OPEN ACCESS
International Journal of Aquatic Science
ISSN: 2008-8019
Vol. 6, No. 2, 76-92, 2015

Qualitative and Quantitative Study of Diatoms in a Lotic Ecosystem, Iraq

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Received: 26 November 2014 **Accepted:** 23 December 2014 **Published:** 06 June 2015

Abstract: The research was conducted to study the diatoms in a lotic ecosystem (Al-Shamiyah River) and related physicochemical factors for the period from March 2013 to January 2014. Four sites were selected along the river and the study included measuring the temperature (air and water), water flow rate, turbidity, light penetration, pH, total available carbon dioxide, dissolved oxygen, biochemical oxygen demand, electrical conductivity, salinity, total suspended solids, total dissolved solids, total alkalinity, hardness, calcium, magnesium, nitrite, nitrate, phosphate and silicate. Furthermore, the quantitative and qualitative studies of diatoms were done. A total of 144 taxa of diatoms was identified with predominate of pennate diatoms (129 species), while the centric diatoms were 15 species. The recorded identified diatoms were 83, 68, 74 and 81 species in sites 1, 2, 3 and 4, respectively. Total number of diatoms ranged 16347.7- 31514.6 cell × 10^3/l. High values of diversity indices were recorded in this study. The results revealed that the river was not under pollution stress.

Key Words: Diatoms, Lotic ecosystems, physicochemical factors, Pennate diatoms, Centric diatoms

Introduction

The WHO and UNICEF (2000) notified the scarcity of safe drinking water, as reflected on the impact of the water scarcity worldwide. This led to more attention to water resources in Iraq, which they have different freshwater ecosyst-ems, which included mainly the Tigris and Euphrates rivers and their branches. Euphrates River is one of the longest rivers in the Middle East, which occupies the number 24 among the world's river, while Tigris River is number 39 in the world (Whitton, 1975; Wetzel, 2001).

The diatoms are a predominant group of phytoplankton in most aquatic systems and play as the basis of the primary production in an aquatic ecosystem due to their ability to fix CO_2 in photosynthesis processes. Many factors have an impact on diatom distributions, and activities (Peterson and Stevenson, 1989; Reynolds, 1984). Also, it's considered as the basic component of food chains in aquatic systems

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(Keithan and Lowe, 1985) an increasing in diatom productivity will reflect on extent of food chains in an aquatic system (Knuckey and Brown, 1998; Huntley, 1996).

The qualitative and quantitative aspects of phytoplankton were related to photochemical factors of an aquatic ecosystem, Adesalu (2012) explained that the studied physicochemical factors in a tidal creek, Lagos, Nigeria influenced phytoplankton composition. Also, the occurrence and succession of phytoplankton were affected by zooplankton grazing (Islam *et al.*, 1974).

Many studies on the Euphrates River showed the effect of physicochemical factors on the quantitative and qualitative of phytoplankton (Hassan, 1997; Al- Saadi *et al.*, 2000; Hassan *et al.*, 2008, Hassan *et al.*, 2014). Salman *et al.* (2013) found in their study on Euphrates River the important roles of some environmental factors (salinity, dissolved oxygen and organic materials) on the seasonal variation of phytoplankton. Hassan *et al.* (2010a) revealed the mid regions of the Euphrates River are oligotrophic conditions according to phytoplankton composition.

Most of studies explained the importance of phytoplankton as bioindicators due to their fast response to the alteration in an aquatic ecosystem (Szczepocka, 2007; Chellappa *et al.*, 2008; Menezesa *et al.*, 2013; Desrosiers *et al.*, 2013). The community of diatoms offers a comprehensive and integrated assessment of water quality as they remain for several months, so they reflect the type of environment of aquatic ecosystems over a period of time (Walsh and Wepener, 2009). Diatoms used as an indication of some aquatic pollutants such as organic, heavy metals and also eutrophication (RHP, 2005; Taylor *et al.*, 2005). Another study focused on diatoms as indicator for different types of anthropogenic activities (Stenger-Kovács *et al.*, 2014).

The present study aimed to evaluate the Al-Shamiyah River as a lotic ecosystems and used the results as a baseline for future monitoring of this river.

Materials and methods

Euphrates River is ramified into two branches (Kufa and Al-Shamiyah Rivers) after passing 1 km from Kifil city. Then the Al-Shamiyah river connects again Kufa river at Shinafiyah city (Diwaniyah province) (UNESCO, 2002). It is long 120km with an average discharge of 180 liter/S. Four sites were selected along the river for the period from March 2013 to January 2014. The first site was located at the beginning of branching of the Euphrates River and characterized by dense macrophytes and there were agriculture activities. Site 2 was located at Salahiya town, Diwaniyah province and also characterized by the presence of macrophytes with few agricultural activities. While, site3 was located at the center of Al-Shamiyah town was impact of human and agricultural activities. The fourth site was located at Ghammas town and characteristic by a density of macrophytes and nearby rice farms (Fig. 1).

