The Epipelic Algal Community in Tigris River and the Effect of Rasheed Power Plant Effluents on its Biodiversity

Fatema Sh. Muftin¹, Muhanned R. Nashaat², Rasha K. Farhan*³
Animal and Fisheries Resources Center, Agricultural Research Directorate, Ministry of Science and Technology, Baghdad, Iraq.
* Irregular provinces in a region Directorate, Ministry of Science & Technology, Baghdad, Iraq.
muhanned_nashaat@yahoo.com

Abstract
In order to find the effect of Rasheed Power Plant (RPP) effluents on biodiversity of Tigris River epipelic algal community, twelve monthly clay samples were collected from January to December 2012, at four selected sites along the Tigris River, which were located upstream RPP (S1), near RPP (S2) and down to the impact of RPP discharge (S3) and (S4). The results showed that epipelic cell density range from \( 60.493 \times 10^3 \) cell /m³ at S1 to \( 155.744 \times 10^3 \) cell /m³ at S2. Shannon diversity index (H) ranged from 0.275-2.517 bit/Ind., species richness (D) ranged from 0.1115-2.1241, species uniformity index (E) ranged from 0.148-2.878. Generally, the biodiversity indicators result showed a positive quantitative effect of thermal effluent on epipelic community, and negative qualitative effect of thermal effluent on its community. Also, it was concluded that the benthic clay of Tigris River was considered as poor diversity and polluted especially at site 2.

Keywords: Rasheed Power Plant; Epipelic; Biodiversity; Tigris River.

1. Introduction
Many published data deals with epipelic algae in Iraq, including Sammara Reservoir [1], southern marshes [2;3;4], Qadisia Lake [5], Shatt Al-Arab River [6; 7 and 8], Euphrates River [9], Tigris River [10], Gradient salinity rivers [11], Many studies conducted the Epipelic algae in river biomonitoring [12; 13;14;15; 16;17;18 and 19]

Studying the impact of the Iraqi power plant effluents on aquatic life is limited, including: Nashaat [20] conducted a study for impact of Al–Durah power plant effluents on physical, chemical and invertebrate biodiversity in the Tigris River, southern Baghdad. However, Nashaat et al. assesses a series of studies that included the impact of Rasheed power plant effluents on the assemblage of food chain biodiversity, such as Rotifer [21]; Cladocera [22]; benthic fauna [23];
Copepodes [24] and Phytoplankton [25]. Also, Muftin et al. [26] and Al-Azawii et al. [27] demonstrated the impacts of the same power plant on some ecological characteristics of the Tigris River and water quality by using the Canadian Water Quality Index (CCME WQI), respectively. On the other hand Al-Naymi et al. [28;29] Assessment the Ecological Risk of Ash Toxicity from Doura power plant in the Freshwater Crustacean Simocephalus vetulus Schfdler; and the Induced of Ash Toxicity Effects from Doura power plant on the hematological and biochemical changes of Cyprinus Carpio L. 1785.

From the literature cited above, It's appear limited works were done on the effects of the power plant (heat waste effluent) discharged into phytoplankton assemblage specially epipelic algal. Therefore, this project was dealing with the effect of Rasheed power plant (RPP) effluents on epipelagic algal community biodiversity in Tigris River.

2. Material and Methods

2.1 Description of the Study Area

Rasheed Power Plant (RPP) built in 1963 on the eastern side of the Tigris River, on the Baghdad Governorate as a source of water for operation and cooling for it, also was constructed near the Al-Dora Refinery obtaining crude oil fuel as an operating energy. It consists of six units which designed on the principle of steam generation as a running design with a design capacity of 25 MW for each unit except the fourth unit which have 45 MW capacity. RPP had withdrawn 500 m³/hour from the Tigris River for each unit. It is treated daily to relieving them from dissolved and suspended salts according to the permissible limits [20].

