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Assessment of eutrophication and organic pollution status of Shatt Al-Arab River by using diatom indices

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Abstract

Many fish cages have been established along Shatt Al-Arab River by Directorate of Basrah agriculture in which the synthetic food supplied to fish may contribute in entrance of organic materials into Shatt Al-Arab water and it might be distributed for a wide distants by tide and waves. So, the present study was conducted to assess the environmental affect of fish cages on Basrah's Rivers. Four diatom indices were applied so as to assessment the potential impact of fish cages on water quality (trophic & organic pollution) at the studied sites. They are: Polluton tolerance index (PTI); Watanebe diatom index (DAIpo); Saprobic index (S) & biological diatom index (IBD). Diatom indices values except DAI_{PO} ones showed that the studied sites were neither very clean nor severe polluted during the study period. PTI values indicated ecological status ranged from beta-mesosaprobic condition to alpha-mesosaprobic one for the studied sites. DAIpo values indicated good conditions for all sites. IBD values indicated ecological status ranged from good to bad condition. S values indicated ecological status ranged from beta-mesosaprobic condition to alpha-mesosaprobic one. In conclusion, our results showed that DAI_{PO} was unsuitable as an index of trophic and saprobity status because its calculation comprised few number of diatom taxa that represent trace percentage of the total abundance of diatom. Both PTI and IBD indices indicated to the presence of eutrophication phenomenon resulting from self-purification process. While Saprobic index gives an obvious picture of the organic & trophic status for the studied sites.

Keywords; fish cags-eutrophication- organic pollution-diatom indices.

Introduction

Aquaculture has become one of the fastest growing food industries in the world. Like many other industries, aquaculture, and especially fish farms may cause negative effects on the environment, such as eutrophication, which is recognized as a major threat to aquatic ecosystems [1]. Cage culture involves the practice of fish in cages and it usually applies to existing water bodies that cannot be drained. The merit of cage culture include the flexibility of management, ease and low cost of harvesting, low capital investment and close observation of fish feeding response, disease, health situations and economical treatment [2]. Many fish cages have been established along Shatt Al-Arab River by Directorate of Basrah agriculture in which the synthetic food supplied to fish may contribute in entrance of organic materials into Shatt Al-Arab water and it might be distributed for a wide distants by tide and waves.

Eutrophic waters are characterized by excessive algal growth as a consequence of nutrient enrichments. However, a number of definitions have been proposed by various authors and authorities [3 , 4 , 5, 6, 7] and [8]. According to Vollenweider [3]: “Eutrophication – in its more generic definition that applies to both fresh and marine waters – is the process of enrichment of waters with plant nutrients, primarily nitrogen and phosphorus that stimulates aquatic primary production and in its more serious manifestations leads to visible algal blooms, algal scums, enhanced benthic algal growth of submerged and floating macrophytes”. The definition proposed by UNEP [7] emphasizes the contribution of organic matter: “Eutrophication is defined as an environmental disturbance caused by excessive supply of organic matter. Although all definitions “agree” that eutrophication is the increase of algal material, they differ as far as the emphasis is concerned, on the impacts. The most comprehensive definition of eutrophication has been given by Vollenweider [3] listing most of the disturbances. On the other hand, Gray [4] excludes the presence of toxic compounds. It is a rather unusual approach the UNEP definition [7] since eutrophic trends are also induced by inorganic nutrients such as agricultural fertilizers. All the definitions mentioned above agree at one point: they consider eutrophication as a “disturbance” and not as a form of pollution.

The value of algae as bio-monitors and bio-indicators has already been recognized in the mid 19th century: the first concept which has been developed was the system of saprobity. It was mainly designed for organic pollution of streams and rivers [9]. It is generally accepted that the communities of aquatic organisms can serve as indices of pollution. According to Padisák [10] after macroinvertebrates and bacteria, algae represent the third most important group applied for monitoring purposes both in freshwater and marine environments. Diatoms are valuable indicators of ecological quality: they respond directly and sensitively to many physical, chemical changes in aquatic environment. They are found in almost all aquatic habitats. They also among the short generation times of all biological indicators, allowing them to respond rapidly to environmental changes and to provide early warning of potential changes in nutrient status for different water bodies [11]. So, the present study was conducted to assess the environmental affect of fish cages on Basrah’s Rivers.

Materials and methods

The study area

Monthly samples of water were collected from three sites along Shatt Al-Arab River (Qurna, Dayr and Abu Al-Khaseeb) located near fish cages on the period extended from February/2013 to June/2013. While periphyton (i.e. attached algae) were collected from the same sites in some months as shown below in figure 1.

Water analyses:

Electrical conductivity was determined n situ by multimeter apparatus. Nitrite, nitrate, orthophosphate were determined according to Strickland & Parson [12]. Total Kjeldah nitrogen (TKN) and total phosohre (TP) were determined according to APHA [13] (1998). COD was digested by using Lovibond kit then determined by titration according to dichromate method mentioned in APHA [13]. BOD_5 was determined by Winkler method according to APHA [13]. Chlorophyll a was determined at 663 nm and 750 nm according to APHA [13].

