Impact of Al-Rasheed Power Plant Effluents on Phytoplankton-

Biodiversity in Tigris River, Southern Baghdad

Muhammad R Nashaat1, Khitam A Merhoon2, Suad K Salman1, Enaam K Abbas1 and Eman H Ali1
1Ministry of Science and Technology. Baghdad, Iraq.
2Department of Environment, College of Science, University of Al-Qadisiyah.
*Corresponding Email: muhanned_nashaat@yahoo.com; E-mail: Khitam.abbas@qu.edu.iq

Abstract. The objective of the current study was to evaluate the effects of Al-Rasheed Power Plant (RPP) effluents on biodiversity of phytoplankton. Samples were collected monthly from January to December 2012, at four sites that were selected on the Tigris River at Baghdad Province. Site 1 was located at the up of RPP, sites 3, 4 were located at the down of RPP, while site 2 was located near RPP. The results showed that the total number of the phytoplankton range from 51.7 - 9146.89 cell * 10^3/L, which was recorded at site 1 and 3, respectively, with average range from 486.68-2053.27 which was recorded at site 1 and 4, respectively. According to the relative abundance index all species were rare, except Cyclotella sp. were less abundant species. The Species richness, Shannon Winner and uniformity index values were ranging from 3.71-21.12, 0.3-3.28 bit/Ind. and 0.13-0.71 at site 2 and 3 respectively, whereas the average value for same index was from 12.42-15.15 at 2 and 1 site; 1.93-2.34 bit/Ind. at 2 and 3 site, and 0.52-0.62 at 2 and 4 site, respectively. Generally the result showed a negative effect of thermal effluent on biodiversity and phytoplankton community. Also, the water of Tigris River was considered a poor diversity and polluted especially at site 2.

Keywords: Al-Rasheed Power Plant (RPP); Phytoplankton; Biodiversity; Tigris River

1. Introduction

Water pollution is a major problem, as all water resources are exposed to pollution because they are exposed to many human residues, industrial and agricultural uses, making the world increasingly interested in water resources and how to address the pollution that has occurred [1]. These ecosystems are suitable habitats for the growth of different species, since any change in their properties affects the growth and diversity of aquatic organisms and is greatly affected by plankton, especially phytoplankton, which are very sensitive to change in the aquatic environment, which affects their composition and thus affects the rest of the aquatic communities in the food chain [2; 3], as phytoplankton and aquatic plants are the basic base of the aquatic food web and any undesirable change in water properties negatively affects them and this indirectly affects on community structure of higher trophic levels [4], the quantity and quality of phytoplankton and its biological diversity have been shown to be adversely affected by liquid residues posed to aquatic systems, causing low biomass and total productivity [5; 6; 7; 8] One of the influencing factors in the survival and diversity of the phytoplankton community in the aquatic environment is warm water which considered to be a liquid thermal waste and significant impact in the water temperature [9]. Also Krishnakumar et al.[10] indicated that the life aquatic environment is threatened by any changes in the water characteristics resulting from exposure to severe heated water which affecting in primary products. Also the liquid of electric power plants effluents causing a change in physical and chemical properties such as viscosity, surface tension, gases solubility and nutrient, as well as they affect significantly on the aquatic biological system and on the all levels of the food chain. Starting from the change in the composition, total number, diversity and productivity of the phytoplankton community [11].

