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The use of diatom indices for the assessment of Shatt AL-Arab river water quality

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Abstract

Indices are the result of attempts to describe physico-chemical changes in water quality (pH, salinity, ammonium, nitrate, phosphate, organic materials,...etc.), there are various indices that used diatoms as bioindicators such as diatomic index, diversity index, diatom assemblage index, generic diatom index, and trophic diatom index. In the present study, samples of water and Planktonic diatoms were collected together in two seasons (Winter 2009 / Summer 2010) from four station (Sindibad, Ashar, Abu Al-Khaseeb and Fao) along Shatt AL-Arab river, a total of 53 species belonging to 26 genera were registered, and the statistical analysis stated that salinity, nitrate, and N:P ratio have an important role in the determination of diatom communities in which there is a negative significant correlation between salinity and the percentage of eutrophic species, and a positive significant correlation between nitrate and the percentage of eutrophic species, also there is a positive strong significant correlation between the study stations were unpolluted except at Abu Al-Khaseeb station in Summer whose water was moderately polluted, but both diatomic index and trophic diatom index values showed that all water stations were polluted, diatomic index values indicated that water stations ranged from slight to moderately polluted, and trophic diatom index values indicated that station waters were either oligo-mesotrophic or mesotrophic state, except at Abu Al-Khaseeb station in which values indicated eutrophic state at both seasons, and the statistical analysis showed significant correlation between diatomic index and both silicate, and percentage of eutrophic species, thus indicated that diatomic index is an a properite index to evaluate the degree of the present study area pollution.

Key-words: Physico-chemical parameters – Diatom composition-Diatom indices- Water quality.

1. Introduction

The pollution of freshwaters is one of the greatest environmental issues in the world. Along these lines, the approaches to water quality evaluation can be basically divided into two categories: The first utilizes physical and chemical methods, and the second considers biological methods of evaluation [5],[18].

Regarding the first approach, physical and chemical methods allow only instantaneous measurements, therefore restraining the knowledge of water conditions to the moment when the measurements were taken. Considering the second approach, when biological methods are used to monitor water quality, long-term environmental effects can be detected, since these methods have the capacity of refelecting conditions which are not anymore present at the time of sampling analysis, but were originated from the process of community development. Therefore, physical and chemical methods are complementary to biological methods. Together they constitute the basis to a correct assessment of the quality of running waters [17].

Indices are the result of attempts to describe physico-chemical changes in water quality (pH, salinity, ammonium, nitrate, phosphate, organic materials, etc.) [31]. Diatoms have long been used as bioindicators because, they are found in abundance in most lotic ecosystems [1],[15],[24].

There are various indices used diatoms as bioindicators such as Diatomic index (Id) [8], Diversity index (H) [6], diatom assemblage index (DAIpo) [26], generic diatom index (GDI) [7], and trophic diatom index (TDI) [16].

The main objective of the study was to determine possible correlations among the water quality parameters, the abundance of tolerant planktonic diatoms to pollution , and diatom indices, and eventually to see if any of the diatom indices significantly correlated with physico-chemical parameters can be used as an indicator of changes in water quality.

2. Material and methods

2.1 Study area:

Shatt AL- Arab river is the only water source of Basrah city for different purposes like drinking and arrigation , its length approximately 150 km, results from the confluence of Tigres and Euphrates rivers at Qurna, north of Basrah [22]. Shatt-al-Arab river also has many tributaries such as Ashar, Khora, Uwasian, and Abu Al-Khaseeb among other many branches before it flows into the Gulf at Ras Al-Bisha in the Fao, they are so much polluted with organic and inorganic pollutants resulting from discharching such as industrial wastes like power plants, papar mill, dairy mills and domestic wastes [11].

2.2 Sampling & water analysis:

Samples of water and Planktonic diatoms were collected together in two seasons (Winter 2009 / Summer 2010) from four station (Sindibad, Ashar, Abu Al-Khaseeb and Fao) along Shatt AL-Arab river (figure 1).Water temperature, pH, salinity were measured in the field using Horiba model W-2030 MFG.No.812003.The analysis of nitrite, nitrate, phosphate, silicate followed the methods of Strickland and Parson [23]. Planktonic diatoms were taken in 4 litre bottle, fixed with lugol's solution and concentrated by sedimentation, then concentrated by centrifuge to 10 ml [13].