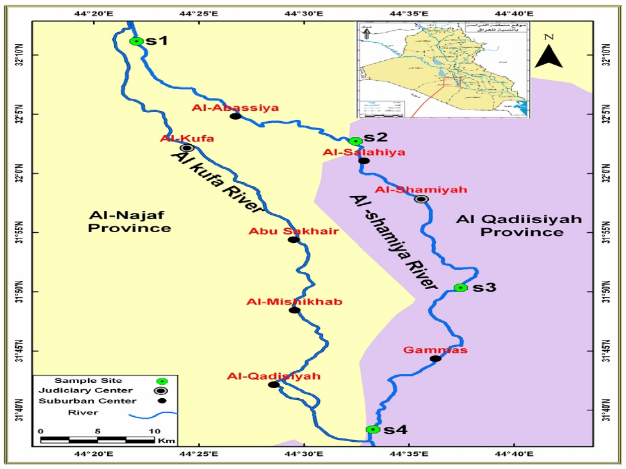

Fig. 1: Map of the studied area.

The studied physicochemical parameters were measured according to Mackerth, *et al.* (1978) for temperature, water flow, turbidity, light penetration, electric conductivity and salinity. While for total alkalinity, total hardness, calcium, magnesium, total dissolved solids, total suspended solids, sulphate, chloride, sodium, potassium, dissolved oxygen and biochemical oxygen demand were measured according to APHA (2003). Nutrients (nitrite, nitrate, phosphate and silicate) followed Parsons *et al.* (1984). Total available carbon dioxide measure-ed by titration methods (Maiti, 2004). Total organic carbon (TOC%) measured by Walkely-Black method (Gaudette *et al.*, 1974). Species richness and Shannon-Weaver index was calculated following Stiling (1999) and Shannon–Weaver (1949).

Qualitative study of diatoms used a phytoplankton net and the identification was done using the following references (Prescott, 1973; Germain, 1981; Al-Handal, 1994; Hassan *et al.*, 2012; Al-Hassany and Hassan, 2014). For quantitative study used micro transects methods (Vollenweider, 1974). SPPS and canonical correspondence analysis (CCA) were used for statistical analysis via the computer program version 4.5 (Ter Braak and Smilauer, 2002).

Results and Discussion

All studied physicochemical parameter results were illustrated in Table 1. The monthly variations of temperature in both air and water were evident and normally noticed in Iraqi climate. Significant differences among sites and study months were noticed ($P \leq 0.05$). A positive correlation between temperature and light penetration was observed ($r=0.928$, $P<0.01$). The high water flow was recorded in January 2014, while the lowest was in April 2013, the fluctuation in the flow rate may be due to several factors such as the morphology of the river and the presence of barrages at the beginning of the river which control its discharge (Wetzel, 2001).

A positive correlation was recorded between water flow and turbidity and total suspended solids ($r=0.806$ and $r=0.823$,

Tab. 1: Rang (mean±SD) of Physicochemical and biological parameters in Al-Shamiyah River during the study period.

Parameter	Sites			
	1	2	3	4
Air Temp. (C^o)	13.66-34.33 (24.63± 6.63)	13.33-37.66 (25.27±7.73)	15.83-39.00 (27.130±7.43)	17.66-39.00 (28.06±7.36)
Water Temp. (C^o)	11.33-35.00 (21.67±7.83)	12.53-34.83 (22.76±7.57)	12.1-35.83 (24.11±7.71)	12.33-36.00 (24.50±7.71)
Water flow (m/min)	28.57-49.99 (39.11±6.57)	24.00-42.86 (33.22±6.16)	20.00-39.99 (30.92±6.33)	22.20-37.5 (30.38±5.34)
Turbidity (NTU)	12.21-22.11 (16.87±3.24)	10.00-19.44 (15.04±3.03)	8.25-17.89 (13.64±2.94)	9.25-15.17 (12.87±1.85)
Light penetration (Cm)	24.40-42.50 (31.33±4.54)	27.50-55.00 (38.36±8.71)	33.80-65.009 (45.54±9.55)	28.80-60.00 (41.93±8.78)
E.C (µs/cm)	1125-1298 (1210.07±61.21)	1114-1280 (1189.17±58.13)	1108-1473 (1260±103.07)	1137-1560 (1314.17±128.99)
Salinity (‰)	0.719-0.831 (0.78±0.039)	0.71-0.82 (0.76±0.037)	0.71-0.94 (0.81±0.066)	0.73-0.99 (0.84±0.082)
T.D.S (mg/l)	719-831 (775±39.39)	713-819 (761±37.24)	709-943 (806±66.16)	728 –998 (841±82.47)
T.S.S (mg/l)	25.65-39.02 (34.35±4.72)	20-38.88 (29.85±5.37)	16.5-35.75 (27.1±5.63)	18.5-31.54 (25.53±4.37)
pH	7.46-8.23 (7.99±0.22)	7.76-8.22 (7.99±0.16)	7.66-8.21 (7.97±0.19)	7.55-8.22 (7.93±0.22)
Dissolved oxygen (mg/l)	7.2-10.5 (8.98±1.1)	6.8-10.2 (8.47±1.08)	6.5-9.4 (7.92±0.99)	6.3-9.1 (7.62±0.97)
BOD (mg/l)	0.99-1.73 (1.37±0.19)	1.1-2.03 (1.53±0.29)	1.43-2.36 (1.81±0.34)	1.14-2.5 (1.85±0.46)
TAcd* (mg/l)	116.6-182 (153.78±19.82)	123.2-193.6 (157.16±28.03)	129.8-209 (161.1±26.63)	123.2-222.53 (155.68±21.32)
Alkalinity (mg CaCO3/l)	97-147 (14.93±128.92)	100-155 (130.00±16.74)	98 -158 (133.08±19.01)	105-162 (137.50±19.5)
Hardness (mg CaCO3/l)	259.63-520 (382.64±91.44)	300-540 (414.66±83.35)	332-556 (447.33±75.08)	352-572 (465±81.41)
Calcium (mg/l)	74.41-125.17 (104.27±14.92)	77.95-150.55 (108.97±22.92)	82.01-150.01 (110.68±21.86)	76.95-137.27 (107.25±18.98)
Magnesium (mg/l)	12.57-54.35 (32.91±13.11)	19.74-53.37 (34.94±9.73)	23.28-53.37 (41.84±7.95)	27.15-63.1 (48.28±10.54)