The impact of the power plant effluents on aquatic life has been studied by many researchers, including the study of these effects on bacteria [12; 13], phytoplankton [14; 15] and zooplankton [16] also, studies were emphases on the impact of electrical power plant effluents on biomass and productivity of phytoplankton that result from the rise in temperature [3; 17; 18] while Muhammad et al. [19] studied the effects of the power plant on the abundance and structure of the species, noting that the waste of power plants has adverse effects on the plankton community, showing a decrease in biomass and total productivity through the use of some bio indicators. Also Lo et al. [20] studied the effect of thermal effluents on the phytoplankton communities before, after and near the power plant effluents and they noted that a low of total number of phytoplankton near effluent site.
Studies on the impact of Iraqi power stations are limited, including: Nashaat [21] conducted a study for impact of Al-Durah power plant effluents on physical, chemical and invertebrate biodiversity in the Tigris River, southern Baghdad. While Hassan et al. [22] study of impact of electric power plant effluents on the physical and chemical properties of water, the total density of phytoplankton and the composition of its species in the waters of the Shatt Al-Basra and the Shatt al-Arab on the effect of liquid effluents of the Hartha and the Nangibia power plants. However, Nashaat et al. [23] assesses the impact of Al-Rasheed power plant effluents on rotifera biodiversity at Tigris River, Southern Baghdad. While Muhammad et al.[19] studied the impact of Musayyib power plant effluents on the Euphrates River properties which shows a change in all water properties that return to its value before the power plant as we move away from the site of discharge as a result of dilution. Nashaat et al. [24] conducted a study on the impact of Al-Rasheed power plant effluents on cladocera fauna biodiversity in the Tigris River, Southern Baghdad, whereas Nashaat et al. [25] studied the impact of Al-Rasheed power plant effluents on biodiversity of benthic fauna in Tigris River. The impact of same power plant effluents on the occurrence and composition of Copepodes in Tigris River was conducted by Nashaat et al. [26], and on the some ecological characteristics of Tigris River [27], also Al-Azawii, et al. [28] assessing the effects of it on the quality of the Tigris River, by using the Canadian Water Quality Index (CCME WQI). From the literature cited above, It's appear limited work were done on the effects of the power plant (heat waste effluent) discharged into phytoplankton assemblage. Therefore, this project was undertaken to study the impact of Al-Rasheed power plant (RPP) effluents on phytoplankton biodiversity in Tigris River.

2. Materials and Methods

To achieve such this study, samples were collected monthly for the duration from January to December 2012 of four sites were identified as follows (Figure 1):

1- Site 1 (S1): was located at 500 m before Rasheed Power Plant (RPP).
2- Site 2 (S2): was located near the RPP flows.
3- Site 3 (S3): was located after 500m from site 2.
4- Site 4 (S4): was located about 2 Km after site 3.

2.1. Samples Collection

Monthly, water samples were collected from the four sites for a whole year from the center of the river at a depth of 30 cm from the surface by 1L polyethylene bottles for the quantitative study of phytoplankton, as the method described by Hadi [29], then the sample was preserved with Lugol solution and concentrated by the
sedimentation method as received in [30; 31]. and was examined under a compound microscope (40X for Nondiatom and 100X for Diatom) finally the species was diagnosed depending on the following diagnostic keys [29, 32; 33; 34; 35] then the results expressed as cell*10³/L. While biodiversity indicators are calculated according to the mathematical formulas as described below, which are presented in the following references

1- Relative abundance Index: depending on Tyler [36].

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

N = number of individuals returning to each taxonomic unit in the sample. Ns = Total number of individuals in the sample.
The results were expressed using the percentage and as 70%>Dominant species(D), 70%-40% abundant species (A), 40%-10% Less abundant species(La) 10%<Rare species(R)

2- Constancy Index: Based on Serafim et al. [37].

\[ S = \left( \frac{n}{N} \right) \times 100 \]

n = number of samples in which the type exists. N = total number of samples. Results are expressed using the percentage by the following method:

- 50% >: Constant species(C), 50% - 25%: Accessory species(Ac), 25%-1% : Accidental species(A)

3- Species richness Index: According to Margalefe [38].

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

S = number of species. N = total number of individuals.

4- Shannon-Wiener Diversity Index: based on Shannon and Weaver [39]:

\[ H = \sum \frac{n_i}{n} \log \left( \frac{n_i}{n} \right) \]

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: calculated on the basis of Pielou [40].

\[ E = \frac{H}{\ln S} \]

H = Shannon Weiner value. S = number of taxonomic unit in the station

3. Results and Discussion

The results showed that the highest value of the total phytoplankton number was recorded at site 1 during August, which was 9146.89 cells/L * 10³ and the lowest number was recorded at station 2, which was 51.7 cell/L*10³ during November, with averages of 1940.49, 1486.68, 1542.9 and 2053.27 cell/ L was recorded for the four study sites respectively (Table 1 and Figure 2). It was noticed two peaks of the total phytoplankton number, the first in the spring and the second in the autumn, according to the differences in the total number of phytoplankton which may be due to the change in the physical and chemical factors of water that may occur as a result of the change in the water level and RPP effluents [41], or may be to the suitable temperatures at spring and autumn for growth, reproduction and blooming of phytoplankton during this season [42].