2.3 Diatom analysis:

The identification of the planktonic diatoms were done up to species level by using identification keys of Patrick & Reimer [19],Wehr & Sheath [27], and the following literatures: Hadi et al.[10]; Al-Handal [4]; Al-Handal & Abdullah [3].

Diversity index was calculated by using the following formula [6]:

Diversity index (H)= S-1/ In N
(1)

Where:

S = The number of diatom species.
N= The total number of diatoms.
In= Natural logarithm.

According to Ali et al [5], values greater than 3 indicate clean water, values in the range of 1-3 are characteristics of moderately polluted conditions and values less than 1 characterize heavily polluted condition.

Figure 1 : map of Shatt Al-Arab river shows the study stations.

Diatomic index (Id) was calculated according to Descy's list which consists of 106 species by using the following formula:

$Id= \sum A_j\ I_j\ Vj / A_j\ V_j$
(2)

Where A_j is the relative abundance of the species j present in the sample, I_j the sensitivity index of the species and V_j its indicating value.The value of the Id index calculated by this formula varies from 1 to 5. For a simplified interpretation of the result, the following quality classes may be adopted:

Id > 4.5 : best biological quality, no pollution;

Id = 4-4.5 : almost normal quality (slight changes in the community, slight pollution);

Id =3-4 : more important changes in the community, decreases of the sensitive species, moderate pollution or significant eutrophication;

Id =2-3 : resistant species dominant, decreases or disappearance of the sensitive species (reduced diversity), heavy pollution;

Id =1-2 : marked dominance of a few resistant species (many species disappear), very heavy pollution;

Trophic diatom index (TDI) was calculated by using the following formula:

$TDI = (WMS \times 25) - 25$ (3)

$WMS = \sum A_j\ S_j V_j / A_j V_j$ (4)

Where WMS is the weighed mean sensitivity of the taxa present in the sample. It calculated according to the list of Kelly et al. [16] which consists of 97 species, A_j is the abundance or proportion of valves of species j present in the sample, S_j is the nutrient sensitivity (1-5) of species and V_j its indicating value (1-3). WMS values ranged from 1 (for sites with very low nutrient concentrations) to 5 (for sites with very high nutrient concentrations) while TDI values ranged from 0-100 which illustrated below with their corresponding ecological states :

TDI < 35 :oligotrophic state;
TDI 35-50 : oligo-mesotrophic state;
TDI 50-60 : mesotrophic state;
TDI 60-75 : eutrophic state;
TDI > 75 : hypertrophic state.

Finally, Data were statistically analysed, using the software SPSS v.17.0 so as to obtain a correlation coffiecient among physico-chemical parameters, percentages of eutrophic species (pollution tolerant species), and diatom indices.

3. Results & Discussion

3.1. Physico-chemical analysis:

In the present study, the measured physico-chemical parameters are shown in table 1. Water temperature ranged from 17.9º in most stations during Winter to 33.7º during Summer. pH of water samples were slightly alkaline at both seasons, they ranged from 7.5 to 7.86. Water salinity, ranged from 1.7‰ to 12.4‰, according to the classification of Reid [21] indicated that station waters were mesohaline during Winter and oligohaline during Summer. Nitrogen & Phosphorous are two major Nurrients required for phytoplankton growth, the third one, Silica, is necessary for diatom growth [2]. During Winter, values of nitrite, nitrate and phosphate elevated at Ashar station (2) and Abu Al-Khaseeb station (3) and decreased at Sindibad station (1) and Fao station (4), this interpreted by high levels of domestic wastes discharching into station (2) and (3), in addition to that water of Fao station was greatly influenced by saline water of Arabian Gulf. In other word, it diluted by saline water which leads to decreased its values at Fao station [11],[12].while silicate is decreased from station (1) to station (4) during Winter and Summer except at station (2) during Summer which registered the lowest value reflecting its consumption by diatoms. The ratio of nitrogen to phosphorous compounds in a water body is an important factor in determining which of the two elements will be the limiting factor of eutrophication [29]. As shown in table 1 values of N:P ratio were $\leq$ 5 at all stations except at Fao station during Summer, which indicated that nitrogen is the limiting factor for the whole phytoplankton community, and this implied that there is an abundance of nitrogen – fixture species [20].

