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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 reflecting 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 (DAI_{po}) [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 irrigation, 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 discharging such as industrial wastes like power plants, paper 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]:

$$\text{Diversity index (H)} = S - 1 / \ln N$$

(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:

$$\text{Id} = \sum A_j I_j V_j / A_j V_j$$

(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:

$$\text{TDI} = (\text{WMS} \times 25) - 25$$

(3)

$$\text{WMS} = \frac{\sum A_j S_j V_j}{\sum A_j V_j} \quad (4)$$

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

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 17.9° in most stations during Winter to 33.7° 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 Nutrients 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 discharging into station (2) and (3),

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 coefficient among physico-chemical parameters, percentages of eutrophic species (pollution tolerant species), and diatom indices.

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 ≤ 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].

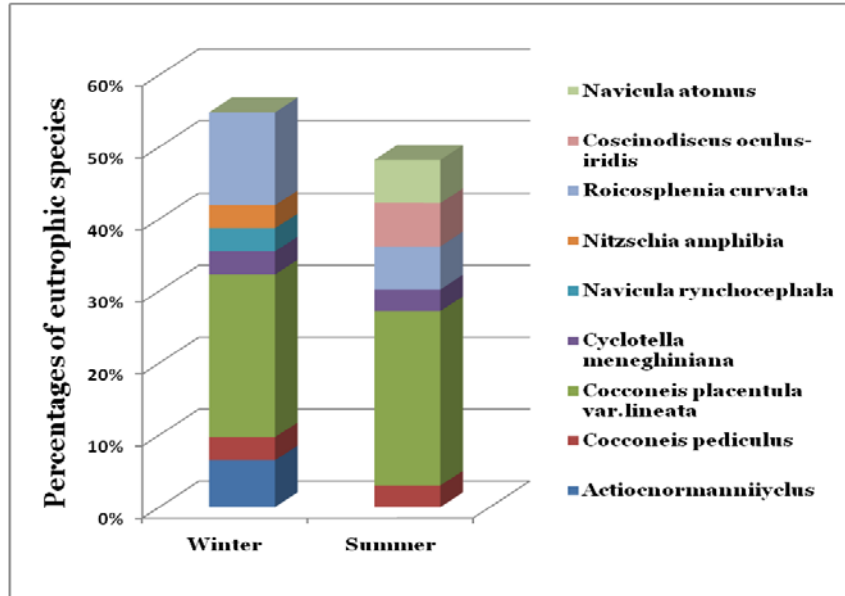


Figure 2: percentages of eutrophic species in Sindbad station.

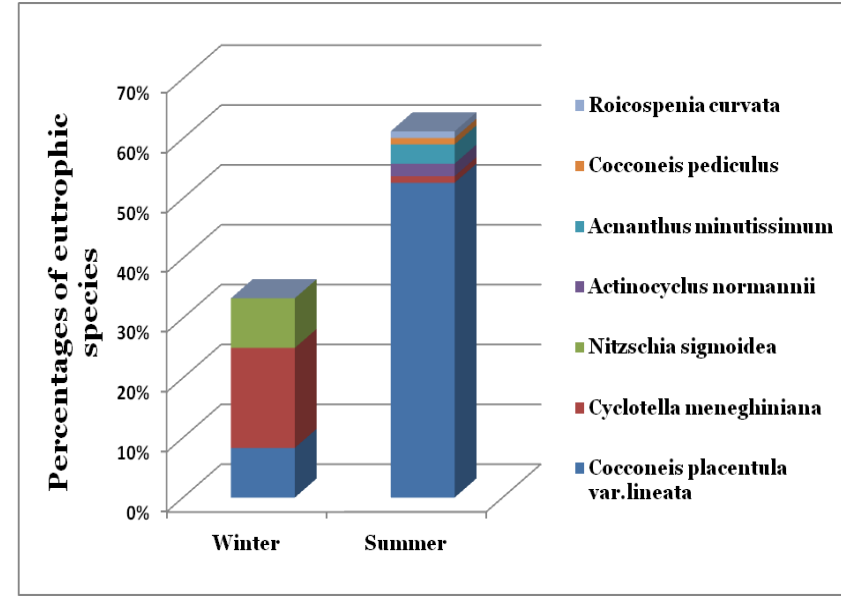


Figure 3: percentages of eutrophic species in Ashar station.