Continuation Tab. 1

Parameter	Sites			
	1	2	3	4
Sodium (mg/l)	86.6-152.4 (117.57±21.42)	83.06-150.99 (114.45±23.99)	78.5-157.66 (119.66±25.64)	75.73-155.99 (116.25±31.06)
Potassium (mg/l)	4.166-7.15 (6.12±0.76)	5.25-9.65 (7.06±1.60)	5.12-9.48 (7.09±1.47)	4.42-10.26 (6.95±1.56)
Sulphate (mg/l)	183.99-414.7 (284.15±76.24)	224.4-454.6 (313.5±73.39)	242.96-486.3 (326.43±76.34)	263.0-483.97 (351.42±68.54)
chloride (mg/l)	47.43-114.03 (73.75±21.5)	70-114.17 (83.28±14.98)	60.6-121.23 (83.75±18.99)	61.43-123.33 (89.81±19.47)
Nitrite (µg/l)	0.16-2.00 (1.22±0.52)	0.39-2.01 (1.29±0.49)	0.43-2.02 (1.36±0.48)	0.89-2.2 (1.54±0.39)
Nitrate (µg/l)	44.33-117.46 (73±24.89)	43.54-108.78 (66.63±20.51)	41.79-97.83 (61.96±18.52)	40.38-89.48 (57.00±15.87)
Phosphate (µg/l)	0.035-0.21 (0.10±0.056)	0.025-0.20 (0.01±0.065)	0.012-0.20 (0.10±0.073)	0.036-0.22 (0.12±0.051)
Silicate (µg/l)	99.66-139.33 (120.25±12.91)	93.13-135.73 (126.16±13.59)	94.56-135.73 (129.29±15.66)	102.83-160.8 (140.73±19.56)
N:P	211.7:1-1824.5:1 (1010.12:1±551.56)	224.2:1-2951.6:1 (1104.1:1±932.82)	232.98:1-5067.7:1 (1256.21:1±1344.14)	207.7:1-1550.8:1 (599.7:1±347.04)
C: SiO3	0.26:1-0.42:1 (0.36:1±0.045)	0.266:1-0.39:1 (0.34:1±0.035)	0.27:1-0.41:1 (0.35:1±0.047)	0.25:1-0.366:1 (0.31:1±0.034)
Total organic Carbon (mg/l)	0.3-0.85 (0.54±0.17)	0.24-1.483 (0.66±0.35)	0.47-1.76 (0.90±0.41)	0.403-1.85 (0.94±0.51)
Total diatoms algae (cell × 10^3/l)	834.2-3977 (2166±1093)	688.7-4015.8 (2048±1139)	1154.3-4762.7 (26217±1284)	320.1-2589.9 (13602±709)
Chlorophyll a (µg/l)	0.73-3.33 (2.40±0.81)	0.72-8.02 (3.27±2.19)	1.08-9.83 (3.37±2.37)	0.365-5.09 (2.94±1.64)
Pheophytin a (µg/l)	0.16-1.26 (0.50±0.35)	0.04-1.61 (0.79±0.49)	0.14-1.54 (0.69±0.54)	0.04-1.27 (0.44±0.37)

TAcd: Total Available carbon dioxide

$P<0.01$, respectively). Lowest light penetration was recorded in January 2014 which synchronized with the highest value of total suspended solids in site 1, and the same manner with the highest light penetration in April 2013 but in site 3. The same fluctuation was noticed with turbidity. The water level and flow play the main roles in values of light penetration, turbidity and total suspended solids, moreover other biological factors

(Ayoade *et al.*, 2009; Salman *et al.*, 2013). The impact of human activities was evident in site 4 where the highest values of electric conductivity, salinity and total dissolved solids, while the lowest values of these parameters may be due to the dilution factor because of the increase in discharge rate of the river, especially in May 2013 (Floder and Burns, 2004). A positive correlation was between conductivity and both total hardness, calcium and magnesium ($r=0.555$, $r=0.640$, $r=0.600$, $P<0.01$).