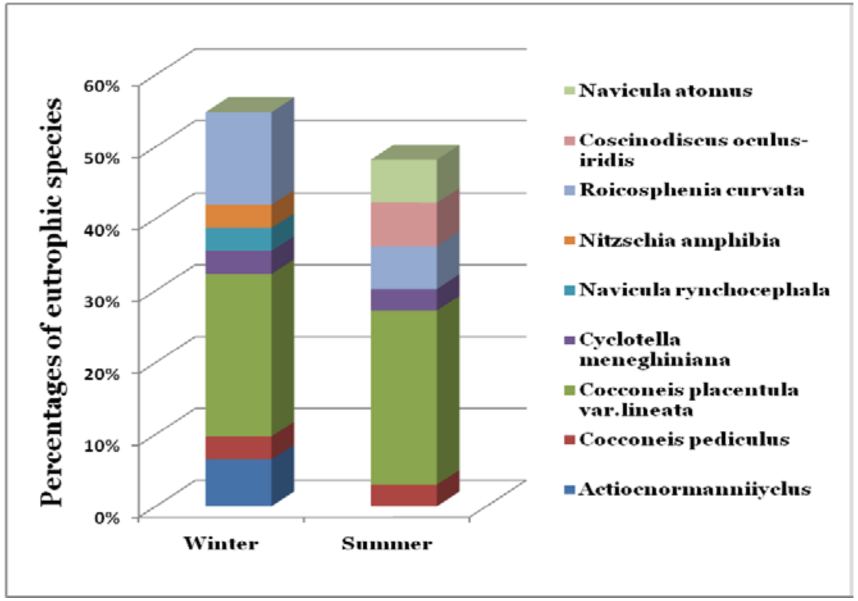

Figure 2: percentages of eutrophic species in Sindibad station.

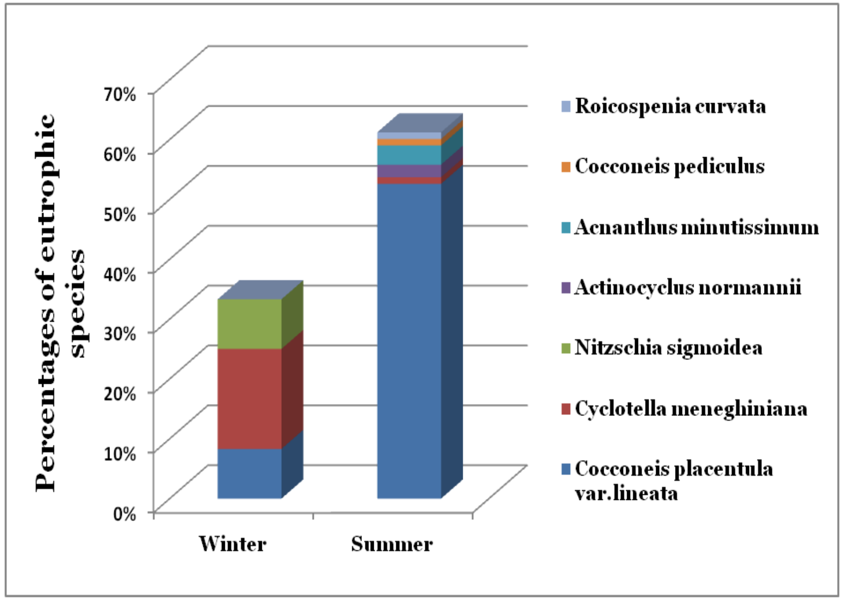

Figure 3: percentages of eutrophic species in Ashar station.

