Occurrence and composition of copepods abundance in Tigris river, southern Baghdad, and effects of Rasheed power plant effluents on its biodiversity

Muhammad R. Nashaat, Fatema S. Muftin, Enaam K. Abbas and Eman H. Ali

1Agricultural Research Directorate, Ministry of Science & Technology, Baghdad, Iraq.

*E-mail: muhammad_nashaat@yahoo.com

Abstract. The quantitative and qualitative structure of the Tigris River copepods communities, were identified to investigate the biological composition, especially near the outcome of Rasheed power plant (RPP), on its biodiversity at four sites those were chosen on the Tigris River in south part of Baghdad Governorate during the period January to December 2012. The sites S2 was located near Rasheed Power Plant to represent the ecological features of the plant site, whereas other sites, S1 was located at the upstream of the RPP as a control site to investigate the ecological characters of the Tigris River. Moreover, 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 copepoda fauna biodiversity by comparison with the control site. Thirty-nine taxonomic units of copepoda fauna were identified in the present study, Including 17 taxonomic units of Cyclopoida, 13 taxonomic units of Calanoida, six taxonomic units of Harpacticoidea and three taxonomic units of Parasitic Copepoda. This study found that the highest copepod density was recorded during the winter period on site below RPP. While at sites near RPP during the summer period, Copepoda showed the lowest density. The results also showed that the sites below RPP included the most constant species, while the lowest were included at site near RPP. The results of the biodiversity indexes generally showed the negative actual impact of RPP on the copepoda community.

Keywords. Biodiversity, Copepoda, Tigris River, Power plant.

1. Introduction

The Power plants drain hundreds of millions or billions of gallons of water each day from rivers, lakes or oceans [1]. According to the United States Geological Survey (USGS) [2]. Water use survey data, 346 billion gallons of freshwater per day (BDG) was used in the United States in 2000, Each kWh of thermoelectric generation requires approximately 25 gallons of water, primarily used for cooling purposes a 500MW power plant would use approximately 300 million gallons of water per day [3]. Power plants and all other cooling water users harm and kill large quantities of fish and other aquatic biota [1]. Through more processes: entrainment (passage through the cooling system of smaller, typically planktonic organisms with cooling-water flow) and impingement (trapping of larger aquatic organisms against intake screens). Both of these processes can cause organism mortality [4].
Rasheed power plant (RPP) in Al-Zafaraniya Region, south of Baghdad, polluted Tigris River water as a result of hot water effluents containing organic compounds, disposed of 430 m$^3$·h$^{-1}$ per high water temperature unit that caused damage to aquatic species in the river environment. Black oil and hot water were used to operate the power plant also it prepared the main sources of air and water pollution in this area. While there are industrial water treatment units, such as acidic acid equation basins and good mixing. As well as the presence of control units for the purification of air from pollutants which resulting from the combustion of fuel to do it within the limits allowed by the environment. The impact on aquatic life of the Iraqi power plant is limited including: [5] led a study to demonstrate the impact of Al–Durah power plant effluents on physical, chemical and invertebrate biodiversity in the Tigris River, southern Baghdad. However, many researchers evaluate series professional studies that included the impact of RPP effluents on the food chain assemblage biodiversity, such as Rotifer [6]; Cladocera [7]; Benthos fauna [8] and Phytoplankton [9]. In addition, [10] and [11] reported the effect of the same power plant on Tigris River ecological characteristics, and water quality using the Canadian Water Quality Index (CCME WQI); respectively. Furthermore, [12, 13] assessment the ecological risk of ash toxicity from Doura power plant in the freshwater Crustacean Simocephalus vetulus Schödler; 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 work were done on the effects of the power plant (heat waste effluent) discharged into this important groups of zooplankton, Thus, to see the impact of this power plant on its biodiversity, it is necessary to study the biological composition, especially copepoda fauna of the Tigris River near RPP. A current study was the first study after the 2003 war, thus the current study was designed to determine the effect of the RPP on the copepoda community's quantity and biodiversity.

2. Materials and Methods

2.1 Description of the Study Area

Rasheed power plant is designed on the principle of steam generation as a running design and consists of six units and a design capacity for each units 25 MW and the fourth unit 45 MW, it was built in 1963 on the eastern side of the Tigris River, which is considered a source of water for operation and cooling, and near the Al-Dora refinery for the purpose of obtaining crude oil fuel. RPP had withdrawn 500m$^3$·hour$^{-1}$ from the Tigris River for each unit. It is tested daily to be treated for relieving them from dissolved and suspended salts according to the permissible limits. So its use of generation steam which it used in the operation of the turbines for the production of electricity [14].