The pH values ranged (7.46-8.23), that was a narrow change in pH values due to buffer systems of Iraqi aquatic ecosystems (Hassan, 1997; Al-Saadi *et al.*, 2000). pH values were affected by photosynthesis activity via phytoplankton and other aquatic plants (Goldman and Horn, 1983; Brown, 1980). The high alkalinity (162mg $CaCO_3$/l) was recorded in this study may be due to increase of temperature and decomposition reactions (Wetzel, 2001). While the lowest value of alkalinity (97mg CaCO3/l) was recorded in Spetmeber 2013, in which this reduction in values was attributed to the activity of photosynthesis by phytoplankton (Wetzel, 1975).

Total available carbon dioxide ranged (116.6-222.53) mg/l in sites 1and 2 during April and June 2013. No hypoxia was observed in this study, the lowest concentration of dissolved oxygen was 6.3 mg/l which could reveal that the river has good aeration and the concentration of dissolved oxygen was affected by temperature and organic materials in an aquatic ecosystem (Hassan, 1997; Ezzat *et al.*, 2012). The BOD_5 concentration ranged 0.99-2.5mg/l during the study period, the highest concentration was related to increasing organic materials and microorganism activities (Salman *et al.*, 2013).

The total hardness results indicated that the river was very hard water according to APAH (2003) and this finding agreed with many studies in Iraqi aquatic ecosystems (Al-Mousawi *et al.*, 1994; Hassan *et al.*, 2010b; Salman *et al.*, 2013). The concentration of calcium was higher than the magnesium concentration which is normal in natural waters (Pitter, 1999). Sodium, potassium and chloride concentration ranged (75.73-157.66), (4.166-10.260) and (47.43-123.33), respectively. The highest concentration of sodium, potassium and chloride might be due to agricultural activities and municipal discharge of wastewater (Agarwal, 2009).

The concentration of nitrite was lowest during the study period due to better aeration of the river, while nitrate concentration ranged (40.38-117.46 µg/l) and phosphate and silicate were 0.012-0.22 µg/l and 93.13-160.80 µg/l. The highest values of sulphate recorded in Euphrates River were due to erosion effect and wastewater outflow from industrial activities (Hassan *et al.* 2005). The fluctuation in nutrient concentration depends on its sources from agro-industrial activities, biological activity and morphology of the river (Wetzel, 2001). Positive significant differences were noticed for the studied nutrients among the studied months and sites (P≤0.05).

A total of 144 taxa of planktonic diatoms were identified, in which 83, 68, 74 and 81 taxa were recorded at sites 1, 2, 43 and 4, respectively (Tab. 2). Pennate diatoms presented 89.6% (129 diatoms) of the total identified diatoms, while centric diatoms were 10.4%. The dominance of diatoms in Iraqi aquatic ecosystems is very known (Al-Mousawi *et al*., 1994; Hassan *et al*., 2010; Salman *et al*. 2013a, b). This dominancy is related to their ability to grow and reproduce in wide environmental alteration (Acs *et al*., 2004). Some of diatoms were found in all sites such as: *Cyclotella comta* (Fhr.) Kutz., *C.* Kuetzingiana, *C. meneghiniana* Kuetzing, *C. ocellata* Pantocsek, *Achnanthes affinis*, *Cocconeis pediculus* Ehrenberg, *C. plancentula* Ehr., *C. placentula* var euglypta (Ehr.) Cleve , *C. placentula* var. lineata (Ehr.) Cleve., *Cymbella affinis* kuetzing , *Diatoma elongatum* (lyngb.) Agardh., *D. vulgare* Bory.

Lange-Bertalote (1979) classified diatoms into three types of tolerance to pollution, in this study eleven species of diatoms were regarded to sensitive to pollution and these species were found in unpolluted water or oligotrophic aquatic systems. Seventeen species of diatoms were regarded of medium tolerance to pollution and these were found in oligotrophic -α- mesosaprobic type of aquatic systems. While eight species of diatoms were tolerant to pollution that these species were found in polysaprobic -α- mesosaprobic type.

The most of abundant pinnate diatoms recorded maximum total number in the spring months (March and April) while only *D. vulgare* recorded in early autumn (September). Where the species were *Achnanthes affinis* 19.4-698.4 cells × 10^3/l at site 4 in September 2013 and April 2013, respectively. *Cocconeis pediculus* 9.7-116.4 cell × 10^3/l at sites 4 and 2 in June 2013 and May 2013. *C. placentula* 9.7-582 cell × 10^3/l at sites 4 and 3 in September 2013 and April 2103, respectively. *C. placentula* var *euglypta* 19.4-766.3 cell × 10^3/l both at site 4 in December 2013 and April 2013, respectively. *C. placentula var lineate* 9.7-552.9 cell × 10^3/l both at sites 4 in July 2013 and January 2014, respectively. *Cymbella affinis* 9.7-87.3 cell × 10^3/l at sites 2 and in both4 and 3 in September 2013 and April 2013. *Diatoma elongatum, 29.*1-388 cell × 10^3/l at sites 1 and 3 in August 2013 and April 2013. *D. vulgare* 19.4-291 cell × 10^3/l at sites 2 and 3 in August 2013 and September 2013.