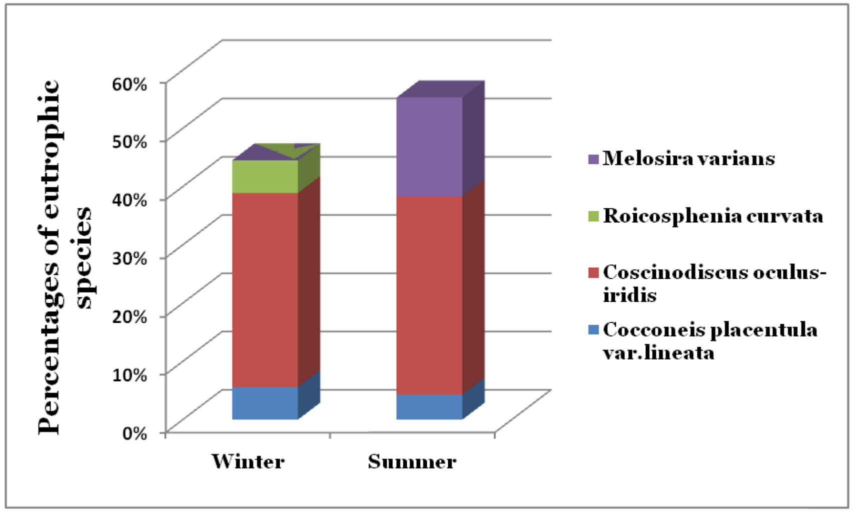

Figure 4: percentages of eutrophic species in Abu Al-Khaseeb station.

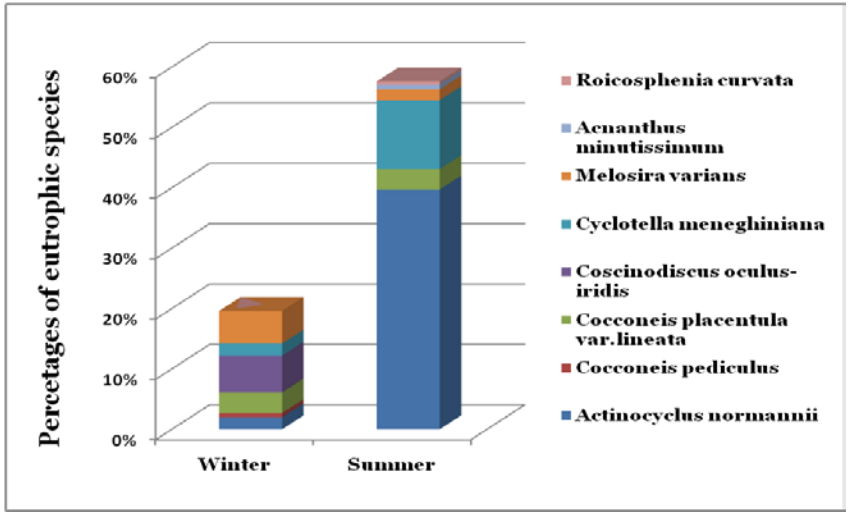

Figure 5: percentages of eutrophic species in Fao station.

Table1: physico-chemical parameters of water at samplng sites.

Stations	Parameters	Water temperature (°C)	pH	Salinity (‰)	NO_2^- (µg /l)	NO_3^- (µg /l)	PO_4^- (µg /l)	N:P *	SIO_3^- (µg /l)
Sindibad	Winter	18.7	7.57	5.8	0.83	57.34	46.72	2.5	18.07
	Summer	33.7	7.77	1.9	0.78	89.31	52.65	1.7	186.13
Ashar	Winter	15.9	7.73	7.3	1.68	70.13	66.74	1	14.08
	Summer	26	7.86	1.7	0.85	105.5	20.76	5.1	116.18
Abu AL-Khaseeb	Winter	18.2	7.56	6.8	1.27	74.87	30.4	2.5	13.87
	Summer	26.97	7.6	2.2	0.27	100.75	22.25	4.5	161.97
Fao	Winter	20.1	7.62	12.4	0.64	51.35	25.96	2	11.55
	Summer	23.4	7.5	3.5	0.09	79.19	10.38	7.6	138.24

*N:P ratio was obtained by dividing the sum of the amount of nitrite and nitrate by the amount of phosphate.