2.2 The Samples Collection

During the period from January to December 2012, the quantitative and qualitative composition of copepoda communities was studied at four sites selected at Baghdad Governorate on the Tigris River. One of the sites was S2 which located near RPP to represent the ecological features of the plant site, whereas other sites, S1 was located upstream RPP as a control site to investigate the ecological characters of the Tigris River. Moreover, 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 copepoda fauna biodiversity by comparison with the control sites (Figure 1).
Monthly sampling was started from January until December 2012 from the four sites under from a depth of 0.5 to 1 m below the water surface, then 45 litre was passing through the zooplankton net with mesh size 55 microns and preserved samples by adding formalin 4%. The samples were examined under a compound microscope and the species was identified according to the diagnostic keys below [15, 16]. The results expressed for individual*m$.^3$. The following Ecological Indices were account:

Relative Abundance Index (Ra): The calculated by (Ra) was depending on the formula contained in [17]. Constancy Index (S): By the presence and frequency of each species, calculated according to the formula contained in [18]. The Species Richness Index (D): This indicator is calculated monthly according to the formula contained in [19]. Shannon - Weiner Diversity Index (H): Values of this indicator were calculated monthly for all groups of invertebrates by using the equation of Shannon and Weiner according in [20]. And the result expressed as the unit bit/Ind. as a bit equal one piece of information. Values < 1 bit * Ind.$^{-1}$. is a little diverse while the values seem more than 3bit *Ind.$^{-1}$. is very diversified [21]. The Species Uniformity Index (E): The species uniformity index measured by the formula referenced in [22]. Values greater than 0.5 in appearance were considered equal or uniform.
3. Results and Discussion

The density of copepoda in the present study varied between great value reached 15577 Ind. * m\(^{-3}\) during of January at site 4 and does not appear in the site 2 during January (Figure 2).

![Figure 2. Monthly variations of the copepoda total density Ind.* m\(^{-3}\) during the period study.](image)

At site 1 before RPP the density varied between great value reached to 3777 Ind. * m\(^{-3}\) during August and minimum 311 Ind. * m\(^{-3}\) in November, Whereas great value at site 2 near RPP was recorded 3577 Ind. * m\(^{-3}\) in August and minimum 22 Ind. * m\(^{-3}\) in May, while as great value at sites down of RPP reached to 15577 Ind. * m\(^{-3}\) in January at site 4 and the minimum value was 155 Ind. * m\(^{-3}\) in February at site 3. Throughout the winter season, 15577 Ind. * m\(^{-3}\) was observed at site 4 at the maximum copepod density at the site below RPP. While, sites 2 showed the lowest zooplankton density with 22 Ind. * m\(^{-3}\) during summer season. Which may be due to affecting copepoda distribution with two stresses, summer season, and RPP thermal effluents that increase the temperature of the water. What's more, other considerations such as oil spill and sewage effluents that disposal from RPP itself, the same result was obtained by [5] on Al-Duara power plant. [6, 7, 8, 9, 23, 24] a decrease in aquatic group density was also recorded when the impact of other power plants on various groups of invertebrates and phytoplankton at the Euphrates River and Tigris River was studied. With regard to relative abundance index (Table 1, Figure 3), nuuplii recorded the highest percentage relative in compared with a total density of other species which it reached to 77%, 34%, 65% and 80% of sites 1, 2, 3 and 4, respectively. While other species such as immature Calanoid, *Halicyclops* sp., *Paracyclops fimbriatus* appeared in different percentages (Figure 3).
Table 1. Aquatic copepods distribution, relative abundance and constancy index frequencies in study area.