While the total number of the centric diatoms were in a lower number than the pennate diatoms. These centric diatoms ranged as follows: *Cyclotella Comta* 19.4-727.5 cell × 10^3/l at sites 4 and 2 in November 2013 and April 2013, respectively. *C. Kuetzingiana* 19.4-223.1 cell × 10^3/l at sites 2 and 3 in August

2013 and October, respectively. *C. meneghiniana* 9.7-388 cell × 10^3/l at sites 4 and 3 in March 2013 and October 2013. *C. ocellata* 9.7-242.5 cell × 10^3/l at sites 4 and 1in January 2014 and March 2013, respectively.

Tab. 2: List of identified diatoms and its total numbers (cell × 10^3/l) in Al-Shamiyah River during the study period.

Taxa	Site			
	1	2	3	4
Bacaillriophyceae				
Centrales				
Aulacosiera ambigua O. Muller	455.9	213.4	523.8	397.7
A. distans (Ehr.) Kuetzing	533.5	-	-	-
A. granulata (Ehr.) Ralfs	77.6	514.1	805.1	107.7
A. italica (Ehr.) Ralfs	-	-	-	9.7
A. roeseana Rabenhorst	-	-	38.8	-
A. varian C. A. Agardh	164.9	-	659.6	174.6
Coscinodiscus lacustris Grunow	145.5	-	-	-
Cyclotella comta (Fhr.) Kutz	795.4	1590.8	1687.8	989.4
C. Kuetzingiana Thwaites	601.4	970	805.1	-
C. meneghiniana Kuetzing	1125.2	1096.1	1813.9	1775.1
C. ocellata pantocsek	658.6	758.7	426.8	300.7
C. stelligera (cl. et Grun.) Van. Heurek.	-	261.9	-	29.1
C. striata (kuetz.) Grun.	455.9	-	-	-
Stephanodiscus astrea (Ehr.) Gran.	203.7	-	-	-
S. dubius (Fricke) Hus.	-	116.4	-	-
penneales				
Achnanthes affinis Grunow	630.5	591.7	630.5	960.3
A. conspicua A. Mayer	-	135.8	-	-
A. delicatula (Ktz.) Grunow	184.3	426.8	-	-
A. exigue Grunow	-	-	194	-
A. flexella Kutz.	-	-	-	48.5
A. hungarica Grunow	-	-	397.7	87.3
A. lanceolata (Breb.) Grun	184.3	-	-	-
A. microcephala (kutz.) Grunow	261.9	426.8	203.7	58.2
A. mintussima Kuetzing	291	436.5	543.2	232.8
Amphiprora alata Kutz.	-	-	-	281.3

Continuation Tab. 2

Taxa	Site			
	1	2	3	4
Amphoa coffeaeformis Agardh	-	-	-	349.2
Amphora ovalis (Ktz.) Kuetzing	-	232.8	194	-
Amphipleura pellucida (ktz.) Kuetzing	-	213.4	-	-
Bacillaria paxilifer (Muell.) Hendey	291	-	-	-
Caloneis permagna (Bail.) Cleve	-	135.8	-	-
Cocconeis diminuta Var. *diminuta*	242.5	-	-	58.2
C. pediculus Ehrenberg	417.1	514.1	591.7	194
C. plancentula Ehr.	1697.5	1949.7	3259.2	455.9
C. placentula Var. *euglypta* (Ehr.) Cleve	611.1	-	766.3	2395.9
C. placentula Var. *lineata* (Ehr.) Cleve	465.6	873	465.6	1641.5
Cymatopleura elliptica (Breb.) W. Smith	38.8	58.2	87.3	-
C. solea (Breb.) W. Smith	58.2	97	87.3	164.9
Cymbella affinis kuetzing	543.2	378.3	543.2	407.4
C. amphicephala Naegeli	58.2	291	135.8	-
C. aspera H. paragallo	184.3	-	58.2	-
C. cistula (Ehr.) Kirchn	174.6	320.1	126.1	-
C. creptocyphala Kuetzing	-	-	-	38.8
C. gracilis (Rabh) Cleve	417.1	-	-	-
C. helvetica kuetzing	126.1	368.6	291	-
C. microcephala Grunow	126.1	145.5	232.8	-
C. parva (w. smith) Cleve	-	-	-	19.4
C. tumida (Breb.) V. Heurck	320.1	-	1134.9	-
C. tumidula Grunow	184.3	-	485	19.4
C. turgida (Greg.) Cleve	164.9	-	87.3	-
C. ventricosa Kuetzing	320.1	135.8	291	-
Diatoma elongatum (lyngb.) Agardh	1231.9	659.6	1668.4	58.2
D. tenue Var. *elongatum* lyngb.	281.3	-	-	-
D. vulgare Bory	475.3	582	620.8	38.8
Diploneis elliptica (ktz)Cleve	242.5	-	-	-
D. ovalis (Hilse) Cleve	126.1	-	58.2	-
Epithemia sorex (Ehr.) Kuetzing	-	-	106.7	-
E. turgida (Ehr.) Kuetzing	-	106.7	-	-
E. zebra (Ehr.) Kuetzing	543.2	349.2	611.1	-
Eunotia formica Ehrenbeg	77.6	-	126.1	19.4
E. pectinalis Ralfs	135.8	184.3	-	-