The study also recorded a highest number at site 1 and the lowest at site 2 which correspond to the findings of Lo et al. [20] this may be due to the impact of the RPP effluents. Moreover, it was also noticed that this value was returned gradually to the reference values when we stay away from the RPP effluents as a result of dilution, this is consistent with Hassan et al. [22].

**Table 1.** Minimum and maximum ( First Line), mean ( Second Line), for Variation of total number of phytoplankton and biodiversity indices in Tigris River during period study.

| Index                  | Sites   | 1            | 2            | 3            | 4            |
|------------------------|---------|--------------|--------------|--------------|--------------|
| Total number of phytoplankton (cell/L*10³) | 142.7-9146.89 | 51.7-5522.6 | 194.4-3553.3 | 399.2-4448.3 |
| Species richness index  | 15.15   | 12.42        | 13.98        | 13.49        |
| Shanon-Wiener index (bit/Ind.) | 1.03-3.09 | 0.3-2.79    | 1.28-3.28    | 1.51-2.9    |
| Evenness index         | 0.54    | 0.50         | 0.62         | 0.62         |
Concerning on a Relative abundance Index and constancy index (Tables 2) it was showed that *Cyclotella ocellata* was recorded less abundant (La) while the other species were rare (R) to appear in all stations, which indicates a sensitivity of these species for all changes in water properties caused by the RPP effluents.

According to the constancy index most of the species were accidently and few were accessory species except *Cyclotella meneghinia*, *C. ocellata*, *Cocconeis* spp., *Diatoma*, *Navicula* spp. and *Nitzschia palea* that considered a constant species at all the studied sites which might be able of all these constant species to be overcome against that extreme conditions. More constant and persistent species are characterized by a wide range of tolerances for change in environmental conditions [43]. This was noted by Kadem [44] Kassim *et al.* [45].

**Table 2.** Relative abundance and constancy frequencies index of phytoplankton species identified in the study area.

| Taxa                     | Site | Relative Abundance Index % | Constancy Index % |
|--------------------------|------|---------------------------|-------------------|
| **CYANOPHYCEAE**         |      |                           |                   |
| *Anabaena* sp.           | R    | R R R C Ac A              |                   |
| *Arthrospira* sp.        | R    | R R R Ac 0 A 0            |                   |
| *Chamaesiphon* sp.       | 0    | R R R Ac A A             |                   |
| *Chroococcus* limneticus | R    | 0 R R Ac A 0              |                   |
| *Chroococcus* turgicus   | R    | R R Ac A 0               |                   |
| *Filament blu green algae* | R  | R R Ac A 0                |                   |
| *Lyngbya* aestuarii      | R    | R R R Ac A 0             |                   |
| *Lyngbya* limnetica      | R    | 0 R 0 Ac 0 Ac            |                   |
| *Lyngbya* perselegans    | R    | R R Ac A 0               |                   |
| *Lyngbya* sp.            | 0    | R R R Ac A 0             |                   |
| *Merismopedia* glauca    | R    | R R R Ac A 0             |                   |
| *Merismopedia* elegans   | R    | R R R Ac A               |                   |
| *Nostoc* sp              | R    | 0 R R Ac A 0              |                   |
| *Oscillatoria* acuminata | 0    | R 0 R Ac A Ac            |                   |
| *Oscillatoria* amoena    | R    | R R R Ac C A             |                   |
| *Oscillatoria* chalybeum | R    | 0 R R A A 0              |                   |
| *Oscillatoria* earlei    | R    | R R R Ac C C             |                   |
| *Oscillatoria* limnetica | 0    | R R R 0 Ac 0             |                   |
| *Oscillatoria* limosa    | R    | R R R 0 Ac A             |                   |
| *Oscillatoria* minutiss  | R    | 0 R R 0 Ac 0             |                   |
| *Oscillatoria* princeps  | R    | R R R A Ac A             |                   |
| *O. tenuis*              | R    | R R R Ac A Ac            |                   |
| *Spirulina* meneghiniana | R    | 0 0 R C Ac 0             |                   |
| **CHLOROPHYCEAE**        |      |                           |                   |
| *Arthrococmus* falcatus  | R    | R R R Ac 0 0 0           |                   |
| *Botrococcus* protuberens| 0    | R R R Ac A A             |                   |
| *Botrococcus* sp.        | R    | 0 R R 0 0 0              |                   |
| *Chlamy comona* sp.      | R    | R R R Ac A 0             |                   |
| *Chlorella* vulgaris     | R    | R R R Ac A 0             |                   |
| *Closterium* henrici     | 0    | R 0 R 0 A 0 Ac          |                   |
| *Coelastrum* nasatum     | R    | R R R A Ac A Ac         |                   |
| *Coelastrum* microsporum | R    | 0 R 0 A 0 0             |                   |
| *Cosmarium*leave         | R    | R R R A 0 0             |                   |
Ceratoneis arcus
Campylodiscus clypeus
Caloneis ventricosa
Amphora ovalis
Amphora coffeformis
Cyclotella stelligera
Cyclotella comta
Coscino ciscus lacustris
Chaetoceros