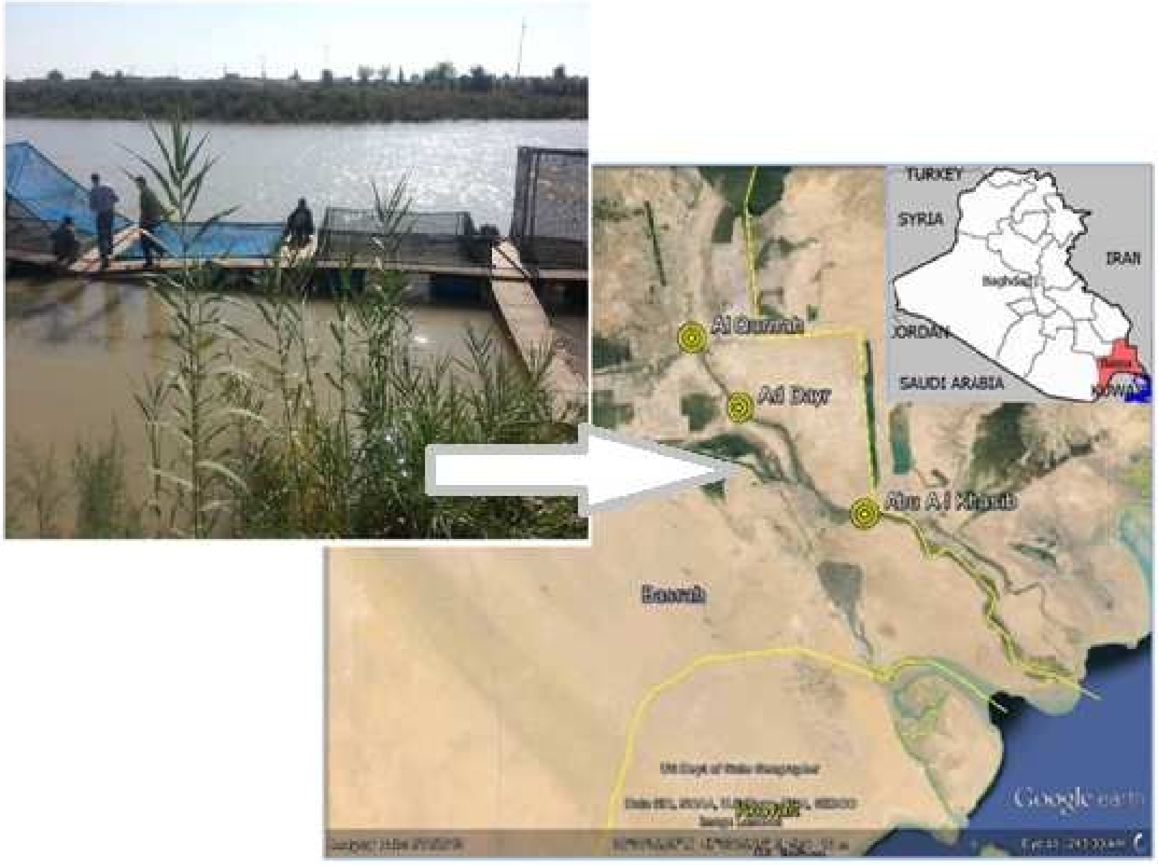

Figure 1: map illustrated the three sites of the studied fish cages at Shatt Arab in Basrah Governorate.

Diatom analyses

N situ, filamentous algae attached on fish cages were collected from the studied sites by scrapping from an area approximately of about 100 cm^2 and preserved with 4 % formalin. Later, after return to laboratory they were sonicated for 5 minutes in order to detach epiphytic diatoms (figure 2) then filtered and cleared by digestion with sulphuric acid and potassium dichromate for identification under light microscope.

Permanent slides for diatoms were made with Canada balsam and the identification were done up to species level by using identification keys of Patrick & Reimer [14],Wehr & Sheath [15], and the following literatures: Hadi *et al*.[16]; Al-Handal [17]; Al-Handal & Abdullah [18]. And at least 400 valves of diatoms were counting in each slide then their results converted to relative percentage.

Trophic & organic pollution indices

Four diatom indices were applied so as to assessment the potential impact of fish cages on water quality (trophic & organic pollution) at the studied sites. They are: Polluton tolerance index (PTI); Watanebe diatom index (DAIpo); Saprobic index (S) & biological diatom index (IBD).

Pollution tolerance index (PTI)

According to Muscio [19], the diatom Pollution tolerance index was calculated based on the following formula:

$$PTI = \frac{\sum(ni\ \ ti)}{N}$$

Where: n_i is the relative abundance of each taxa ; N is the total number of all taxa ; t_i is the tolerance value of each taxa which ranged from 1(tolerance) to 4 (sensitive). According to the formula above, n_i / N of each taxa is multiplied by its tolerance value (t_i), and summed over all data. The result for each sample is a composite value representing the pollution tolerance of the community sampled. Tolerance values from 1 to 4 have been assigned using Lange – Bertalot's designations [20] as follows: 1= polysaprobic (excessively polluted); 2 = alpha-mesosaprobic (heavily polluted); 3 = beta-mesosaprobic (moderately polluted) and 4 = oligosaprobic (slightly polluted).