Continuation Tab. 2

Taxa	Site			
	1	2	3	4
Fragilaria brevistriata Grunow	174.6	-	-	-
F. capucina Desmazieres	194	261.9	310.4	58.2
F. construens (Ehr.) Grunow	-	-	213.4	-
F. crotonensis Kitton	640.2	475.3	572.3	48.5
F. virescens Ralfs	58.2	-	-	-
Gomphonema acuminatum Ehrenberg	300.7	-	-	-
G. angustatum (Kutz) Rabh	58.2	19.4	261.9	29.1
G. angustatum Var. *productum* Grun	970	1658.7	-	-
G. constrictum Ehrenbeg	-	145.5	-	-
G. intricatum Kuetzing	291	281.3	407.4	-
G. intricatum Var. *lunata*	58.2	-	213.4	-
G. lanceolatum (Ehr.)	87.3	-	58.2	-
G. parvulum (Kuetzing)Grunow	514.1	475.3	407.4	388
G. tergestinum (Gruh) Fricke	-	-	-	58.2
Gyrosigma acuminatum (Ktz.) Rabenhorst	311.69	87.3	155.2	106.7
G. attenuatum (Ktz.) Rabenhorst	29.1	87.3	-	-
G. scalproides (Rhbenh.) celve	-	-	-	29.1
G. spencerii (w. smith) cleve	-	-	-	19.4
G. Stregilii w. smith	-	-	-	58.2
Mastogloia smithii Thwaites	77.6	-	-	67.9
Meridion circulare Agardh	-	-	-	19.4
Navicula americana Ehr.	-	-	-	29.1
N. cinta (Ehr.) Kuetzing	29.1	164.9	-	67.9
N. cryptoephala kuetzing	679	417.1	485	-
N. cuspidate (Ktz.) Kuetzing	-	87.3	-	-
N. dicephala (Ehr.) W. Smith	320.1	87.3	-	-
N. decussis Oestrup	-	-	-	77.6
N. gastrum Ehr.	-	-	-	9.7
N. gracilis Ehr.	358.9	562.6	620.8	67.9
N. graciloides A. Mayer	-	271.6	-	19.4
N. gregaria Donkin	-	-	-	87.3
N. grimmei Krasske	-	174.6	-	19.4
N. halophila (Grum) celve	252.2	320.1	126.1	48.5
N. hungarica Grunow	-	-	-	9.7
N. lanceolata (Agardh.) Ehr.	48.5	514.1	523.8	58.2

Continuation Tab. 2

Taxa	Site			
	1	2	3	4
N. pseudohalophila Cholnoky	-	-	-	48.5
N. phyllepta Kutz	97	-	-	-
N. Pupula Kuetzing	-	-	97	-
N. pygmaea Kutz	19.4	-	-	155.2
N. radiosa Kuetzing	1086.4	261.9	184.3	155.2
N. rhynchocephala kutzing	97	-	-	-
N. salinarum Grun	-	-	-	67.9
N. trivialis Lange-Bertalot	-	-	-	29.1
N. viridula kuetzing	-	-	-	67.9
Nitzschia acicularis w. smith	378.3	77.6	436.5	58.2
N. acuta Hantzsch	-	-	-	38.8
N. amphibia Grunow	-	-	29.1	-
N. apiculata (Greg.) Grunow	-	184.3	-	155.2
N. closterium (Ehr.) W. Smith	164.6	116.4	-	-
N. communis Rabenhorst	-	-	-	19.4
N. commutate Grunow	126.1	-	-	9.7
N. dissipata (Kutz) Grun	-	184.3	126.1	48.5
N. filiformis (W. smith) Hustedt	-	-	116.4	155.2
N. fonticola Grunow	67.9	-	242.5	-
N. fruticosa Hustedt	-	-	-	38.8
N. gracilis Hantzsch	-	-	252.2	-
N. granulata Grunow	291	-	-	-
N. hungarica Grunow	174.6	-	377.6	38.8
N. intermedia Hustedt	-	-	-	97
N. linearis W. Smith	-	77.6	485	-
N. longissima (Breb.) Ralfs	407.4	232.8	232.8	48.5
N. obtusa W. Smith	-	-	9.7	-
N. palea (Ktz) W. Smith	261.9	116.4	126.1	145.5
N. paleacea Grunow	378.3	455.9	494.7	38.8
N. puctata (W. Smith) Gruonw	-	-	87.3	-
N. pusilla Kuetzing	-	417.1	-	-
N. romana Grum	48.5	-	261.9	1222.2
N. sigma (Kutz) w. smith	_	-	126.1	19.4
N. sigmoidea (Ehr.) w. smith	87.3	87.3	213.4	126.1
N. stagnorum Rabh	-	-	-	38.8
N. tryblionella Hantzsch	378.3	203.7	-	-