2.2 The Samples Collection

From January to December 2012, twelve clay sample was collected from four selected sites which selected along the Tigris River to evaluate the effect of RPP on quantitative and qualitative composition of epipelic communities. Site one (S1) was located at the upstream of the RPP as a control site to investigate the ecological characters of the Tigris River, site two (S2) was located near RPP to represent the ecological features of the plant site, whereas the two other sites (S3) and (S4) were located down to the impact of RPP to reflect the possible effects of the plant on the epipelic flora biodiversity by comparison with the control sites (Fig. 1).
Figure 1. Map of Iraq and Baghdad Governorate showing sites of present study Source: Ministry of water Resources 2012\ map scale 1\100000

Epipelic algae recovered from the clay sample according to the procedure described by Bere and Tundisi [13], the sediment samples were collected from 2-3 mm depth after surface layer removal; the sample was stored in a polyethylene container with little of river water and transferred as soon as possible to the laboratory in dark cool box. The samples were processed as follows:

Forty gram from each sample were placed in Petri dish and the clay was covered with lens tissue and kept overnight away from sunlight, then lens tissue was removed and the epipelon algae was recovering from lens tissue by shaking vigorously in lougales solution, while quantitative and quantitative study was done according to Vollenweider [30], the algae taxa were identified
according to Desikachary [31]; Prescott, [32]; Foged, [33]; Foged, [34]; Germain, [35]; Hadi et al. [36]; Haustedt, [37].

While biodiversity indicators are calculated according to the mathematical formulas as described below, which are presented in the following references

1- **Relative abundance Index** [38]:

\[ Ra\% = \frac{(N/Ns)}{N} \times 100 \]

N : Number of individuals at each taxonomic unit in sample; Ns : Total algal number in the sample.

2- **Constancy Index** [39]:

\[ S = \frac{(n/N)}{100} \]

n = positive sample number; N = total sample number.

3- **Species richness Index** [40]:

\[ D = \frac{(S-1)}{\log N} \]

S : species number; N : individuals total numbers.

4- **Shanon-Weiner Diversity Index** [41]:

\[ H = -\sum \frac{n_i}{n} \log \frac{n_i}{n} \]

ni : number of individuals per taxonomic unit; n : total summation of individuals. The results are expressed by a bit/individual unit.

5- **Species Uniformity Index** [42]:

\[ E = H/\log S \]

Ln S : diversity largest theoretical value; H : Shannon Weiner value; S : taxonomic unit number in each site.

### 3. Results and Discussion

One hundred and two algal taxa were identified during this study belong to five families (Cyanophyceae, Euglinophyceae, Pyrrophyceae, Chlorophyceae and Bacillariophyceae) (Table 1). The results showed that the two groups of Bacillariophyceae comprise 78.43%, which represented by 80 species, eight for Centrales and seventy two for Pennales, this results come in accordance with other local and elsewhere studies which revealed this dominance of Bacillariophyceae [43; 44; 45; 46; 47]. Cyanophyceae was represented by 11 species 10.78% followed by 9 species of Chlorophyceae.

**Table 1.** Number of identifying algal taxa according to five families (Cyanophyceae, Euglinophyceae, Pyrrophyceae and Bacillariophyceae).

| Algal Taxa      | S1 Sp. | S1 Genus | S2 Sp. | S2 Genus | S3 Sp. | S3 Genus | S4 Sp. | S4 Genus | Total | %     |
|-----------------|--------|----------|--------|----------|--------|----------|--------|----------|-------|-------|
| Cyanophyceae    | 8      | 3        | 8      | 4        | 7      | 2        | 7      | 3        | 11    | 10.78431 |
| Euglinophyceae  | 1      | 1        | 1      | 1        | 1      | 1        | 1      | 1        | 1     | 0.980392 |
| Pyrrophyceae    | 0      | 0        | 0      | 0        | 0      | 0        | 1      | 1        | 1     | 0.980392 |
| Chlorophyceae   | 4      | 4        | 4      | 4        | 3      | 3        | 5      | 5        | 9     | 8.823529 |
Species number showed clear variation among the sites studied. Results also showed that the algal density was varied between studying sites, site 2 which located near RPP flows have the highest algal density compared to the other sites. These cell numbers decrease gradually in the lower sites (S3 & S4) to reach a level less than the upper site (S1) prior to the RPP as shown in Figure (2). This result can be explained by the effect of organic matter released with power plant effluents.

