia W.*Smith	_	_	α	_	_
N.linearis W.Smith	_	+	_	+	_
N. palea (Ktz.) W.Smith	+	_	_	_	_
N. rustellata Hustedt	_	+	_	_	_
N.sigmoideo (Ehr.) W.Smith	_	+	_	_	_
N.vermicularis (Ktz.) Hantzsch	_	+	_	+	_
N.vitrea Norman	_	_	_	+	_
Nitzschia sp.	_	α	_	α	_
Plagiotropis lepidoptera (Gregory) Kuntze	_	α	_	_	+
Rhoicosphenia curvata (Ktz.) Grunow	+	_	_	+	+
R.marina Kuetzing	+	+	_	_	_
Rhopalodia gibba (Ehr.) O.Mueller		_	+	_	_
R. gibberula (Ehr.) O. Mueller	+	_	_	_	_
Scolipleura ovalis de Brebisson	+	_	_	_	_
S. peisonics Grunow	_	_	_	_	+
S.spiralis Kg.	+	_	_	_	_

Staurastrum analinum Cooke and Willis	_	α	_	_	_
Stauroneis acuta W.Smith	+	α	_	+	+
Stauroneis sp.	_	α	_	_	_
Surirella capronii de Brenisson ex. Ktz.	_	+	_	_	_
Surerilla ovata Ktz.	_	_	+	_	_
Synedra acus Kuetzing	_	_	α	+	_
S .robusta Ehr.	_	_	+	+	+
S. rumpens Kg.	+	_	_	_	_

Results in Table 6 below show a moderate Trophic diatom index [23] values of 60.7 at site 2 to 72.4 at site 4, classifying the river as mesotrophic with average water quality. We detected *Diatoma vulgare, Cyclotella comta, Cocconeis pediculus, Cymbella siffinis, Fragilaria capucina, F. pinnata and Nitzschia vermicularis* supporting our findings as described previously [5, 13]. Mean PTI determined by diatom*s* [32] ranged from 2.33 at site 4 to 2.88 at site 2. These results suggest that river was less to moderately polluted as reported by Lang-Bertalot (1974) [24]. The presence of *Cyclotella meneghiniana, Achnanthes affinis, Cocconis placentula, Navicula lanceolata , Nitzschia acicularis* and *N. linearis* support our findings as described by Wang et al., (2014) [13].

Concerning biodiversity, the mean Shannon – Weaver diversity index (*H*) ranged 0.5 at site 4 to 0.69 at site 1 suggesting moderate biodiversity for Euphrates with no dominant diatoms. The high *H* index of up to 0.90 at all sites suggested acceptable water quality [33]. Mean NSF-WQI ranged from 75 at site 3 to 79 at site 2 and 5 similar to sites of extreme temperature and low biological oxygen demand, nitrate, phosphate, suspended solid, alkalinity and high concentrations of dissolved oxygen [11].

Table 6 Mean ± SD biological and water quality indices of Euphrates river water.

Index	Site 1	Site 2	Site 3	Site 4	Site 5
Trophic Diatom Index	64.5 ± 1.5 40 - 78	60.7 ± 1.8 30 - 82	68.7 ± 1.4 43 – 92	72.4 ± 6.6 55 – 75	61.0 ± 1.8 22 – 81
Pollution Tolerance Index	2.70 ± 0.30 2.09 – 3.00	2.33 ± 0.31 2.00 – 2.77	2.63 ± 0.30 2.06 – 3.00	2.88 ± 0.20 2.50 – 3.21	2.68 ± 0.70 2.00 – 4.00
Shannon Weaver Diversity Index (H)	0.69 ± 0.2 0.37 – 0.96	0.57 ± 0.3 0.10 – 0.95	0.64 ± 0.2 0.26 – 0.93	0.50 ± 0.3 0.01 – 0.95	0.59 ± 0.2 0.35 – 0.94
Water Quality Index (NSF-WQI)	76.3 ± 4.3 70 - 83	79.1 ± 1.5 76 - 81	75.8 ± 5.1 63 – 80	78.3 ± 4.3 72 – 86	79.0 ± 1.9 75 - 81

We find that the Euphrates is moderately polluted mainly due to human discharges and low rainfall during the study, water discharge from agricultural and industrial purposes increase physical and chemical pollution of the river [11]. We conclude that the Euphrates is low to moderately polluted, oligotrophic to mesotrophic of moderate biodiversity by diatom NSF-WQI were identical to physical and chemical parameters compared with biological indices did not show a pattern and visibility between WQI and TDI , but some showed compatibility between H, PTI and WQI .

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