3.2. Phytoplanktonic diatom composition :

In the present study, a total of 53 species, belonging to 26 genera were registered, and stated with their ecological preferences in table 2 depending on Whitmore [28], Fore & Grafe [9], Lobo et al [17], and Al-Handal & Al-Abdullah [3]. Then they were utilized into diatom indices calculation as stated in table 3. The greater total number and number of species were registered at Fao station during both seasons while the least ones were registered in other stations during Winter.

Table 2 : Diatom species with their abundance and ecological preference occurred in Shatt AL-Arab stations during the study period.

TAXA	Winter				Summer				Ecological preference
	Station				Station				
	1	2	3	4	1	2	3	4	
Actinocyclus normannii	2			3		2		152	ol. , e.,
Acnanthus spp.		1					1		
Acnanthidium minutissimum						3		3	Cir., e. ,
Amphiprora spp.								2	
Aulacosira spp				20			6	10	
Campylodiscus intermedius								2	
Cocconeis convexa						2			
Cocconeis pediculus	1			1	1	1			alp., ol. , e. ,
Cocconeis placentula var. lineata	7	1	1	5	8	50	2	13	alp., e.
Cocconeis spp			1		1				
Coscinodiscus oculus-iridis			6	9	2		16		Ph., e.
Cyclotella meneghiniana	1	2		3	1	1		45	alp.-cir., ol., e.
Cyclotella ocellata				3					
Cyclotella podanica								8	
Cyclotella stelligera				1					Cir., o-e.
Cyclotella striata	2			17				55	mh.
Cyclotella stylorum		2		3		1		37	
Cyclotella spp				56				13	
Cymatopleura								1	
Cymbella affinis					1				
Cymbella spp	1					6			
Encyonema spp						2			
Eunotia spp,	1	1				2			Most species acido and halophobic,
Fragillaria capucina var. gracilis								3	alp.,-cir.,o-m.
Fragillaria intermedius					3				

Fragillaria spp	1	1	2	2			2	2	
Gomphonema affinis					1				
Gomphonema constrictum var. capitata					6				
Gomphonema spp	1			1		3			
Gyrosigma tenuirostrum	1								
Gyrosigma spp			2					5	
Lyrella spp			1						
Melosira granulata					2				alp.-cir., m-e.
Melosira varians				8			8	7	alp., e.
Meridion circulae		1				1			
Navicula atomus					2				alp., e.
Navicula rynchocephala	1								alp., mh, e.
Navicula spp	2	1	2	1	1	4	1	3	
Nitzschia amphibia	1								alp., ol.(indifferent), e.
Nitzschia apiculata	1								
Nitzschia obtusa								2	alp., ol. (indiffirent).
Nitzschia palea				11	1				alp.,ol. (indifferent), o-e.
Nitzschia tryblionella				1				3	
Nitzschia sigma	1								alp., ph.
Nitzschia sigmoidea		1							alp., e.
Nitzschia spp			1	1		4	1	6	
Roicosphenia curvata	4		1		2	1		2	al., e.
Surirella spp								2	
Synedra fasciculata	3				2			1	m-e.
Synedra ulna								3	Alp., ol.(indifferent)
Synedra spp						2			
Thalassiosira spp			1	1		10	10	2	
Tryblionella spp		1						1	
Total number	31	12	18	147	33	95	47	383	
Number of species	17	10	10	19	14	18	9	27	

Where: 1: Sindibad, 2: Ashar, 3: Abu Al-Khaseeb, 4: Fao, Cir: circumnatural, alp.-cir: alkilophilous-circumnatural, alp.: alkilophilous, ol.: oligohalobous, mh.: mesohalobous, ph.: polyhalobous, o-e: oligo-eutrophic, o-m: oligo-mesotrophic, m-e: meso-eutrophic, e: eutrophic.