Aulacosiera varians
Aulacosiera italica
Aulacosiera granulata

Actinastrum hantzschii
Ankistrodesmus falcatus
Botryococcus braunii
Chlorella vulgaris
Oocystis

Cyclostephanos sp.
Cyclotella comta

Scenedesmus acuminatus
Scenedesmus acuminatus var. zeae
Scenedesmus bijuga
Scenedesmus bijuga var. altena

Staurastrum paradoxum

Tetrae croziani
Peciastrum simplex

Stephanos cuspidaster

B-Pennales

Bacillariophyceae

Bacillariophyceae
Nitzschia acicularis
Navicula cryptocephala var. minuta
Navicula cryptocephalavar.intermedia
Mastogloia braunii
Hantizschia amphibia
Gomphoneis livacea
Fragilaria vauchaeria
Fragilaria ulna var. oxyrhynchus
F. nana
Fragilaria brevistriata
Fragilaria constrems
Fragilariopsis cf. striata
E. formica
Diatoma elongatum var. tenuis
Diatoma acutangula
Diploneis pseudovalvis
Diploneis ovialis
Eunotia formica
Eunotia pectinata
Eunotia sp.
Fragilariopsis acus
Fragilaria affinis
Fragilaria constricta
Fragilaria brevistriata
F. fasciculata
F. internecia
F. namaplanctonica
Fragilaria ulna
Fragilaria ulna var. biceps
Fragilaria ulna var. oxyphrychus
Fragilaria utricularia
Fragilariopsis australis
Fragilariopsis constricta var. capitata
Gomphonema parvulum
Gomphonema palaicum
Gyrosigma acuminatum
G. peisonis
G. penceri
Hantzschia amphioxus
Mastogloia braunii
Navicula cincta
Navicula cruciata
Navicula cryptopleura
Navicula cryptopleura var. euglypta
Navicula cryptopleura var. intermeCia
Navicula cryptopleura var. minutu
Navicula cryptocephala
Navicula cryptocephala var. veneta
Navicula curticulata
Navicula ephidera
Navicula matica
Navicula parva
Navicula gracilis
Navicula radiosa
Navicula radiosa var. tenella
Navicula rhyncocephala
Navicula spinica
Navicula avis
N. sp
Nitzschia acicularis
N. angustissima var. acuta
Nitzschia apiculate R R R R 0 0 Ac Ac
Nitzschia clausii R R R R Ac A Ac Ac
Nitzschia cissipata R R R R Ac A Ac Ac
Nitzschia cuba R R R R Ac A Ac Ac
Nitzschia fasciculata R R R R C A Ac Ac
Nitzschia filiformis R R R R Ac Ac Ac
Nitzschia frustulum R R R R Ac Ac 0
Nitzschia frustulum var. perminuta R R R R Ac Ac 0
Nitzschia grisea R R R R Ac C Ac A
Nitzschia hungarica R R R R Ac 0 A Ac
Nitzschia ignorata R R R R Ac Ac Ac Ac
N. linearis R La R 0 A C Ac Ac
Nitzschia longissima 0 0 R R A 0 Ac Ac
N. microcephala R R R R 0 Ac Ac Ac
N. obtusa R R R R Ac 0 Ac Ac
Nitzschia palea R R R 0 C C C C
N. punctata var. coarctata 0 0 R R Ac 0 0 Ac Ac
Nitzschia sigma R R R R Ac Ac Ac Ac
Nitzschia sigma var.acuta R R R R Ac 0 0 0
Nitzschia sigmodiea R R R 0 C Ac Ac A
Pinnularia sp. 0 0 R R Ac 0 0 Ac
Pleurosigma obtusum R R R R Ac Ac 0
Pleurosigma salinarum R R 0 R Ac Ac Ac Ac
Pleurosigma variabilis R R 0 R Ac Ac Ac Ac C
Surirella ovalis R R R R Ac Ac 0
Surirella ovata R R R R Ac Ac A
Surirella vatavar.africana R 0 R R A A C A