The highest cell count of epipilic algae during this study was $85.746 \times 10^4$/m$^3$ during July at site 2, while the lowest cell count was $0.062 \times 10^4$/m$^3$ during November also on site 2 (Fig 3). Summer peaks of the epipelic algae (Fig 4) due to flourishing of Oscillatoria species. This result was agreed with Jindal et al. [48] who found that the Oscillatoria sp. represents 50% of the algal population and he notice that its abundant at high temperature in summers and minimum at low temperature during winters.

It seems that the RPP effluents effect the algal cell density and species number since their density in upper sites less than lower sites.

Rimet [12] reported that two types affect benthic algae assemblage in the river of environmental factors; the first group is not affected by human activity such as the geology of the river basin, sites altitude, and the sampling sites distance from the source while the second type are those affected by human activity such as; nutrient load into the river and its concentration.

| Species       | S1 | S2 | S3 | S4 | Total |
|---------------|----|----|----|----|-------|
| Bacillariophyceae | 61 | 25 | 52 | 15 | 617   |
| Centrales    | 6  | 4  | 6  | 2  | 18    |
| Pennales     | 55 | 21 | 46 | 13 | 75    |
| Total        | 74 | 33 | 65 | 24 | 102   |

**Figure 2.** total algal cell number percentage recorded at each site during study period.
3.1 Biodiversity Indices
3.1.1 Species Richness Index
Species richness is a number of identifying units. This indicator represents the diversity in the sample; it is defined as the absolute number of taxonomic units in the bio-community at any location in a water body [49]. In the present study, the highest value of the epipelic algae species richness index 2.12 was recorded in March at the fourth site whereas the lowest value of this index 0.1 was recorded in April at the third site (Figure 5 & Table 2;3). It was seemed that the species richness index values in the site up to the RPP were higher than sites lower of RPP that may be related to the effect of its influence on epipelic species on these sites. Barbour et al. [50] reveal that the increase in the species richness index of taxonomic unites linked with increased bio-community health, and places in which to live.
Table 2. Minimum and Maximum value of studied Biodiversity indices.

| Index | Min. | Max. |
|-------|------|------|
| H     | 0.275| 2.517|
| E     | 0.148| 1    |
| D     | 0.112| 2.124|

Table 3. Total number of epipelic algae, minimum and maximum value of biodiversity indices in studied sites on the Tigris River during period study.

| Index                                           | Sites   | S1             | S2             | S3             | S4             |
|------------------------------------------------|---------|----------------|----------------|----------------|----------------|
| Total number of phytoplankton (cell * 10^4/ m³) |         | 60.493         | 155.744        | 80.34          | 54.642         |
| Species richness index                         |         | 0.544-1.976    | 0.112-1.738    | 0.112-1.53     | 0.173-2.124    |
| Shanon-Wiener index (bit/Ind.)                 |         | 0.275-2.456    | 0.625-2.145    | 0.34-2.517     | 0.364-0.96     |
| Species uniformity index                       |         | 0.482-2.878    | 0.397-1        | 0.148-0.918    | 0.364-0.96     |

Figure 5. Epipelic algal species richness index (D index).

3.1.2. Shannon-Weaver Index
Epipelic algae diversity values by Shannon-Weiner indicated that there was considerable fluctuation in diversity value which were ranged from 2.63 bit/cell at site 1 to 14.2 bit/cell at site 2 (Fig 6), this result indicate the effect of RPP flow on this important biodiversity index that its values were increase at site 2 (located near the RPP effluents). The effect of the site's flows have led to an increase in the biological diversity values in the studied regain, which may be due to the containment of the organic matter deposits deposited in the mud bottom and formed a nutrient source for epipelic algae. Registered low values of biodiversity may be due to several reasons included the high velocity of water flow in the drainage areas. As a rule, the local environment is
highly affected [20]. In contrast to this study results, Reec and Richarson [51] showed decrease of benthic fauna diversity as a result of increased in turbidity.