As water becomes polluted, the variety of diatoms decreases, but the population of eutrophic species increases [30], at Sindibad station (figure 2) the percentages of eutrophic species comprised 54.83 % and 48.48 %, at Ashar station (figure 3) they comprised 41.66 % and 61.05 %, at Abu Al-khaseeb station (figure 4) they comprised 44.44 % and 55.32 %, and at Fao station (figure 5) they comprised 20.40 %,57.96 % in Winter and Summer respectively.

The statistical analysis according to spearman's rho correlation (table 4) stated that salinity, nitrate, and N:P ratio have an important role in the determination of diatom communities in which there is a negative significant correlation between salinity and the percentage of eutrophic species, and a positive significant correlation between nitrate and the percentage of eutrophic species, also there is a positive strong significant correlation between N:P ratio and the pecentage of eutrophic species. Water salinity has long been considered as a main factor affecting diatom communities [19],[27], also both Irive & Murphy [14] stated that the composition of diatom assemblages changed from one sampling site to another which generally is believed to change with nutrient loading and in response to pollutant levels.

3.3. Diatom indices:

The dominance of certain species and frequency of the presence of these species are hence the characteristics of polluted waters. In other words, the diversity index of community is correlated in some cases with the degree of pollution [27]. In general, the value of diversity index of community in less polluted waters will be higher [5]. In the present study, values of diversity index (table 3) showed that all of the study stations were unpolluted except at Abu Al-Khaseeb station in Summer whose water was moderately polluted, but the statistical analysis according to spearman's rho correlation (table 4) showed no significant correlation among it and any other studied physico-chemical parameters, and/or percentages of eutrophic species, and this coincided with many researchers who have investigated that the diversity index was not correlated with purity of waters [1],[8],[30].

Two diatom indices (Id and TDI) are applied to the present classified data according to lists of Descy [8] and Kelly et al [16] respectively, and their values were illustrated in table 3. Both Id and TDI values showed that all water stations were polluted, Id values indicated that water stations ranged from slight to moderately polluted, and TDI values indicated that station waters were either oligo-mesotrophic or mesotrophic state, except at Abu Al-khaseeb station in which values indicated eutrophic state at both seasons, also the statistical analysis showed significant correlation between Id and both silicate and the percentage of eutrophic species, but TDI showed no significant correlation with any physico-chemical parameters, and/or percentages of eutrophic species, and this may belong to the diatom composition of its list, in addition to various factors affecting diatom composition and the abundance and some of which are not related directly to water quality (e.g. current speed, grazing) [16], thus indicated that Diatomic index (Id) is an a properite index to evaluated the degree of the present study area pollution.

Table 3 : values for different diatom indices applied to diatom data of the present study stations.

Season	Station	H	Pollution level	Id	Pollution level	TDI	Trophic state
Winter	Sindibad	4.7	clean	3.8	Moderate eutrophication	58.6	Mesotrophic
Summer	Sindibad	4.3	clean	3.8	Moderate eutrophication	49.3	Oligo-mesotrophic
Winter	Ashar	3.6	clean	4.3	Slight pollution	39.3	Oligo-mesotrophic
Summer	Ashar	3.5	clean	4.0	Slight-moderate eutrophication	50.8	Mesotrophic
Winter	Abu Al-Khaseeb	3.1	clean	4.0	Slight-moderate eutrophication	63.5	Eutrophic
Summer	Abu Al-Khaseeb	2.1	Moderately polluted	3.3	Moderate eutrophication	66	eutrophic
Winter	Fao	3.6	clean	4.1	Slight pollution	64	oligo-mesotrophic
Summer	Fao	4.4	clean	3.5	Moderate eutrophication	57.8	mesotrophic

Table 4 : spearman’s rho correlation coefficients between physico-chemical parameters of water, eutrophic species percentages and diatom indices .