Watanebe diatom index (DAIpo)

The calculation of DAIpo was according to Watanebe *et al* [21] whose classification based on relative abundances of pollution tolerance taxa and this index score represents the species' optimum tolerance to BOD_5 (Biological Oxygen Demand: a proxy indicator for organic content) on a scale of 1-100; The taxa employed in this index are divided into three groups: saprophiles, eurysaprobes and saproxenes. The index has the following two versions [22]:

$$DAIpo = 100 - \sum_{j=1}^{n} s_j - 0.5 \sum_{j=1}^{n} e_j$$

$$DAIpo = 50 + 0.5(\sum_{j=1}^{n} x_i - \sum_{j=1}^{n} s_i)$$

Where DAIpo: is the index value (%), s_j : relative abundance (%) of the saprophilous taxa j , e_j : relative abundance (%) of the eurysaprobic taxon j , x_j : relative abundance (%) of the saproxenic taxon j. At DAIpo > 60 % saproxenic diatom prevail and the quality of water is regarded as good. DAIpo < 20 % indicates prevalence of saprophilous diatom and water is regarded as strongly polluted.

Saprobic condition index (S)

The number and frequency of the diatom species was analyzed to reveal any possibility of an association between diatom communities and the organic pollution prevailing at the sampling station. The saprobic index (S value) was evaluated based on the formula proposed by Pantle and Buck [23] as shown below:

$$\mathbf{S = \sum (s\ h) / \sum (h)}$$

Where *s* is the indicating value of indicator species according to the list of Van Dam *et al* [24] and *h* is the frequency of the presence of each indicator species found which is divided into three: rare = 1, common

= 3, and abundant = 5 . The saprobic index (S value) of community ranks from 1 to 4: S from 1 to 1.5 for oligosaprobity (clean), S from 1.5 to 2.5 for beta-mesosaprobity (moderately polluted), S from 2.5 to 3.5 for alpha-mesosaprobity (heavily polluted), and S from 3.5 to 4 for polysaprobity (excessively polluted).

Biological diatom index (BDI)

The calculation of BDI index, or IBD in French , was done by an excel programme. According to Coste *et al* [25], BDI is a standard index, and is routinely used to assess the water quality of rivers and streams. In its calculation, the abundance of diatom taxa and the level of pollution sensitivity or " ecological profile " determined for each of them by multimetric statistical analysis against seven ecological parameters (pH, conductivity, dissolved oxygen, biological oxygen demand, ammonium, orthophosphates and nitrates) were used. The pollution sensitivity is determined through the species presence probability values F(i) along the seven quality classes gradient as follows:

$$F(i) = \frac{\sum_{x=1}^{n} AxPx(i)Vx}{\sum_{x=1}^{n} AxVx}$$

Where Ax is the abundance (%) of taxon x; Px (i) is the presence probability of taxon x for the quality class i; Vx is the value of the ecological amplitude (or degree of stenoecy) of taxon x; N is the number of taxa which abundance ≥ 7.5%. The seven values of F (i) are calculated, and computed to obtain B: the final BDI score:

$$B = 1^{x} F(1) + 2^{x} F(2)+3^{x}F(3)+4^{x}F(4)+5^{x}F(5)+6^{x}F(6)+7*F(7).$$

The calculated scores range from 1 to 20, and water courses are assigned to one of five quality classes: very bad if $1 \leq BDI \leq 5$, bad if $5 < BDI \leq 9$, medium if $9 < BDI \leq 13$, good if $13 < BDI \leq 17$, and very good if $17 < BDI \leq 20$ [26].

Statistical analyses

ANOVA test was predicted to demonstrate the variations in the environmental analyses and diatom indices. A statistical correlation was achieved between the environmental analyses & diatom indices and among the indices themselves.

Results

Environmental analyses

The present study results of several chemical parameters were illustrated below in table1. The statistical analysis of variance (ANOVA) showed significant spatial variations only for electrical conductivity ($p < 0.001$) and. Also, it showed significant temporal variations among the study months for nitrate ($p < 0.001$), nitrite ($p < 0.001$), total phosphate ($p < 0.05$), orthophosphate ($p < 0.001$), and biological oxygen demand ($p < 0.001$).

Table 1: the descriptive results of environmental analyses for the present study.