*calculated from% occurrence in samples. Rare (R) are phytoplankton occurring in less than 10%, Less abundant species (La) phytoplankton occur in 10% - 40% of samples, Abundant species (A) occur in 40% - 70% of samples and Dominant species (D) occur in more than 70%. While as for constancy index(S) are phytoplankton Accidental species (A) phytoplankton occur in 1%-25%, Accessory species (Ac) occur in 25%-50% of samples and constant species (C) occur in more than 50% .

Moving to species richness index, It was recorded the highest value of the species richness index was 21.12 at site 3 and at least 3.71 at site 2 with averages of 15.15, 12.42, 13.98 and 13.49 for the four sites respectively (Table 1and Figure 3). It was observed from the results that there was a variation in the values of this index between sites and seasons, which may be due mainly to the variation in the total number of phytoplankton during the duration of the study, abundance and the degree of water pollution [46] especially at site 2, and also depend on the change by RPP in the water temperature degree, which is one of the factors influencing in the increasing or decreasing of the number of phytoplankton and the lack of primary productivity [47].

Figure 3. Variation of phytoplankton species richness index.

Regarding Shannon-Weiner Diversity Index, results for phytoplankton diversity hit its peak at 3.28 bit/Ind. at site 3, whereas, the lowest of which was 0.3 bit/Ind. that recorded at site 2, with average of this index was 2.14, 1.93, 2.27 and 2.34 bit/Ind. at all sites, respectively (Table 1and Figure 4).
The Shannon-Weiner Index is a guide to water quality and pollution. When its value is less than one, it indicates severe environmental pressures, as follows [48]: More than 3 bit/ind. indicates a high biodiversity and clean water, 3-1 bit/ind. indicates a moderate pollution, less than 1 bit/ind. indicates a highly polluted environment that causes death or migration of sensitive species. So it was revealed that from Shannon-Weiner index results that Tigris River water is moderately polluted except second site, which was highly polluted especially in August and this may be the result of the impact of the RPP effluents. Our results match with Dimitrova et al. [49] which indicated that lack of diversity is associated with increased pollution, also confirmed by Salmen and Nassar [50] whom indicated that increase in organic pollution due to the supply of sewage and the impact of human and industrial residues causes a lack of biological diversity. However, this result was in line with the study of Muhammad et al. [19].

Moving to the Species Uniformity Index (Evenness), site 2 have shown the lowest values in the phytoplankton species uniformity index, which were 0.13, while the highest values was 0.79, which were recorded at site 3, also all sites was recorded averages of this index was 0.54, zero, 50, 0.62 and 0.62 respectively (Table 1 and Figure 5).