| Sites | Taxa | Ra | Ra | Ra | Ra | S | S | S | S |
|-------|------|----|----|----|----|---|---|---|---|
|       |      | 1  | 2  | 3  | 4  | 1 | 2 | 3 | 4 |
| CYCLOPOIDA |      |    |    |    |    |   |   |   |   |
|       | Cyclop sp. | R  | R  | R  | R  | Ac | A  | A  | Ac |
|       | Cyclop (♂) | R  | R  | R  | R  | A  | A  | C  | C  |
|       | C. insignist | R  |    |    |    |    |    |    | Ac |
|       | C. magnus | R  |    |    |    |    |    |    | A  |
|       | C. navus | R  |    |    |    |    |    |    | A  |
|       | C. viridis | R  |    |    |    |    |    |    | A  |
|       | Ectocyclop sp. | R  | R  | R  | R  | A  | A  | A  | Ac |
|       | Eusyclop agilis | R  | R  | R  | R  | A  | A  | Ac | Ac |
|       | Haicyclops sp. | R  | R  | La | R  | C  | C  | C  | C  |
|       | Immature Cyclop | R  | R  | R  | R  | A  | A  | A  | C  |
|       | Macrocyclop ater | R  | R  | R  | R  | A  | A  | A  | Ac |
|       | Mesocyclop hyalimus | R  | R  | R  | R  | A  | Ac | A  | Ac |
|       | Mesocyclop othonoides | R  |    |    |    |    |    |    | A  |
|       | Paracyclops fimbritus | R  | La | La | R  | C  | C  | C  | C  |
|       | P. affinis | R  | R  | R  | R  | A  | A  | A  | A  |
|       | Tropocyclops prasinus | R  |    |    |    |    |    |    | A  |
|       | Nauplii of Copepoda | D  | La | A  | D  | C  | C  | C  | C  |
| CALANOIDA |      |    |    |    |    |   |   |   |   |
|       | Diaptomus sp. | R  | R  | R  | R  | A  | Ac | A  | A  |
|       | Diaptomus arapahoensis | R  |    |    |    |    |    |    | A  |
|       | Diaptomus amatilanensis | R  |    |    |    |    |    |    | A  |
|       | Diaptomus fimbriatus | R  |    |    |    |    |    |    | A  |
|       | Diaptomus lech | R  | R  | R  | R  | A  | A  | A  | A  |
|       | D. minutus | R  | R  | R  | R  | A  | A  | A  | A  |
|       | Diaptomus nudus | R  |    |    |    |    |    |    | A  |
|       | D. sarsioli | R  |    |    |    |    |    |    | A  |
|       | D. sens | R  |    |    |    |    |    |    | A  |
|       | Leptodiaptomus minutus | R  |    |    |    |    |    |    | A  |
|       | Onychocamptus sanguineus | R  |    |    |    |    |    |    | A  |
|       | Other Calanoid | R  | R  | R  | R  | A  | Ac | A  | A  |
|       | Immature Calanoida | R  | La | R  | R  | Ac | C  | A  | A  |
| HARPACTECOIDA |      |    |    |    |    |   |   |   |   |
|       | Harpactecoida sp. | R  | R  | R  | R  | A  | A  | A  | A  |
|       | Acroperus harpae | R  |    |    |    |    |    |    | A  |
|       | Nitocra sp. | R  | R  | R  | R  | C  | Ac | C  | C  |
|       | Nitocra lacucetrus | R  |    |    |    |    |    |    | C  |
|       | Pseudonychocamptus proximus | R  | R  | R  | R  | A  | A  | A  | A  |
|       | Immature Harpactecoida | R  |    |    |    |    |    |    | A  |
| PARASITIC COPEPODA |      |    |    |    |    |   |   |   |   |
|       | Ergasilus sp. | R  | R  | R  | R  | A  | Ac | Ac | A  |
|       | Ergasilus versicolor | R  |    |    |    |    |    |    | A  |
|       | Lernia | R  | R  | R  | R  | A  | A  | A  | A  |
Figure 3. The relative abundance of dominating Copepoda species.

The difference in increased copepoda density may be associated with the nutrients appropriate and their individual is affected by concentrations of salts and organic matter in water [25]. In addition, they are affected by selective vertebrate and aquatic organisms that may be predation of certain sizes, also cyclopoida is the most susceptible to predation by fish larvae [26]. In population of copepoda the numerical predominance of young forms, especially nauplii is the most common pattern, as observed by [22, 27, 28] in different freshwater habitats and as also found in the present study. [29] refer that the dominant group among copepods on lake Lichenskie (with two power plants) were juvenile and harpacticoida found among aquatic plants, and were the most common, constituting nearly 60-80% of zooplankton communities. The low density of the Calanoid group compared to the other suborder may be due to the fact that most species are planktonic, rarely lateral and bloom in lakes and ponds which appropriate in a lentic available environment (Figure 4).
As for the other two suborders, Cyclopoida and Harpacticoida, they prefer the coasts of the water bodies, especially when there is a covered with vegetation [30] (Figures 5, 6).

**Figure 4.** Monthly variations of the Calanoid group density Ind. m$^{-3}$.

**Figure 5.** Monthly variations of the Cyclopoida group density Ind. m$^{-3}$.
Figure 6. Monthly variations of the Harpacticoida group density Ind.\* m\(^{-3}\).