	Tem.	pH	S‰	NO_2	NO_3	PO_4	N:P	SIO_3	H	Id	TDI	Total no.	Eu. %
Tem.	1.000	.786*	-.786*	-.619	.690	-.381	.323	.810*	-0.429	-0.539	0.095	0.548	0.524
pH		1.000	-.810*	-.262	.810*	-.310	.252	.738*	-0.429	-0.371	-0.357	0.405	0.595
S‰			1.000	.214	-.905**	.357	-.491	-.833*	0.048	0.611	0.214	-0.262	-0.833*
NO_2				1.000	-.143	.619	-.503	-.452	0.190	0.587	-0.476	-0.810*	-0.333
NO_3					1.000	-.429	.503	.738*	-0.214	-0.515	-0.143	0.214	0.762*
PO_4						1.000	-.922**	-.167	0.167	0.371	-0.429	-0.833*	-0.667
N:P							1.000	.287	0.144	-0.572	0.347	0.635	0.838**
SIO3								1.000	0.024	-0.802*	-0.214	0.214	0.643
H									1.000	-0.275	-0.310	-0.333	0.190
Id										1.000	-0.156	-0.252	-0.731*
TDI											1.000	0.310	-0.048
Total no.												1.000	0.429
Eu. %													1.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Abbreviation: Tem: water temperature; S ‰ : salinity; NO_2^- : nitrite; NO_3^- : nitrate; PO_4^{-3} : phosphate; N:P: nitrogen to phosphore ratio; SIO_3 : silicate; H: diversity index; Id: diatomic index; TDI: trophic diatom index; Total no. : Total number; Eu %: percentages of eutophic species.

4. References

[1] Àcs, E. ; Szabo, Z. ; Toth, B. & Kiss, K.T. Investigation of benthic algal communities especially diatoms of some Hungarian streams in connection with reference conditions of the water framework directives. Acta. Bota. Hunga. 46 (3-4), 255-277. (2004).

[2] AL-Gahwari, Y. A. Use of phytoplankton abundance and species diversity for monitoring coastal water quality. Thesis submitted in fulfillment of the requirements for the degree of Master of Science.University of Sains Malaysia. 214 pp.http://eprints.usm.my/ (2003).

[3] AL-Handal, A. Y. & Abdullah, D. S. Diatoms from the restored Mesopotamian marshes, south Iraq. Algological studies. 133, 65-103. (2010).

[4] AL-Handal, A. Y. Littoral diatoms from the Shatt AL-Arab estuary, north west Arabian Gulf. Crypto. Algol., 30(2): 1-31. (2009).

[5] Ali, M. Salam, A. Jamshaid, S. & Zahra, T. Studies on biodiversity in relation to seasonal variations in water of river Indus at Ghazi Ghatt, Punjab, Pakistan. Pakistan J. Biol. Scie. 6 (21): 1840-1844.(2003).

[6] Boyed, C. E. Water quality in warm water fish ponds. Craftmaster printers Alabama. (1980.)

[7] Coste, M. &. Ayphassorho, H. Etude de la qualitè des eaux du Bassin Artois- Picardie à’ aide des communautès de diatomèes benthiques (Apllication des indices diatomiques) Rapport Cemagref

Bordeaux- Agence de l'Eau Artois-Picardie, Douai, 227 pp. (1991).

[8] Descy, J. P. A new approach to water quality estimation using diatoms. J. Nova Hedw. Beih. 64. 305-.323. (1979).

[9] Fore, L. S. & Grafe, C. Using of diatoms to assess the biological conditions of large rivers in Idaho (U. S. A.). J. Fresh. B. 47, 2010-2037. (2002).

[10] Hadi , R.M. , Al-Saboonchi , A.A. & Haroon , A.K.Y. Diatoms of the Shatt Al-Arab at Basrah , Iraq . J. Nova Hedw. 39 : 513-57. (1984) .