![Figure 6. Variation of epipelic species Shannon –Weaver index.](image)

3.1.3. Species Uniformity Index

Uniformity Index results showed (Fig. 7) that these species are considered as uniform in its distribution across the species and appearance as Smith et al. [52] suggested that a species uniformity index higher values is a sign of each species rapprochement abundance. Also Ricotta and Avena [53] indicate that when individual densities are so close to each other the index values close to 1, as it seen in current study results at site 2 which it located near RPP effluents. Green [54] demonstrate that low uniformity index values reveal the dominance of the few species in high densities. The values of this indicator range from 0-1; as low values to one or more, species have a strong impact on the ecosystem, the results of this study were close to the results of Kadem, [55] which recorded values ranging from 0.2- 0.8.
3.1.4. Constancy Index (S)

Table (4) shows that *Chlorella vulgaris*, * Cocconeis placentula var. euglapta*, *Diatoma vulgaris*, *Navicula cryptocephala* were existing in high frequency, so it was constant species in all sites, while *Achnanthes minutissima*, *Cymbella affinis*, *Rhoicosphaenia curvata* and *Synedra ulna* were constant in all sites except sites 3, 3, 4 and 2 respectively.

It was found that on site 1 included 17 constant species while this number of constant species was dropped to nine constant species at site 2 that located near RPP, whereas appeared six constant species at site 3 and finally the number of constant species increased to nine constant species after removal the influence of the RPP effluents at site 4.

Also it was noted according to constancy index the following species were constant species in the Tigris River: *Chlorella vulgaris*, *Tetraedron minimum*, *Melosira granulate*, *Achnanthes minutissima*, *Cocconeis pediculus*, *C. placentula*, *C. placentula var. euglapta*, *Cymbella affinis*, *Diatoma vulgaris*, *Gyrosigma peisonis*, *Navicula cryptocephala*, *N. gracilis*, *Nitzschia filiformis*, *N. frustulum*, *N. hungarica*, *N. obtusa*, *N. palea*, *Rhoicosphaenia curvata*, *Synedra ulna*.

These constant units, totaling 19 taxa unequally distributed in the study sites so site 1 were contain constant species more than other sites, while at site 3 which is on the down RPP were less contained and the reason for this may be related to the fact that at site 1 more stable environmentally than the rest sites also it located far away from RPP effluents. Also, species that
appear with abundance frequency in the site 2 and 3, which recorded high densities in the current study, the reason may be due to wide-spread in warm water with contaminated organically [56], or perhaps that have a wide range to endure environmental conditions [57]. The presence of large constant species numbers in Site 1 and 4 with high frequency in the current study agree with the clean environment description by Proto-Neto [58] that contains a large number of species and high-frequency especially species that do not tolerance the pollution.

Relative abundant frequencies values of epipelic algae reveled that *Chlorella vulgaris* was less abundant species that occur in 10-40% of the sample while the other species are rare species in the study area. This variation may be due to the variations in water temperature and organic matter that results from exposed to the RPP discharge that precipitate on the clay. Kulkarni and Surwase [59] indicated that the more persistent and constant species are highly tolerate to a wide range of environmental conditions change. Kadem [55] and Kassim *et al.* [60] also noted this.