Area results / Factors		Qurnah	Dayr	Abu Al-Khaseeb
EC (ms/cm)	**min-max**	**1.20–2.94**	**1.1-2.83**	**2.73-8.15**
	stdev	**0.54**	**0.55**	**2.17**
NO_3^- (µg/l)	**min-max**	**0.46-24.47**	**1.99-17.97**	**1.20-18.18**
	stdev	**7.89**	**5.84**	**6.86**
NO_2^- (µg/l)	**min-max**	**1.52-52.49**	**0.09-19.74**	**0.54-50.35**
	stdev	**16.29**	**7.36**	**16.26**
PO_4^{3-} (mg/l)	**min-max**	**0.01-0.10**	**0.02-0.15**	**0.01-0.19**
	stdev	**0.03**	**0.04**	**0.05**
TKN* (mg/l)	**min-max**	**0.14-0.77**	**0.14-0.35**	**0.07-3.08**
	stdev	**0.21**	**0.07**	**0.96**
TP (mg/l)	**min-max**	**0.09-1.27**	**0.06-1.11**	**0.05-1.30**
	stdev	**0.36**	**0.37**	**0.36**
BOD_5 (mg/l)	**min-max**	**2.9-5.2**	**3.4-4**	**2.2-3.5**
	stdev	**1.06**	**0.32**	**0.50**
COD (mg/l)	**min-max**	**140-320**	**320-400**	**11-552**
	stdev	**127.28**	**56.57**	**208.39**
Ch.a (µg/l)	**min-max**	**0-10.21**	**0-39.53**	**0-57.78**
	stdev	**4.02**	**11.16**	**14.61**

*** TKN: Total Kjeldah nitrogen.**

Diatom identification and indices

A total of 74 species, belonging to 25 genera were registered attached to fish cages located at Qurnah, Dayr and Abu Al-Khaseeb and the number of species which integrated in diatom indices was 44, 8, 33 and 62 species for PTI, DAI_{PO}, S and IBD respectively (table 2). In Qurnah, the percentage of species abundance integrated in diatom indices were between (57.69-100%), (30.76-86.62%), (49.23-99.90%) and (94.61 % - 100 %) for PTI, DAI_{PO}, S and IBD respectively. In Dayr, the percentage of species abundance were between (88.88-90.14%), (28.97-44.98%), (56.34-80.28%) and (93.65 % - 99.24 %) for PTI, DAI_{PO}, S and IBD respectively and in Abu Al-Khaseeb, the percentage of species abundance were between (25.58-89.50%), (11.04-40.93%), (23.25-44.71%) and (37.20 % - 96.83 %) for PTI, DAI_{PO}, S and IBD respectively. Their abundance were used to estimated four diatom indices (table 3) in order to assess the potential status of trophic & organic pollution (saprobity) for the studied sited.

Anova test of variance showed temporally variations in values of diatom indices only. All of these indices showed high significantly correlation ($p < 0.01$) with each others as follows: PTI and DAIpo ($r = 0.719$); PTI and IBD ($r = 0.893$); PTI and SI (0.604); DAIpo and IBD ($r = 0.784$); DAIpo and S ($r = 0.563$); IBD and S ($r = 0.659$).

Also, they significantly correlated with some environmental parameters. PTI correlated with both COD ($r = -0.436, p < 0.01$) and chlorophyll a ($r = 0.375, p < 0.05$); DAIpo correlated with BOD_5 ($r = -0.408, p < 0.01$), COD ($r = -0.327, p < 0.05$) and chlorophyll a ($r = 0.435, p < 0.01$). IBD correlated with both COD ($r = -0.327, p < 0.05$) and chlorophyll a ($r = 0.461, p < 0.01$). S correlated with chlorophyll a only ($r = 0.721, p < 0.001$).

Table 2: List of diatom species identified in the studied areas during the study period.

Occurrence during the studied months				**Diatom indices**			
Taxa	**Qurnah**	**Dayr**	**Abu Al-Khaseeb**	**PTI**	**DAI$_{PO}$**	**S**	**IBD**
Achnanthes brevipes var. intermeia	+	+	+				
Achnanthes hungarica	+	+				+	+
Achnanthes kuwaitensis			+				
Achnanthidium minutissimum	+	+		+	+	+	+
Achnanthes microcephala		+					+
Amphipleura pellucida	+			+			+
Amphiprora alata			+				+
Amphora copulata		+				+	+
Amphora exigua			+				
Amphora ovalis		+	+	+		+	+
Amphora veneta		+		+		+	+
Bacillaria paradoxa		+		+			+
Cocconeis pediculus	+	+	+	+		+	+
Cocconeis placentula var euglypta		+		+		+	+
Cocconeis placentula var lineata	+	+	+	+	+	+	+
Cymatopleura solea		+		+		+	+
Cymbella aspera		+		+		+	+
Cymbella cistula		+	+	+			+
Cymbella gracilis			+	+			+
Cymbella minuta	+	+	+	+	+		+
Cymbella tumida		+	+	+			+
Diatoma hiemale var.mesodon			+			+	+
Diploneis elliptica	+			+			+
Diploneis ovalis			+	+			+
Encyonema pusilla		+					
Eunotia formica		+	+	+			+
Eunotia incise	+						+
Eunotia rhomboidea	+	+					+
Fragilaria brevistriata		+				+	+
Fragilaria capucina			+	+			+