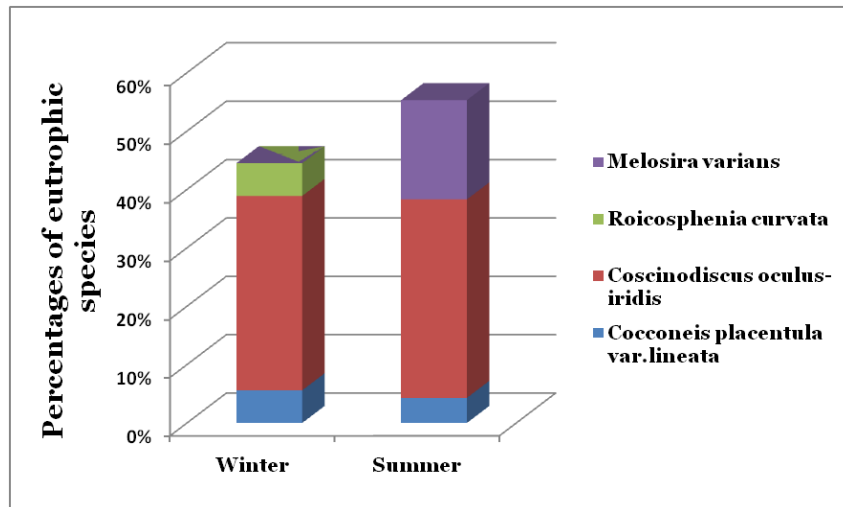


Figure 4: percentages of eutrophic species in Abu Al-Khaseeb station.

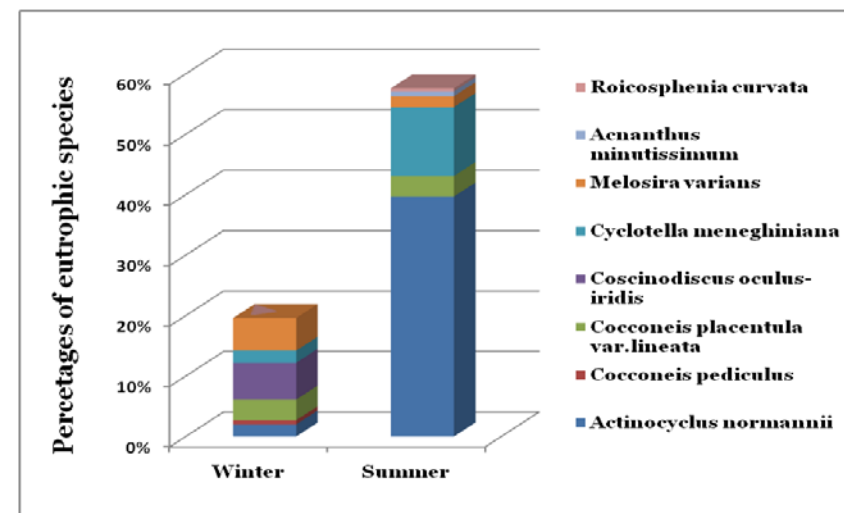


Figure 5: percentages of eutrophic species in Fao station.