**Table 4.** Epipelic algae taxonomic units, relative abundance and constancy Index of study sites.

| Taxa.                                    | Sites | S   | Ra |
|------------------------------------------|-------|-----|----|
|                                          | 1     | 2   | 3  | 4  | 1  | 2  | 3  | 4 |
| **CYANOPHYCEAE**                         |       |     |    |    |    |    |    |    |
| *Anabaena* sp.                           | A     | A   | R  | R  |
| *Cyanoba limnetica*                      | A     | A   | R  | R  |
| *Oscillatoria amoena*                    | A     | A   | Ac | R  | La | R  | R  |
| *O.anguina*                              | A     | A   | A  | R  | La | R  |
| *O.chalybeum*                            | A     |     |    |    |    |    |    |    |
| *O.limnetica*                            | A     | A   | Ac | R  | La | R  | R  |
| *O.limosa*                               | A     | A   |    | R  |    | R  |
| *O. tenuis*                              | A     | Ac  | A  | R  | La | R  | R  |
| *Oscellatoria sp.*                       | A     | A   | R  | R  | R  |
| *Spiralina laxa*                         | A     |     | R  | R  |
| *S.major*                                | A     |     | R  | |
| **EUGLENOPHYCEAE**                       |       |     |    |    |    |    |    |    |
| *Euglena* sp.                            | A     | A   | A  | Ac | R  | R  | R  | R  |
| **PYRROPHYCEAE**                         |       |     |    |    |    |    |    |    |
| *Peridinium cinictum*                    | A     |     |    |    |    |    |    |    |
| **CLOROPHYCEAE**                         |       |     |    |    |    |    |    |    |
| *Ankistrodesmus falacatus*               | A     | A   | R  | R  |
| *Botryococcus brumii*                    | A     |     | R  | |
| *Chlamydomonas sp*                       | A     |     | R  | |
| *Chlorella vulgaris*                     | C     | C   | C  | C  | La | La | La |
| *Cosmarium* sp.                          | A     |     |    |    |    |    |    |    |
| *Pandorina morum*                        | A     |     | R  | |
| *Scendesmus quadricauda*                 | A     |     | R  | |
| Taxa                                           | Sites  | S  | Ra |
|-----------------------------------------------|--------|----|----|
| Tetraedron minimum                            | A      | A  | C  | R  | R  | R  | R  |
| Ulothrix sp.                                  | A      |     |    |    |    |    |    |
| **BACILLARIOPHYCEAE**                         |        |    |    |    |    |    |    |
| **A-Centrales**                               |        |    |    |    |    |    |    |
| Coscinodiscus lacustris                       | A      |     |    |    |    |    |    |
| Cyclotella comta                              | A      |     |    |    |    |    |    |
| Cyclotella kuetzingiana                       | A      | A  | A  | R  | R  | R  | R  |
| Cyclotella meneghiniana                       | C      | Ac | A  | R  | R  | R  | R  |
| Cyclotella ocellata                           | A      | Ac | Ac | A  | R  | R  | R  |
| Melosira granulata                            | C      | Ac | C  | Ac | R  | R  | R  |
| Stephanodiscus astrae                         | A      | A  | A  | A  |able | R  | R  | R  |
| **B-Pennales**                                |        |    |    |    |    |    |    |
| Achnanthes lanceolata                         | A      |     |    |    |    |    |    |
| Achnanthes minutissima                        | C      | C  | Ac | C  | R  | R  | R  |
| Amphora coffeiformis                          | A      | A  |     |    |    |    |    |
| Anomoneis exilis                              | A      |     |    |    |    |    |    |
| Cocconeis pediculus                           | C      |     |    |    |    |    |    |
| Cocconeis placentula                          | C      | C  |     |    |    |    |    |
| Cocconeis placentula var. englapta            | C      | C  | C  | C  | R  | R  | R  |
| Cocconeis placentula var. lineata             | A      | A  |     |    |    |    |    |
| Cymatopleura solea                            | Ac     |     |    |    |    |    |    |
| Cymbella affinis                              | C      | C  | Ac | C  | R  | R  | R  |
| Cymbella affinis var. excisa                  | A      |     |    |    |    |    |    |
| C. aspera                                     | A      |     |    |    |    |    |    |
| Cymbella cistula                              | A      | A  |     |    |    |    |    |
| Cymbella microcephala                         | A      | Ac |     |    |    |    |    |
| Cymbella tumida                               | A      | Ac |     |    |    |    |    |
| Cymbella ventricosa                           | A      |     |    |    |    |    |    |
| Diatoma elongatum                             | A      | A  |     |    |    |    |    |
| Diatoma vulgare                               | C      | C  | C  | C  | R  | R  | R  |
| Diploneis ovalis                              | Ac     | Ac |     |    |    |    |    |
| Fragilaria sp.                                | A      |     |    |    |    |    |    |
| Gomphioneis olivacea                          | Ac     | Ac | Ac |     | R  | R  | R  |
| Gomphonema angustatum                         | Ac     | A  | A  |     | R  | R  | R  |
| Gomphonema constrictum var. capitata          | A      |     |    |    |    |    |    |
| Gomphonema lanceolatum                        | A      |     |    |    |    |    |    |
| Gyrosigma acuminatum                          | A      | A  |     |    |    |    |    |
| G. peisonis                                   | C      | A  | Ac |     | R  | R  | R  |
| G. spencerii                                  | A      |     |    |    |    |    |    |
| Hantzschia amphioxus                          | Ac     | A  |     |    |    |    |    |
| Navicula cryptocephala                        | C      | C  | C  | C  | La | R  | R  |
| Navicula cryptocephala var. veneta            | Ac     | Ac | Ac | Ac | R  | R  | R  |
| Navicula cuspidata                            | A      |     |    |    |    |    |    |