Fragilaria intermedia			+			+	+
Gomphonema clavatum	+			+			+
Gomphonema constrictum	+	+		+		+	+
Gomphonema intricatum var.pumila		+	+	+			+
Gomphonema lanceolatum		+					+
Gomphonema minutum	+			+		+	
Gomphonema montanum			+				
Gomphonema olivacium	+	+	+			+	+
Gomphonema parvalum	+	+	+	+	+	+	+
Gyrosigma spencerii			+	+			+
Mastogloia smithii			+	+			
Meridion circulare	+	+	+	+		+	+
Navicula bacilloides			+	+			
Navicula cincta		+	+	+		+	+
Navicula confervacea		+					+
Navicula cryptocephala	+	+	+	+		+	+
Navicula digitoradiata		+					+
Navicula halophila		+	+	+			+
Navicula margalithi		+					+
Navicula pupula var.rectangularis			+				
Navicula radiosa var. tenella			+	+		+	+
Navicula rhynchocephala		+		+	+		+
Navicula shoeteri		+		+			
Navicula viridula var . Rostellate			+	+		+	+
Nitzschia amphibia			+	+		+	+
Nitzschia dissipata		+	+	+		+	+
Nitzschia filiformis		+	+	+			+
Nitzschia gracilis			+			+	+
Nitzschia granulata		+	+				
Nitzschia hungarica	+	+				+	+
Nitzschia intermidia			+			+	+
Nitzschia obtusa		+	+				+
Nitzschia palea	+	+	+	+	+	+	+
Nitzschia sigma		+	+	+		+	+
Nitzschia sigmoidea			+	+		+	+
Pleurosira laveis	+		+	+			+
Rhoicosphenia curvata	+	+	+	+	+	+	+
Surirella ovata			+	+			+
Synedra acus			+		+		+
Synedra Fasciculata	+	+					+
Synedra filiformis var gracilis		+					

Synedra ulna			+		+		+	+
Tabellaria tabulata			+					+
Tryblionella debilis				+			+	+
Total number of species	**74**			**Total number**	**44**	**33**	**8**	**62**
Number of genera	**25**							

Table 3: the description of ecological status of the studied sites based on trophic and saprobity indices.

Station	Sampling date	Diatom index values		Ecological status
Qurnah	**February/2013**	**PTI**	**2.98**	**α-β meso saprobic (II-III)**
		DAIpo values	**83.58**	**Good**
		IBD	**14.3**	**Good**
		S	**2.31**	**β-saprobic (II)**
Qurnah	**April/2013**	**PTI**	**2.86**	**α-β meso saprobic (II-III)**
		DAIpo values	**74.23**	**good**
		IBD	**9.9**	**medium**
		S	**2.28**	**β-saprobic (II)**
Qurnah	**May/2013**	**PTI**	**2.89**	**α-β meso saprobic (II-III)**
		DAIpo values	**67.66**	**good**
		IBD	**13.2**	**good**
		S	**2.56**	**α-mesosaprobic (III)**
Dayr	**February/2013**	**PTI**	**2.78**	**α-β meso saprobic (II-III)**
		DAIpo values	**83.65**	**good**
		IBD	**9.3**	**medium**
		S	**2.52**	**α-mesosaprobic (III)**
Dayr	**March/2013**	**PTI**	**3.25**	**α-mesosaprobic (III)**
		DAIpo values	**63.49**	**good**
		IBD	**11**	**medium**
		S	**2.47**	**β-saprobic (II)**
Dayr	**April/2013**	**PTI**	**2.66**	**α-β meso saprobic (II-III)**
		DAIpo values	**78.22**	**good**
		IBD	**10.2**	**medium**
		S	**2.44**	**β-saprobic (II)**
Abu Al-Khaseeb	**February/2013**	**PTI**	**2.35**	**α-mesosaprobic (III)**
		DAIpo values	**71.51**	**good**
		IBD	**7.5**	**bad**
		S	**2.3**	**β-saprobic (II)**
Abu Al-Khaseeb	**April/2013**	**PTI**	**2.32**	**α-mesosaprobic (III)**
		DAIpo values	**72.39**	**good**
		IBD	**10.13**	**medium**
		S	**2.50**	**β-saprobic (II)**
Abu Al-Khaseeb	**May/2013**	**PTI**	**2.36**	**α-mesosaprobic (III)**
		DAIpo values	**60.70**	**good**
		IBD	**6.4**	**bad**
		S	**2.53**	**α-mesosaprobic (III)**
Abu Al-Khaseeb	**June/2013**	**PTI**	**2.03**	**α-mesosaprobic (III)**
		DAIpo values	**68.53**	**good**
		IBD	**9.5**	**medium**
		S	**2.78**	**α-mesosaprobic (III)**

(*α-β meso saprobic: Alpha-Beta meso saprobic, β-saprobic: Beta-saprobic, α-mesosaprobic: Alpha-mesosaprobic*).