Continuation Tab. 2

Taxa	Site			
	1	2	3	4
N. vermicularis (ktz) Hantzsch	-	203.7	-	48.5
Pinnularia appendiculata (Ag.) Cleve	-	-	77.6	-
P. borealis Ehr.	-	-	679	-
P. aleptosome (Grun.)Cleve	-	-	-	48.5
Rhoicosphena curvata (kutz) Grunow	-	-	271.6	184.3
Surirella angusta Kuetzing	126.1	-	-	97
S. ovalis de Brdbisson	-	67.9	-	-
S. ovata Kuetzing	-	-	48.5	-
Synedra acus Kuetzing	184.3	164.9	77.6	145.5
S. pulchella (Ralfs) Kuetzing	-	-	38.8	-
S. tabulate Var. *fasciculate* Agardh	-	-	-	126.1
S. ulna (Nitzsche) Ehr.	339.5	329.8	620.8	38.8
S. vaucheria Kuetzing	126.1	116.4	717.8	145.5
Total No. (Cell × 10^3/l)	26616.8	24553	31514.6	16347.7

The minimum and maximum range of Richness index (1.53 and 6.97) was recorded on site 3 in January 2014 and September 2103, respectively. While the minimum value of Shannon- Weaver index was 1.84 and the maximum was 3.93 at sites4 and 1 in February 2013 and September 2103, respectively (Fig. 2). These high values indicated to high biological diversity of the study area. Many factors have played roles in biological indices of diatoms such as pollution, grazing, and physicochemical factors (Jonge 1995; Ghosh *et al.*, 2012; de Jonge *et al.*, 2012). Shehata *et al.* (2009) mentioned that unpolluted aquatic ecosystems are characterized by high values of diversity indicated.

CCA analysis showed the positive and negative correlations (figs. 3 and 4). The first axis in Figure 3 showed the positive correlation with water flow (CV) and percent nitrogen to phosphorus (N: P) and carbon to silicate (C:SIO_3). In the second axis the positive correlation between different parameters such as water temperature, BOD_5, CO2, Ca, Mg, total organic carbon (TOC), total hardness (T.H), total alkalinity (T.H.), chloride (Cl), sulphate (SO4), light penetration (L.p), total dissolved solids (TDS), electric conductivity (EC), Salinity (Sal), and silicate (SiO_3). These parameters have negative correlation with parameters in third axis such as BOD5 and TOC with dissolved oxygen (DO) and these results

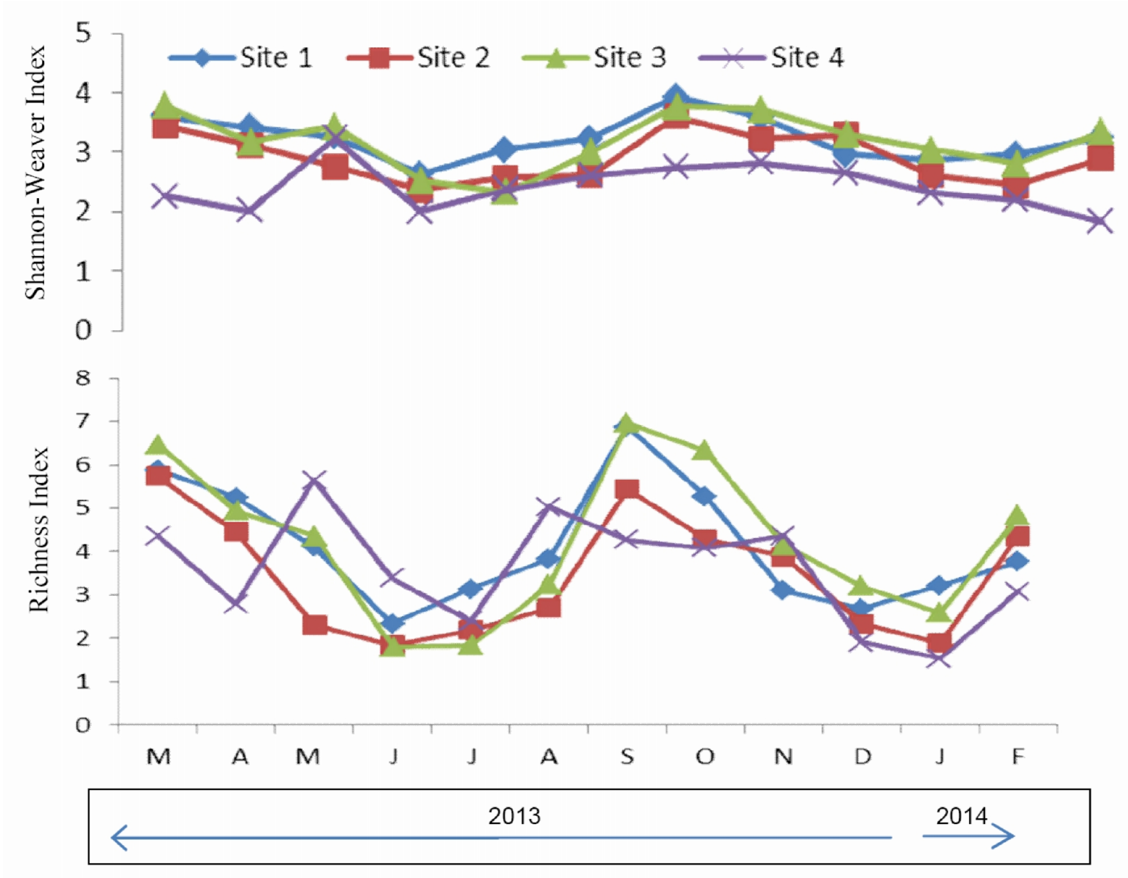

Fig. 2: Seasonal variation of Shannon-Weaver and Richness indices during the study period.

agree with Pandey and Sundaram (2002) study. All parameters (total suspended solids (TSS), chlorophyll-a (chl.a), pheophytin-a (pha.p), pH, turbidity (Tur) and nitrate (NO_3)) were of negative correlation with parameters present in the second axis. Only two parameters (SiO_3 and Na) were far away from the other parameters.