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| Taxa.                      | Sites | S   | Ra | | | |
|---------------------------|-------|-----|----|----|----|
| Navicula gracilis         | C     | Ac  | Ac | C  | R  | R  | R  |
| Navicula ruddiosa         | Ac    | Ac  |    | R  | R  |
| Navicula spicula          | Ac    | Ac  |    | R  | R  |
| Navicula sp.              | A     | Ac  |    | R  | R  |
| Nitzschia acicularis      | A     | Ac  |    | R  | R  |
| Nitzschia amphibia        | Ac    | A   | Ac |    | R  | R  | R  |
| N. angustata var. acuta   | A     | A   |    | R  | R  |
| Nitzschia aciculae        | Ac    | A   | Ac | Ac | R  | R  | R  |
| Nitzschia clausii         | A     | Ac  |    | R  | R  | R  |
| Nitzschia dissipata       | Ac    | Ac  |    | R  | R  | R  |
| Nitzschia fasciculata     | A     | A   | A  | A  | R  | R  | R  |
| Nitzschia filiformis      | C     | Ac  | Ac |    | R  | R  | R  |
| Nitzschia frustulum       | C     | C   | Ac | Ac | R  | R  | R  |
| Nitzschia granulata       | A     |    |    | R  |
| Nitzschia hungarica       | Ac    | Ac  | A  | C  | R  | R  | R  |
| Nitzschia longissima      | Ac    |    | A  |    | R  |
| N. microcephala           | Ac    | Ac  | Ac |    | R  | R  | R  |
| N. obtusa                 | Ac    | Ac  | C  | Ac | R  | R  | La | R  |
| Nitzschia palea           | C     | C   | C  | C  | R  | R  | R  |
| N. punctata               | A     |    |    | R  |
| N. pusilta                | A     |    |    | R  |
| Nitzschia sigma           | A     | Ac  |    | R  | R  |
| Nitzschia signmodiea      | A     | A   |    | R  | R  |
| Nitzschia trybliionella   | A     |    |    | R  |
| Rhocosphaenia curvata     | C     | C   | C  | Ac | R  | R  | R  |
| Stauroneis sp.            |       |    |    |    |
| Surirella ovalis          | Ac    | Ac  |    | R  | R  |
| Synedra acus              | Ac    |    |    | R  |
| S. ulna                   | C     | Ac  | C  | C  | R  | R  | R  |

Obviously, that present study sites was strongly tended to be affected by seasonal environmental changes in freshwater. Also, anthropogenic activities have considerable effect on changes in an epipelic algal community. Consequently, comprehending the dynamic of environmental parameters and their effect on epipelic algal productivity is essential as it acts an important role in the food web and productivity.

4. Conclusions: - the biodiversity indicators result showed a positive quantitative effect of thermal effluent on epipelic community, and negative qualitative effect of thermal effluent on its community. Also, it was concluded that the benthic clay of Tigris River was considered as poor diversity and polluted especially at site 2.
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