Discussion

Electrical conductivity is a useful indicator of both mineralization and salinity or total salt in a water sample [26], [27]. According to Ayers and Westcot [28], its values were slightly saline water at both Qurnah and Dayr (0.7-3 ms/cm) . While its values ranged from slightly saline water to highly saline one at Abu Al-Khaseeb (> 6 ms/cm and < 14 ms/cm).

The problem associated with high nutrient concentration and algal biomass is commonly called eutrophication from the Greek word “ευτραφής” meaning well fed, underlying the excessive algal growth. If waters are nutrient poor with low productivity are characterized as “oligotrophic” whereas, nutrient rich waters with high algal biomass are characterized as “eutrophic”. The intermediate conditions characterize “mesotrophy” [8]. According to the criteria of Doods *et al.*[29] for river trophic state, the trophic status of the studied sites based on total nitrogen (< 700 µg / l oligotrophy, 700 – 1500 µg / l mesotrophy and > 1500 µg / l eutrophy) were oligotrohy to mesotrophy at Qurnah, oligotrophy at Dayr, and oligotrophy to eutrophy at Abu Al-Khaseeb. And based on total phosphore values (< 25 µg / l oligotrophy, 25 – 27 µg /l mesotrophy and > 75 µg / l eutrophy), the trophic status was eutrophy at Qurnah, and mesotrophy to eutrophy at both Dayr and Abu Al-Khaseeb. While the trophic status based on chlorophyll a values (< 10 µg / l oligotrophy, 10 – 30 µg / l mesotrophy and > 30 µg / l eutrophy) was oligotrophy to mesotrophy at Qurnah and it was oligotrophy to eutrophy at both Dayr and Abu Al-Khaseeb.

Both the BOD_5 and COD tests are a measure of the relative oxygen-depletion effect of an organic contaminant. Both have been widely adopted as a measure of pollution effect. The BOD test measures the oxygen demand of biodegradable pollutants whereas the COD test measures the oxygen demand of oxidizable pollutants [13]. According to Klein [30], water of the studied sites based on BOD_5 values (1 mg / l = very clean, 2 mg / l = clean, 3 mg / l = fairly clean, 5 mg / l = doubtful, and 10 mg / l = bad) was classified as clean to doubtful at Qurnah, fairly clean at Dayr, and clean to fairly clean at Abu Al-Khaseeb. While water of all the studied sites based on COD values was classified as bad (> 7 mg / l).

Water quality exert a selective action on the flora and fauna which constitute the living population of water and the effects produced in them can be used establish biological indices of water quality [31]. All diatoms can generally be classified into at least three categories according to their tolerance towards increasing pollution: (1) most tolerant diatom like *Amphora veneta, Nitzschia palea and Gomponema parvulum, and Synedra ulna* (2) less tolerance onces as represented by *Nitzschia amphibia, Nitzschia filiformis, Nitzschia hungarica, Surirella ovate, Achnanthes hungarica, Cymatopleura solea, Navicula cincta, Navicula pupula, Nitzschia sigma, and Synedra acus* (3) relatively sensitive ones represented by *Achnanthidium minutissimum, Amphora ovalis, Cocconeis pediculus, Cocconeis placentula, Gomphonema olivacium , Nitzschia dissipata, Rhoicosphenia curvata, Amphipleura pellucida, Cymbella cistula, Cymbella tumida, Fragilaria capusina, Gomphonema constrictum, Navicula rhynchocephala and Nitzschia sigmoidea* [20].

So, Indices are the result of attempts to describe changes in water quality. However, due to differences in species distribution, not a single one can be applied universally [31]. As shown in table 3, diatom indices values except DAI_{PO} ones showed that the studied sites were neither very clean nor severe polluted during the study period. PTI values indicated ecological status ranged from beta-mesosaprobic condition to alpha-mesosaprobic one for the studied sites. DAIpo values indicated good conditions for all sites. IBD values indicated ecological status ranged from good to bad condition. S values indicated ecological status ranged from beta-mesosaprobic condition to alpha-mesosaprobic one.

In spite of being inorganic nitrogen and phosphore the main nutrients for algae but the present results for all diatom indices, based on statistical analysis, showed the responding of diatoms to organic pollutants only. These results coincided with Palmer [32] in that organic pollution tends to influence the algal flora more than other factors in the aquatic environment such as light, pH, temperature and often other types of pollutants**.** In addition to that high organic pollution is always accompanied by elevated nutrient concentrations because of decomposition processes. For this reason, species living in highly organic waters are often also indicators of high nutrient loading, as a multitude of factors determine the optimal conditions for a taxon [33]. The statistical results of diatom indices except saprobic index ones showed significantly negative but weakly correlation with BOD_5 and/or COD because biological indicators show the cumulative effects of present and past conditions, whereas chemical and physical measures apply only to the moments of sampling [34].