The high density of the copepoda group may be due to the increase of the nauplii, as this group has the ability to withstand the environmental conditions of the RPP more than the rest of the group may be of its small size with few appendixes and the hardness of the outer wall This case was recorded by other researchers [5, 28] (Figure 7).

Figure 7. Monthly variations of the nauplii density Ind.\* m\(^{-3}\).
As for constancy index(S) Table (1) shows that species:- Cyclops♂, Haicyclops sp., Immature Cyclop, Paracyclops fimbriatus, Nauplii, Immature Calanoid, Nitocra sp., Nitocra lacucetrus were the most appeared and frequent. Therefore they are constancy species in the environment of the Tigris River, according to the constancy index, due to it was found in more than 50% of the total samples that taken in the current study. The results showed that sites 3 and 4 were included the most constancy species, while site 2 was included the lowest. However, the location of both sites 3 and 4 were below RPP and with more environmentally stable than other sites [28]. The presence of species belonging to zooplankton were under to a number of factors to be settled to the aquatic environment, including temperature, salinity, light, turbidity, and the presence or absence of predators, so the constant species in the environment is not an absolute issue, As it may turn out the taxonomic units from Accessory to constant species when conditions are favourable [30] especially after removals the effect of RPP effluents. The different in appearance frequency of taxonomic units was varying during the current study or along study sites in both up and below RPP, so some of which were wide-ranging and abundance species, may be due of the widespread tolerance to environmental variability, especially the presence of RPP effluents, Including the temperature, the presence of more than one generation, the suitable environmental conditions and location of the presence and reproduction of some species, and the ability of some species to continuation along the river [31], such as Cyclops sp. and nauplii which appeared seasonally and locally in high density, this may be due to the fact that each of them contained more than one undiagnosed species so these taxonomic units formed for a high percentage or may be due to contains it a various strategies that it ability to resist the unsuitable conditions that imposed on it by the RPP, so some of its individuals enter the diapuse stage, horizontal migration, change their location or change the source of depends food as a result of changing environmental conditions [32]. On the other hand, it was found a clear presence of limited species at a specific location at sites 3 and 4 below the RPP this may be due to the adaptation of some species to situational conditions or to the narrow tolerance of some species to the environmental conditions or as a result of the process of predation and competition, or due to the drift of some species to the sites 3 and 4 and from surrounding areas and their inability to continuation for further distances. Few species exceeded 50% of occurrence frequency were noticed, and the result agreed with [5, 6, 7, 29]. In the current study, the presence of few high frequency species was incompatible with [21] description of clean environment; that this environment with many species and high frequency species especially those didn’t tolerate pollution. As for Species Richness Index, Thirty-nine copepoda taxonomic units have been identified, 17 of which belong to Cyclopoa, 13 to Calanoid, 6 to Harpactecoida and 3 to Parasitic Copepoda (Table 1). To compare the species composition of this study with the investigated copepoda fauna near Al-Mussaib power site at the Euphrates River by [24] they identified 27 copepod taxa. While as at Al-Durah power plant on Tigris River [5] identified 44 taxa of copepod. On the other hand, [29] identified 18 taxa of copepod in the Lake Lichenskie with two power plants in Poland, Sometimes these differences can be related to the level of classification in the study and to the quantity of power plant discharge. The species richness index ranged from lowest value reached in 0 at site 2 in May and highest value reached to 5.1 at site 4 in August (Figure 8).
The species richness index values varied in the site 1 from $0.34 - 2.79$ was recorded in the February to August respectively, either at sites that located after RPP the values of this index was decreased, so at site 3 the value ranged from $0.91-4.02$ in February to September respectively, finally at site 4 the ranged value of this index has increased from $0.79-5.06$ in February to August respectively. On the other hand, at site 2 the values of this index show a decline in values throughout the period of the current study, which had an impact clearly on the sites that located close to the RPP. [29] showed that species richness varied significantly in particular months, and was the lowest in June and highest in September at Lake Lichenskie with two power sites in Poland. Our result agrees with [5, 6, 7] when they recorded the greatest species richness index at the site below Al-Durah and Rasheed power plant on the Tigris River. The results of the present study showed that the high values of the species richness index were recorded at the end of the summer and at the beginning of the autumn season, and this may be due to higher primary productivity through these seasons [33]. It was found in the current study some of the species showed with the highest number of species such as: *Cyclops* appeared in 6 species, *Diaptomus* with 9 species, one species for *Macrocyclops* and two species for each of *Mesocyclops* and *Paracyclops*. The genus *Diaptomus* belongs to the Calanoid group and is characterized by its large size compared with other groups. Several studies have confirmed it's as dominated species in the Iraqi water bodies [34; 35]. The Shannon-Weiner diversity index is one of the most widely indicators used for biodiversity. This indicator has a value from 0-5 and where the value of this indicator is exceeds 3 it indicates that the stricter of the ecological habitat is stable. When this indicator has a value of less than 1 it indicates that there is ecosystem defect caused by pollution [36]. The Shannon-Weiner indice values for the copepoda groups ranged from the lowest value of 0 bit.*Ind.$^{-1}$ was recorded at sites 2 in January and May, whereas the highest value 3.855 bit.*Ind.$^{-1}$ was recorded at site 2 in April (Figure 9).