Figure 4 illustrated the correlation between environmental parameters and diatom species. In the first axis, the species of *C. kuetzingiana*, *F. crotonensis*, *S. ulna* was not affected by the most of environmental parameters but have positive correlation with the percents of N:P, C:SiO_3 and water flow. While in the second axis, *Achnanthes minutussimia, C .meneghiniana, C. ocellata, C. placentula* and *C. placentula var.lineate* have a positive correlation with salinity, TDS, Mg, PO4, EC, TH, Chloride, Sulphate, nitrite, water temperature, BOD5, Ca, CO2, light penetration, TA, and TOC. Moreover, these species were negative correlation with TSS, Turbidity, pH, nitrate, DO and potassium (K). The same correlation observed in the third axis between these parameters and other species (*C. affinis*, *N. palea*, *D. elongatum*, *G.parvulum* and *A. affinis*). In fourth axis, a positive correlation with the two species *C. pediculus*, *D. vulgare* and SiO_3 and Na.

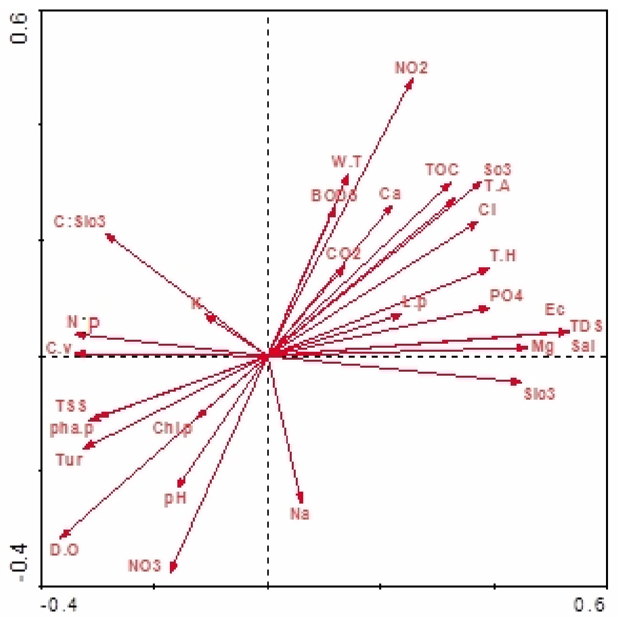

Fig. 3: CCA analysis of Physico-chemical factors.

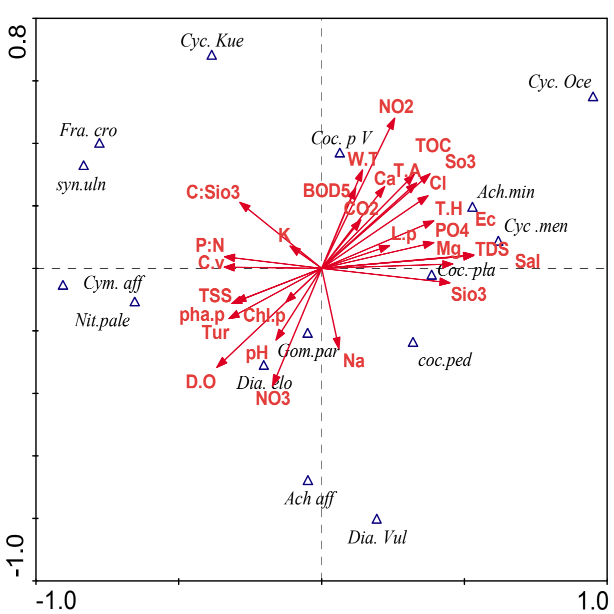

Fig. 4: CCA analysis of Physico-chemical factors and Diatoms.

According to the present results the Al-Shamiyah River was alkaline and oligohaline according to Reid (1961), so these diatoms prefer these conditions. Also, the existence of these diatoms may be due to the relatively slow-flowing of the studied river in most of the year (Whitton, 1975). The most of identifying diatoms were of benthic sources which are a common condition in streams and rivers by drift benthic diatoms into the water column (Wetzel, 2000). The diatoms such as *Synedra, Nitzschia, Navicula, Fragilaria, Cymbella* were of benthic origin, this was also recorded in another study (Salman *et al*., 2013) in which they recorded the dominancy of benthic diatoms in phytoplankton community of *D. vulgare, D. elongatuo*m, *C. cistula, C. affinis* and these species were noticed in this study. The dominance of pinnate diatoms was recorded in the river Adige (northeastern Italy) while Cyclotella represented obviously centric diatoms (Salmaso and Zignin, 2010), the same results were recorded in the present study.

Acknowledgment

The authors express their thanks to the department of Biology in, Al-Qadisiyah University and University of Baghdad for their support of all requirements of the current work.

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