Also, algae biomass expressed as chlorophyll a showed significantly positive correlation with all diatom indices reflected changes in water quality. In other words, the ecological status of the studied sites in terms of PTI, IBD and DAI_{PO} tend to be less polluted when high chlorophyll a tend to increase. While in terms of S, it tend to be more polluted when high chlorophyll a tend to increase. Palmer [35] stated that rivers which have been polluted with organic compounds gradually become richer in algal nutrients, especially nitrates and phosphates, which incorporated into the cells of algae during self-purification process. During this process the ecological status underwent with several of decomposition stages. The stage of active decomposition called α-mesosaprobic status, where bacteria and organic-tolerant algae begin to flourish while the stage of recovery called β-saprobic status, where algae are abundant while bacteria are decreased in number [36].

In conclusion, our results showed that DAI_{PO} was unsuitable as an index of trophic and saprobity status because its calculation comprised few number of diatom taxa that represent trace percentage of the total abundance of diatom. Both PTI and IBD indices indicated to the presence of eutrophication phenomenon resulting from self-purification process. According to Hassan [37], the process of self-purification was very low at all parts of Shatt Al-Arab River in particular in the downstream. While Saprobic index gives an obvious picture of the organic & trophic status for the studied sites and its results coincided with Sládeˇcek [38] who stated that Saprobic index is a linear indirect measure of BOD_5. Similar results were obtained by Barinova *et al* [39] who used algae indices to monitor pollution level of Jordan River and he found that saprobic index was positively correlated with the abundance of *E.coli* alone which survives in the organically polluted water. And the present results coincided with the conclusions of Köster & Hübener [33], who suggested that the best method for monitoring freshwater by diatoms is the combined application of saprobity and trophic indices. In our country, there is few studies concerning the biological indices of trophic and organic pollution for rivers [40], [41], we hope that more studies will be done so as to assess the trophy and saprobity status for our rivers**.**

References

[1] Nordvarg, L. Predictive models and eutrophication effects of fish farms. Acta Universitatis Upsaliensis. Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology 602. 44 pp. 2001.

[2] Onyema, I. C. The water chemistry and periphytic algae at a cage culture site in a tropical open lagoon in Lagos. Acta SATECH, Vol. 4, No.1:p.p. 53 – 63. 2011.

[3] Vollenweider R.A. Coastal Marine Eutrophication: principles and control pp.1-20, In: Marine Coastal Eutrophication, Vollenweider R.A., Marchetti R. and Viviani R. (eds.), Elsevier, London. 1992.

[4] Gray S.J. Eutrophication in the sea, in G. Colombo and R. Viviani (Eds), Marine Eutrophication and Pollution Dynamics, Olsen & Olsen, Fredensborg, 394p. 1992.

[5] Nixon S.W. Coastal marine eutrophication: a definition, social causes and future concerns, Ophelia,Vol. 41: p.p.199-219. 1995.

[6] OSPAR. Strategies of the OSPAR Commission for the protection of the Marine Environment of the North – East Atlantic (Reference number 2003-21) In: OSPAR Convention for the protection of the marine environment of the North East Atlantic: Ministerial Meeting of the OSPAR Commission Bremen: 25 June 2003 Vol. Annex 31 (Ref. B-4.2). 2003.

[7] UNEP. Eutrophication monitoring strategy of MED POL. Meeting of the MED POL. National Coordinators(Sangemini, Italy, 27-30 May 2003) Mediterranean Action Plan Report. UNEP (DEC)/MEDWG.231/14, 13P. 2003.

[8] Karydis, M. Eutrophication assessment of coastal waters based on indicators: A literature review. Global NEST Journal, Vol. 11, No.4:p.p.373-390. 2009.

[9] Markert, B. A.; Breure, A. M. and Zechmeister, H. G. Algae as ecological bio-indicators. Elsevier Science Ltd. 327 pp. 2003.

[10] Padisák, J. Use of algae for water quality monitoring. In:J.Salánki & V. Istvánovics (eds.) Limnological bases of lake management. Proc. Of the ILEC/UNEP training course:73-83. Internat. Lake Environm. Committee Foundation, Shiga. .1993.

[11] Rovira, L.; Trobajo, R. and Ibáñez, C. Periphytic diatom community in a mediterranean salt wedge estuary: the Erbo Estuary (NE Iberian Peninsula).Acta Bot. Croat. Vol. 68, No.2: p.p.285-300. 2009.

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

[13] APHA. Standard methods for the examination of water and wastewater (20th ed.). Washington: EEUU, American Public Health Association, American Water Works Association, Water Environment Federation.1998.

[14] Patrick, R. and 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.

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

[16] Hadi , R.M. , Al-Saboonchi , A.A. and Haroon , A.K.Y. Diatoms of the Shatt Al-Arab at Basrah , Iraq . J. Nova Hedw. Vol.39: pp. 513-57. 1984.

[17] AL-Handal, A. Y. Littoral diatoms from the Shatt AL-Arab estuary, north west Arabian Gulf. Crypto. Algol., Vol.30, No.2: pp.1-31.2009.

[18] AL-Handal, A. Y. and Abdullah, D. S. Diatoms from the restored Mesopotamian marshes, south Iraq. Algological studies. Vol.133: pp. 65-103. 2010.