Figure 8. Monthly variation of the copepoda species richness index in the Tigris River during the period study.
With regard to the copepoda species uniformity index, the lowest value ranged from 0 was recorded at site 2 in January and May to 2.39 was recorded at site 2 in April (Figure 10).

**Figure 10.** Monthly variation of the copepoda species uniformity index (E) in the Tigris River during the period study.
It was clear as for copepoda Shannon Weiner index at site 1 values did not lower than 0.21 bit *Ind\(^{-1}\). during the period of study, whereas the values of this index decreased at all sites below RPP, especially at site 3 which as ranged from 0.7-1.43 bit * Ind\(^{-1}\). Either at sites 2, it was a clear decline due to the effect of RPP effluents on the values of this index which reached to the highest value 1.97% in October except on April which it reached to 3.85 bit * Ind\(^{-1}\) that may be related with increased primary productivity in this season from phytoplankton bloom, because zooplankton is determined by the density and structure of phytoplankton [37] (Figure 6). According to [22] the environments in rich with organic matter characterized by having low diversity with a few dominated species. Our study agrees with [23] when they recorded the average values for the Shannon-Weiner index of the cladocera group of ranged from 1.5-2.9 bit /Ind. on in the Euphrates River near the Al-Musayib power plant and found that the hot effluents had a negative impact on the presence of individuals of different cladocera species. Our result also agrees with [5, 6, 7] when they recorded the greatest Shannon Weiner index at the site below Al-Durah and RPP on the Tigris River Presence of Aquatic Plant abundance leads to the formation of environmentally heterogeneous habitats that are stimulated to present different zooplankton communities [38]. Whereas low Shannon-Weiner index values were recorded at site 2, may be due to the impact of the direct effluents of RPP to the river as well as other human interventions [39]. Or may be the reason for the lower values of the Shannon-Weiner index at site 2 related with the increased turbidity and total suspended solids at this site which resulting from the RPP discharge effluent, where turbidity is the reason for the lack of biodiversity, [20] also showed that increased turbidity leads to an increase in the diversity of zooplankton. Regarding to species uniformity index, It was found that the highest value of copepoda uniformity index at site 1 was 0.8 in May, while these values decreased at the sites after RPP which reached to the minimum value of 0.67 in October at site 4, whereas repeated non-appearance of this value of for several time appeared at site 2 near RPP (Figure 9). Higher values of this index in the study sites indicate that the species was uniformity in appearance because of the absence of any environmental stress, which provides a favourable environment for the stability of the zooplankton community and allow to dominate of the larger species, and this is what happened at the site 1 where they exceeded the values of 0.5 throughout the study period, thus considered uniformity species in appearance. While indicating low values of this index to the dominated by a few species with a high density of it, which is a indicate of the presence of environmental stress, and this agrees with [28] when they referred that the decline in the value of uniformity species index indicates the presence of stress prevents the appearance of the dominated many species, which is what happened at the site 2, where that the decline the value of uniformity index of the species due to increasing organic matter, low of dissolved oxygen concentrations, high nutrient requirement of life and values to the degree of food abundance that allowed to dominated of few species with high densities of it. Our result was conflicted with the study of [5] when he recorded a value of the species uniformity index, ranged from 0.364 to 1.06 at sites up to Al-Duarah power plant while at sites below Al-Duarah power plant a values were ranged from 0.31- 1.05. But the results of the current study agree with [6, 7] when they studied the effect of RPP on rotifer and cladocera of this index was not affected by the effluents of RPP.

4. Conclusion

From a current study we can concluded that copepod assemblage especially near RPP affected on it density and constancy species index by it. Also the other biodiversity Indicators showed the negative RPP effect on the copepoda community.

5. Acknowledgement

The authors appreciated to thank staff of Fish Environment and Diseases Laboratory, Department of Fisheries, Agricultural Research Directorate, Ministry of Science &
Technology, to accomplish this series of research on the impact of RPP on the food chain organisms.

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