[11] Hassan, W. F. , Hassan, I. F. & Jassim, A. H. The effect of industrial effluents polluting water near their discharging in Basrah Governorate / Iraq. J. Basr. Res.1(37): 21-32.(2011 a). (in Arabic)

[12] Hassan, W.F., Kareem, S. M. , Kassaf, D. K. & Aliwe, Y. G. Quality of water for irrigation in Fao, Basrah governorate/ Iraq. J. Basr. Res.(37): 33-41.(2011 b). (in Arabic)

[13] Hötzel, G. & Croome, R. A phytoplankton methods manual for Australian freshwaters. Land and resources research and development corporation (LWRRDC), 57 PP. (1999).

[14] Irvine, K. N. & Murphy, T. P. Assessment of eutrophication and phytoplankton community impairment in the Buffalo river area of concern. J. G. L .R. 35: 83-93. (2009).

[15] Ivanov, PL. Chipev, N.Temniskova, D. Diatoms of the river Iskar (Sofia plain) and their implication for water quality assessment. Part II. Diatom indieces and their implication for water quality monitoring. J. Enviro. Prot. Eco. 4(2), 301-310. (2003).

[16] Kelly, M.G. , Adams, C. , Graves, A. C., Jamieson, J., Krokowski, J. , Lycett, E. B. , Murray-Bligh, J., Pritchard, S. & Wilkins, C. The tophic diatom index: A user s manual. Revised edition. R&D technical report E2/TR2. Environment agency.www.environment agency.gov.uk/. (2001).

[17] Lobo, E. A. ; Callegaro, V. L. M. ; Hermany, G. ; Bes, D. ; Wetzel, C. A. ; Olivera, M. A. Use of epilithic diatoms as bioindicators from lotic systems in southern Brazil, with special emphasis on eutrophication. Acta. Limnol. Bras., 16(1): 25-40. (2004).

[18] Panich-pat, T. Yenwaree, W., Ongmali, R. Monitoring of water quality using phytoplankton, protozoa, and benthos as bioindicator in chadeebucha canal, nakhon pathom province. J. Enviro. Res. 31(2): 1-14. (2009).

[19] Patrick, R. & Reimer, C.W. The diatoms of the United State. Exclusive of Alaska and Hawaii, volume 1. the Academy of Natural Science of Philadelphia. 688 pp. (1966).

[20] Pinto, P. T., & Litchman, E. Interactive effects of N:P ratios and light on nitrogen –fixer abundance. Oikos. 119: 567-575. (2010).

[21] Reid, G. K. Ecological of inland waters and estuaries-Rhiem hold corp, New York, 375 pp. (1961).

[22] Saad, M. A. H. Review of limnological and oceanographic data base in Iraq during 1973-1977. Int. J. ocean. oceanogr. 2(1): 1-16. (2007).

[23] Strickland , J.D.H. & Parsons, T.R. A practical handbook of sea – water analysis. Bull.167. Fish Res, Board .310 pp. (1972).

[24] Szczepocka, E. Benthic diatoms from the outlet section of the Bzura river 30 years ago and presently.Int. J. Oceano. Hydrob. Vol.XXXVI, supplement 1: 255-260. (2007).

[25] Van Dam, H., A. Mertens, and J. Sinkledam. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Nether. J. Aqua. Ecol. 28(1): 117-133. (1994).

[26] Watanabe, T. ; Asal, K. ; Houki, A. Numerical estimation to organic pollution of flowing water by using the epilithic diatom assemblages----diatom assemblage index (DAI_{po}). Scie. Tot. enviro. 55: 209-218. (1986).

[27] Wehr, J. D. & Sheath, R. G. Freshwater algae of north America.Ecology and classification. Academic press U.S.A. 930 PP. (2003).

[28] Whitmore, T. J. Florida diatom assemblages as indicators of trophic state and PH. Limnol. Oceanogr.,34(5): 882-895. (1989).

[29] World Health Organization. Eutrophication and health. European communities, http://europa.eu.int. (2002).

[30] Wu, J.T. 1984. Phytoplankton as bioindicator for water quality in Taipei. Bot. Bull. Academia Sinica 25: 205-214. (1984).

[31] Wu, J-T. Ageneric index of diatom assemblages as bioindicator of pollution in the Keeling river of Taiwan. Hydrobio. 397: 79-87. (1999).