[19] Muscio, C. The diatom pollution tolerance index: assigning tolerance values. Water Protection & Development Review Department. Environmental Resource Management. 17 pp.2002.

[20] Lange-Bertalot, H. Pollution Tolerance of Diatoms as a Criterion for Water Quality Estimation. Nova Hedwigia ' Beiheft, Vol. 64:pp. 285-304. 1979.

[21] Watanabe, T. ; Asal, K. ; and Houki, A. Numerical estimation to organic pollution of flowing water by using the epilithic diatom assemblages----diatom assemblage index (DAIpo). Scie. Tot. enviro. Vol. 55:pp. 209-218. 1986.

[22] Ivanov, PL. Chipev, N. and Temniskova, D. Diatoms of the river Iskar (Sofia plain) and their implication for water quality assessment. Part II. Diatom indices and their implication for water quality monitoring. J. Enviro. Prot. Eco. Vol.4, No.2, pp.301-310. 2003.

[23] Pantle, R. and Buck, H. Die biologische Uberwachung der Gewasser und die Darstellung der Ergebnisse. Gas Wasserfach 96, 604 pp.1955.

[24] Van Dam H, Mertenes A, and Sinkeldam J. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands J Aquat Ecol, Vol.28:pp.117-133.1994.

[25] Coste, M. ; Boutry, S. ; Tison, -Rosbery, J. ; and Delmas, F. Improvement of the biological diatom index (BDI):description and efficiency of the new version (BDI - 2006). Ecological indicators.Vol. 9:pp.621-650.2009.

[26] Rimet, F. Diatom an ecoregional indicator of nutrients, organic matter, and micropollutants pollution. THÈSE Pour obtenir le grade de DOCTEUR DE L'UNIVERSITÉ DE GRENOBLE Spécialité : Biodiversité, écologie, environnement. Frannce. 203 pp.2012.

[27] Wangui, G. A. Using GIS to study pollution on Nairobi River. A project submitted as a partial fulfillment for the requirement for the award of the degree of Bachelor of Science in Civil Engineering/ University of Nairobi. 53 PP.2014.

[28] Ayers, R. S. and Westcot, D. W. Water quality for agriculture, FAO Irrigation and Drainage Paper NO.(29), Rev.(1), U.N. Food and Agriculture Organization, Rome.1985.

[29] Dodds, W.K.; Jones, J.R. and Welch, E. B. Suggested criteria for stream trophic state: Distributions of temperate stream types by chlorophyll, total nitrogen and phosphorus.Water Research, Vol. 32:pp. 1455–1462.1998.

[30] Klein L. River Pollution 11 Control, Butterworths, London. 1966. Cited by Wangui, 2014.

[31] Wu, J-T. Ageneric index of diatom assemblages as bioindicator of pollution in the Keeling river of Taiwan. Hydrobio. Vol. 397: pp.79-87.1999.

[32] Palmer, M. C. A composite rating of algae tolerating organic pollution. J. Phycol. Vol. 5: pp.78-82.1969.

[33] Köster, D. and Hübener, T. Application of diatom indices in Planted Ditch constructed for tertiary sewage treatment in Schwaan, Germany.Internat. Rev. Hydrobiol. Vol. 86, No.2 : pp. 241-252.2001.

[34] Michels, A. Use of diatoms (Bacillariophyceae) for water quality assessment in two tropical streams in Costa Rica. Rev. Bio. Trop. Vol. 46, No.6: pp. 143-152.1999.

[35] Palmer, C. M. Algae and water pollution. Castle House Publications LTD. 123 pp.1980.

[36] Fjerdinstad, E. Pollution of streams estimated by benthal phytomicroorganisms:1.ÊA Saprobic System based on communities of organisms and ecological factors. Internationale Revue der gesamten Hydrobiologie, Vol.49:pp.61-131.1964.

[37] Hassan, W. F. The nitrogen and phosphate forms in water of Shatt Al-Arab River in Basra/ Iraq. Marsh Bulletin Vol.8, No.2: pp.182-192.2013.

[38] Sládeˇcek, V. Continental systems for the assessment of river water quality. In James, A. and L. Evison (eds), Biological Indicators of Water Quality. A Wiley- Interscience Publication, NY: 3-1-3-32.1979.

[39] Barinova, S.; Tavassi, M.; Glassman, H. & Nevo, E. Algal indication of pollution in the Lower Jordan River. Applied Ecology and Environmental Research. Vol. 8, No.1:pp.19-38.2010.

[40] Al-Saboonchi, A. A. Benthic algae as indicator to organic pollution in Shatt Al-Arab River and some of its branches. BDH Thesis/ College of Agriculture/University of Basrah. 108 pp.1998.

[41] Mahdee, A. A. and Abdul-Razak, H. A. Algae as bioindicators for water pollution in the Al-Sora-Al-Sofia Drainage Canal and its effect on Euphrates River-Al-Kaldia.Journal of Anbar University for pured sciences. Vol. 6, No.1:pp.1-12.2012.