It’s noted from the Uniformity Index results that these species are under high environmental pressure, because the values did not exceed 0.5 especially at site 2 which it located near RPP during different months. Thus, these species are considered non-uniform in its appearance and its distribution across the species [51]. Low Uniformity Index values demonstrate that dominance of few species with high densities due to the environmental pressure as Green [52] suggested. The values of this indicator range from 0-1; as low values to one or more, species have a strong impact on the ecosystem, while higher values indicate equal abundance of each species [51] whereas the proximity of individual density to each other
makes the index values closer to 1 [53]. However, the results of this study were similar to the results of Kadem [44], which recorded values ranging from 0.8-0.2

4. Conclusions: it is clear from the findings of the study that the RPP effluents affected negatively on the phytoplankton community of Tigris River and its biodiversity, by causing a decreasing in total numbers and a lack of biodiversity, also the river water is moderately to highly polluted, especially at the second site, which located directly on the influence of RPP effluents and decreases gradually it affect at third and fourth site as a result of the dilution process.

References
[1] Adewoye S O 2010 Effects of detergent effluent discharges on the aspect of water quality of ASA river, Ilorin, Nigeria. *Agri. Bio. J. of North America* 1(4) 731-736.
[2] Sridhar R, Thangaradjou T, Kumar S S, Kannon L 2006 Water quality and phytoplankton characteristics in the park Bay, Southeast coast of India. *J. Environ. Biol.*, 27(3):561-566.
[3] Li T, Liu S, Huang L M, Huang H, Lian J S, Yan Y, Lin S J 2011 Diatom to dinoflagellate shift in the summer phytoplankton community in a bay impacted by nuclear power plant thermal effluent. *Mar. Ecol. Prog. Ser.* 424, 75–85.
[4] Lo W T, Hwang J J, Hsu P K, Hsieh H Y, Tu Y Y, Fang T H, Hwang J S 2004 Seasonal and spatial distribution of phytoplankton in the waters off nuclear power plants, north of Taiwan. *J. Mar. Sci. Technol.* 12, 372–379.
[5] Negi, R K and Rajput A 2013 Impact of pulp and paper mill effluents on phytoplanktonic community structure in Ganga River at Bijnor (Up), India. *Journal of Entomology and Zoology Studies* 1(5):70-73.
[6] Choi K H, Young O K, Joon B L, Soon Y W, Lee M W, Pyung G L, Dong S A, Jae S H, and Ho Y S 2012 Thermal impacts of a coal power plant on the plankton in an open coastal water environment. *Journal of Marine Science and Technology* 20(2): 187-194.
[7] Poornima E H 2005 Impact of thermal discharge from a tropical coastal power plant on phytoplankton *Journal of Thermal Biology* 30: 307-316.
[8] Shiah, F K, Wu T S, Li K Y, Kao S J, Tseng Y F, Chung J L, and Jan S 2006 Thermal effects on heterotrophic processes in a coastal ecosystem adjacent to a nuclear power plant *Marine Ecology Progress Series* 309: 55-65.
[9] Davison I R 1991 Environmental effects on algal photosynthesis: temperature *J. Phycol.* 27, 2-8.
[10] Krishnakumar V, Sastry J and Swamy G N 1991 Implication of Thermal Discharges into the Sea – A Review *Indian Journal of Environmental Protection* 11, 525-527.
[11] Sonawane M 2015 Impact of effluent discharge from thermal power station on status of fish species of River Tapi at Bhusawal, District Jalgaon Maharashtra Sandhya *Journal of Environmental Science, Toxicology and Food Technology* 9(7):63-72.
[12] Choi D H, Park J S, Hwang C Y, Huh S H, and Cho B C 2002 Effects of thermal effluents from a power station on bacteria and heterotrophic nanoflagellates in coastal waters *Marine Ecology and Progress Series* 229: 1-10.
[13] Shiah F K, Tu Y Y, Tsai H S, Kao S J, Jan S 2005 A case study of system and planktonic responses in a subtropical warm plume receiving thermal effluents from a power plant *TAO* 16, 513–528.
[14] Martinez A S, Abundes M E, Gonzalez M and Rosas I 2000 On the influence of hot water discharges on phytoplankton communities from a coastal zone of the Gulf of Mexico Water Air Soil Pollution 119:209-230.