Table1: physico-chemical parameters of water at sampling 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 | |
| <i>Actinocyclus normanii</i> | 2 | | | 3 | | 2 | | 152 | ol., e., |
| <i>Acanthus spp.</i> | | 1 | | | | | 1 | | |
| <i>Acanthidium minutissimum</i> | | | | | | 3 | | 3 | Cir., e., |
| <i>Amphiprora spp.</i> | | | | | | | | 2 | |
| <i>Aulacosira spp</i> | | | | 20 | | | 6 | 10 | |
| <i>Campylodiscus intermedius</i> | | | | | | | | 2 | |
| <i>Cocconeis convexa</i> | | | | | | 2 | | | |
| <i>Cocconeis pediculus</i> | 1 | | | 1 | 1 | 1 | | | alp., ol., e., |
| <i>Cocconeis placentula var. lineata</i> | 7 | 1 | 1 | 5 | 8 | 50 | 2 | 13 | alp., e. |
| <i>Cocconeis spp</i> | | | 1 | | 1 | | | | |
| <i>Coscinodiscus oculus-iridis</i> | | | 6 | 9 | 2 | | 16 | | Ph., e. |
| <i>Cyclotella meneghiniana</i> | 1 | 2 | | 3 | 1 | 1 | | 45 | alp.-cir., ol., e. |
| <i>Cyclotella ocellata</i> | | | | 3 | | | | | |
| <i>Cyclotella podanica</i> | | | | | | | | 8 | |
| <i>Cyclotella stelligera</i> | | | | 1 | | | | | Cir., o-e. |
| <i>Cyclotella striata</i> | 2 | | | 17 | | | | 55 | mh. |
| <i>Cyclotella stylorum</i> | | 2 | | 3 | | 1 | | 37 | |
| <i>Cyclotella spp</i> | | | | 56 | | | | 13 | |
| <i>Cymatopleura</i> | | | | | | | | 1 | |
| <i>Cymbella affinis</i> | | | | | 1 | | | | |
| <i>Cymbella spp</i> | 1 | | | | | 6 | | | |
| <i>Encyonema spp</i> | | | | | | 2 | | | |
| <i>Eunotia spp,</i> | 1 | 1 | | | | 2 | | | Most species acido and halophobic, |
| <i>Fragillaria capucina var. gracilis</i> | | | | | | | | 3 | alp.,-cir.,o-m. |
| <i>Fragillaria intermedius</i> | | | | | 3 | | | | |

| | | | | | | | | | |
|--|----|----|----|-----|----|----|----|-----|------------------------------|
| <i>Fragillaria spp</i> | 1 | 1 | 2 | 2 | | | 2 | 2 | |
| <i>Gomphonema affinis</i> | | | | | 1 | | | | |
| <i>Gomphonema constrictum</i> var. <i>capitata</i> | | | | | 6 | | | | |
| <i>Gomphonema spp</i> | 1 | | | 1 | | 3 | | | |
| <i>Gyrosigma tenuirostrum</i> | 1 | | | | | | | | |
| <i>Gyrosigma spp</i> | | | 2 | | | | | 5 | |
| <i>Lyrella spp</i> | | | 1 | | | | | | |
| <i>Melosira granulata</i> | | | | | 2 | | | | alp.-cir., m-e. |
| <i>Melosira varians</i> | | | | 8 | | 8 | 7 | | alp., e. |
| <i>Meridion circulae</i> | | 1 | | | | 1 | | | |
| <i>Navicula atomus</i> | | | | | 2 | | | | alp., e. |
| <i>Navicula rynchocephala</i> | 1 | | | | | | | | alp., mh, e. |
| <i>Navicula spp</i> | 2 | 1 | 2 | 1 | 1 | 4 | 1 | 3 | |
| <i>Nitzschia amphibia</i> | 1 | | | | | | | | alp., ol.(indifferent), e. |
| <i>Nitzschia apiculata</i> | 1 | | | | | | | | |
| <i>Nitzschia obtusa</i> | | | | | | | | 2 | alp., ol. (indifferent). |
| <i>Nitzschia palea</i> | | | | 11 | 1 | | | | alp.,ol. (indifferent), o-e. |
| <i>Nitzschia tryblionella</i> | | | | 1 | | | | 3 | |
| <i>Nitzschia sigma</i> | 1 | | | | | | | | alp., ph. |
| <i>Nitzschia sigmoidea</i> | | 1 | | | | | | | alp., e. |
| <i>Nitzschia spp</i> | | | 1 | 1 | | 4 | 1 | 6 | |
| <i>Roicosphenia curvata</i> | 4 | | 1 | | 2 | 1 | | 2 | al., e. |
| <i>Surirella spp</i> | | | | | | | | 2 | |
| <i>Synedra fasciculata</i> | 3 | | | | 2 | | | 1 | m-e. |
| <i>Synedra ulna</i> | | | | | | | | 3 | Alp., ol.(indifferent) |
| <i>Synedra spp</i> | | | | | | 2 | | | |
| <i>Thalassiosira spp</i> | | | 1 | 1 | | 10 | 10 | 2 | |
| <i>Tryblionella spp</i> | | 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 percentage 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** |
| SIO ₃ | | | | | | | | 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; NO₂⁻ : nitrite; NO₃⁻ : nitrate; PO₄⁻³ : phosphate; N:P: nitrogen to phosphore ratio; SIO₃ : silicate; H: diversity index; Id: diatomic index; TDI: trophic diatom index; Total no. : Total number; Eu %: percentages of eutrophic species.

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