[15] Poornima E H, Rajadurai M, Rao V N R, Narasimhan S V, Venugopalan V P 2006 Use of coastal waters as condenser coolant in electric power plants: impact on phytoplankton and primary productivity J. Therm. Biol. 31, 556–564.

[16] Jiang Z, Zeng J, Chen Q, Huang Y, Xu X, Liao Y, Shou L, and Liu J 2009 Tolerance of copepods to short-term thermal stress caused by coastal power stations Journal of Thermal Biology 33: 419-423

[17] Rajadurai, M.; Poornima, E. H.; Narasimhan, S. V.; Rao, V. N and Venugopalan, V. P. (2005) Phytoplankton growth under temperature stress: Laboratory studies using two diatoms from a tropical coastal power station site. J. Therm. Biol., 30: 299-305.

[18] Chuang Y, H Yang, and H Lin 2009 Effects of a thermal discharge from a nuclear power plant on phytoplankton and periphyton in subtropical waters Journal of Sea Research 61:197–205.

[19] Muhammad Q H, Hussein A H and Lafta J A 2014 The effect of Musayyib thermal power station waste water on some physical and chemical properties of the Euphrates River water Journal of AL-Qadisiyah for Engineering Sciences 7(4):275-290.

[20] Lo W T, Pei-Kai H, Tien-His F, Jian H, and Hung-Yen H 2016 Phytoplankton communities impacted by thermal effluents off two coastal nuclear power plants in Subtropical Areas of Northern Taiwan Terr. Atmos. Ocean. Sci. 27(1): 107-120.

[21] Nashaat M R 2010 Impact of Al–Durah Power Plant Effluents on Physical, Chemical and Invertebrates Biodiversity in Tigris River, Southern Baghdad. Ph.D. Thesis, Coll. Sci., University of Baghdad, Iraq: 183pp.

[22] Hassan W F, Hassan I F and Jasim A H 2011 The effect of industrial effluents polluting water near their discharging in Basrah Governorate /Iraq Journal of Basrah Research "Scientifics" 37(1):21-32.

[23] Nashaat M R, Ali E H, Abbas E K and Moftin F S 2013 Impact of Al-Rasheed power plant effluents on rotifer biodiversity at Tigris River, Southern Baghdad Proceedings of 6th National Conference of the Environment and Natural Resources October 29-31 for the Environment Department of College of Sciences /University of Basra :122-135.

[24] Nashaat M R, Abbas E K, Ali E H, and Moftin F S 2015 Impact of Al-Rasheed power plant effluents on cladocera fauna biodiversity in Tigris River, Southern Baghdad Iraqi Journal of Biotechnology 14(2): 243-254.

[25] Nashaat M R, Radhi A G, Mohammad A A, Reassn K H 2017 Impact of Al-Rasheed power plant effluents on biodiversity of benthic fauna in Tigris River, Southern Baghdad Ibn Al-Haitham J. for Pure & Appl. Sci. 30 (1):315-324.

[26] Nashaat M R, Moftin F Sh, Abbas E K, Ali E H 2018 Occurrence and composition of Copepodes in Tigris River, southern Baghdad, and impact of Al-Rasheed Power Plant on its Biodiversity Ecology 2018 symposium 19-23/June 2018 Kastamonu University (Abstract only)

[27] Moftin F S, Nashaat M R, Rasheed R S, Racine K H 2018 Impact of Al-Rasheed power plant effluents on some ecological characteristics of Tigris River, Southern Baghdad City Jornal of Madenat Al-Alem. (Accepted)

[28] Al-Azawii L H A, Nashaat M R and Moftin F S 2018 Assessing the effects of Al-Rasheed electrical power plant on the quality of Tigris River, Southern of Baghdad by Canadian Water Quality Index (CCME WQI) Iraqi J.Sci. 59(3A): 1162- 1168.

[29] Hadi R A M 1981 Algal studies on the river Usk. Ph.D. Thesis, Univ. College Cardiff U.K.
[30] Vollen-weider R A 1969 *A manual on methods for measuring primary production in aquatic environments* Int. Biol. program Hand book 12.Blak well scientific publication ltd., Oxford p 225

[31] Willen E and Willen T 1978 *About freshwater phytoplankton*. In A-Sournia, ed phytoplankton manual. Unesco p :297-300.

[32] Tyler A V 1971 Periodic and resident components in communities of Atlantic Fish. *J.Fish .Res.Bd.Can.* 28(7):935-946.

[33] Desikachary F R 1959 *Cyanophyta*, Acad press London.

[34] Foged N 1977 Fresh water Diatom in Ireland Bibliotheca phycologia Herausgeseben von. *J. cramer Band 34.*

[35] Germain H 1981 *Flora des Diatomees Diatom phyees eau deues et summates dumassif Americiom et des contrees voisines d Europe occidental*. Societe nouvelle des Ed Boubee, Paris.

[36] Prescott G W 1982 *Algae of the western Great Lakes area*. Koenigstein. Otto Koeltz Science Publishers.

[37] Serafim J R M, Lansac-Toha F A, Paggi J C, Velho L F M and Robertson B 2003 Cladocera fauna composition in ariver-lagoon sytem of the upper parana River Floodplain, with a new record for Brazil *J. Biol.* 63:34-76.

[38] Margalefe R 1968 *Pers pectives in ecology*. University of Chicago. Press Chicago p:111.

[39] Shannon C E and Weaver W 1949 *The mathematical theory of communication*. Univ.Illions.Press Urbane p:117.

[40] Pielou E C 1977 *Mathematical ecology*. John Wiely New York p:385.

[41] Gallegos L C, Jordan E T and Hedrickes S S 2009 Long term dynamics of phytoplankton in the Rhode river , Maryland (U.S.A) *Estuaries and coasts*. DOI 10.1007/5/2237-009- 9172.

[42] Klug J 2003 Effects of variation in nitrogen and phosphorus ratios and concentrations on phytoplankton communities of the Housatonic River *Ecology* 81: 387-398.

[43] Kulkarni D A and Surwase S S 2013 Studies on occurrence, richness and composition of zooplankton in Seena river water at, Mohal, Dist- Solapur, MS *India Int. Res. J. Biological Sci* 2(2), 25-28.

[44] Kadern N F 2005 Phytoplankton biodiversity and relationship with some physical and chemical properties at Shatt AL-Hilla. M.Sc. Thesis, Collage of Science - Babylon University .

[45] Kassim T I and Al-Saadi H A and Farhan R K 2006 Vertical distribution of phytoplankton in Habbaniya lake , Iraqi *Marsh Bulletin* 1 ( 1 ) : 19 – 31.

[46] Ghosh S, Barinova S and Keshri J P 2012 Diversity and seasonal variation of phytoplankton community in the Santragachi Lake, West Bengal, India. *Q. Scinece Connect* 3: 1-19.

[47] Long S M, Ismail N, Chukong L N 2014 Freshwater zooplankton of Bakun dam Sarawak. Malaysia. *Asian Journal of Biological and Life Sciences* 3(2):120-124.
[48] Goel, P K 2008 *Water Pollution, Causes, Effects and Control.* 2nd Ed, Reprint New Age international (P) Limited, Publishers, New Delhi p 285

[49] Dimitrova, R., Nenova, E., Uzunov, B., Shishiniova, M. and Stoynova, M. 2014 Phytoplankton abundance and structural parameters of the critically endangered protected area Vaya Lake (Bularia) *Biot. Biot Equip.* 28(5): 871-877.

[50] Salman, J. M. and Nassar, A. J. 2012 The biodiversity of some Gastropods species in Euphrates River in Iraq *The 4Th Environmental Science Conference University of Babylon, 5-6 December, 2012, Iraq.*

[51] Smith, M. D. and Knap, A. K. 2003 Dominant species maintain Ecosystem function with non-random species loss *Ecol. Lett.* 6: 509-517.

[52] Green, J 1993 Diversity and dominance in planktonic rotifers *Hydrobiologia* 255/256: 345-352.

[53] Ricotta, C. and Avena, G. 2002 On the information – theoretical meaning of Hill, Sparametric Evennes. *Acta Biotheoretica* 30: 63-71.