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EFFECT OF THERMAL POWER STATION EFFLUENTS ON WETLAND ECOSYSTEM

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Abstract:
The water quality and impact of re-circulated hot water on the ecology of storage reservoir and its suitability for industrial use has been studied in the present investigation. The species diversity, density, dominance and distribution of phytoplankton and zooplankton were studied from different locations with respect to water quality. The water quality parameters, which were monitored during the study period, include temperature, pH, dissolved oxygen, nitrates, alkalinity, turbidity and heavy metals like Copper, Zinc, Lead, Chromium, Nickel, Iron, and Silicon. From the basic biological data, various pollution indices like Palmers algal pollution index, and Shannon-Weiner index were calculated to quantify the water quality of the water bodies. Forty-seven different species of phytoplankton represented by four different groups were recorded. Members of ***Bacillariophyceae*** were dominant (*Synedra*, *Nitzschia*), followed by members of ***Chlorophyceae*** and ***Cyanophyceae***. It is observed that Shannon Weaver Diversity Index value ranges from 3.31 to 3.63, while Palmer's Pollution Index value ranges from 32- 36. The Diatoms were found in high concentration as compared to green algae and blue green algae. Twenty-one different zooplankton species represented by seven different groups were recorded. The enriched status of reservoir water was indicated by occurrence of Ostracoda group. The Shannon Weaver Diversity Index value for zooplanktons was recorded ranging between 2.57 to 3.42. The part of the wetland near the effluent disposal point of the thermal power plant was observed to be ecologically deteriorated because of increased temperature and concentration of heavy metals in the water due to leaching effects of fly- ash slurry. No algae, zooplankton and other biological components were recorded at the disposal point. However a gradual recovery of water quality was observed from disposal point to opposite point of the reservoir, from where water is taken for the reuse of thermal power plant for various purposes. The present study points out the enriched status of reservoir water with varied and diverse forms present.

Keywords: Wetland, Thermal Power Plant, Phytoplankton, Zooplanktons, Wastewater, Heavy Metals, Diversity

Introduction

In the last 25 years, unprecedented population growth and rapid industrialization coupled with intensive agricultural and aqua-cultural practices have exerted intolerable strain on the aquatic resources all over Indian sub continent. A number of thermal power plants have been established in India to meet the ever-increasing demand for energy. In India, large number of thermal power plants are working and utilizing a large amount of water as a coolant for boilers and discharge huge amount of hot wastewater subsequently. Coal is one of the most important resources in India and will play a very important role in thermal power generation. Power generating units are mega project, which require not only huge capital investment but also various natural resources like, fossil fuels and water thus create some impacts on the environment and generate a stress in the local eco system. The solid- waste produced from coal combustion in these plants contains large amount of ash slurry and fly-ash. The fly-ash and the hot wastewater are the sources of physico-chemical pollution for the soil and water bodies in the adjoining areas. On an average, fly ash contains over 60% of SiO_2 and 25% Al_2O_3. In the tropical countries, the temperature of the wastewater from thermal power stations is eight to ten degrees higher than the normal water temperature and the temperature of receiving bodies is close to the upper tolerance limit of the most biological species (**Mazumdar *et al.,* 1990).**

In the aquatic environment, different types of organisms live independently. These aquatic organisms include phytoplankton, zooplankton, benthos, fish and macrophytes. In the aquatic environment phytoplankton, zooplankton and benthic forms reflect the overall water quality. The knowledge of diversity of water-body contributes to an appreciation of general productivity and to understand its basic nature. In principle, occurrence of any species and its relation with surrounding environment and other species could be used as an indicator of environmental quality of a water-body. Similarly, many environmental factors would interact to regulate spatial and seasonal growth and succession of planktons and other biotic communities **(Wetzel, 1975; Jayabhaye and Madlapure, 2006).** Algal growth is dependent on sunlight and nutrient concentrations. An abundance of algae is indicative of nutrient pollution **(De Lange, 1994).** Moreover, algae are sensitive to some pollutants at levels, which may not visibly affect other organisms in the short term or may affect other communities at higher concentrations.

Coal combustion residues (CCRs) are a collective term referring to the residues produced during the combustion of coal regardless of ultimate utilisation or disposal. It includes fly ash, bottom ash, boiler slag, and fluidised bed combustion ash and other solid fine particles (Murarka 1993). Uncontrolled dumping of ash slurry and wastewater makes the water turbid and change the dissolved oxygen- level, pH, and quantity of trace elements **(Subramaninan *et al.,* 1990).** There are reports on the phytoplankton periodicity and primary production **(Zutschi and Vaas 1977, Pollingher 1981, 1986).** The information regarding the effect of such power plant effluents and the prevalence of different biological species and productivity are very scanty.

For a number of years there has been a series of proposals indicating that one or more algae could be used as organisms indicative of water quality (**Palmer, 1959**). He also demonstrated that algal assemblages could be used as indicators of clean water or polluted water. Later, **Patrick (1971)** also described a technique, which could be useful in determining water quality. She proposed that an examination of the diatom flora would give a good idea of the water quality of a water body.

The artificial wetland in the vicinity of Koradi Thermal Power Station (KTPS) in the state of Maharashtra located near Nagpur city is employed for storage and reuse of wastewater generated by the plant. The wastewater after processing is being discharged into the wetland reservoir for storage and circulation constantly. This wetland not only used as a raw water source for the power plant but also reclaims the wastewater discharged into it for re-use and re-circulation. This emphasizes that for sustainable ecological function, the self purification capacity of the wetland, which is the function of indigenous flora and fauna, should not be overburdened by the excess discharge of the power plant- waste or poisoned by discharge of any toxic elements. The ultimate purpose of this study was to identify the causes of pollution and suggest the ways to control them so as to save this precious wetland. In this investigation, an attempt was made to evaluate the water quality and the impact of effluents on the zooplanktons and phytoplankons with respect to different physio-chemical parameters. In India, studies on biological parameters were carried out by many prominent investigators but till date studies with respect to power plant effluents are very scanty hence this study has been carried out.

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Methods and Material

***Sampling site and sample collection*:**

The present investigation was carried out in the wetland ecosystem impacted by the thermal power plant effluent situated in its vicinity. Five sampling locations were selected along the reservoir viz., Station # 1, effluent disposal point (on south- west side), Station # 2 (on the west), Station # 3 (on the south), Station # 4 (on the north), and Station # 5 (on the east), near the water intake point for the thermal power plant. The power plant is one of the four major power plants in Vidarbha situated at Koradi (21.256062, 79.098644) near Nagpur. The plant operates 7 units and has a total power generation capacity of 1080 MW. This plant requires 16,000 to 17,000 tonnes of coal per day and cold water for cooling the boilers and washing purposes.

Water samples from the above said five sampling locations were collected in clean containers (Tarson *500 ml capacity*) for physio-chemical analysis **(APHA, 1985).** Water samples for the Phytoplankton analysis were collected in 100 ml capacity Tarson bottles and fixed immediately by adding 0.7 ml Lugols's Iodine solution for every 100 ml of water sample. The samples for Zooplankton analysis were collected by filtering 30 liter of water with silk- bolting cloth plankton net (55 μ mesh size). These samples were preserved in 4% formalin. Temperature of water was recorded in the field itself. Dissolved oxygen of the water samples was fixed in BOD bottles and carried to the laboratory for further analysis. The water samples for heavy metals estimation were collected using one-liter polypropylene bottles, which were previously soaked in 10% nitric acid and thoroughly rinsed with de-ionized water. At each sampling point three replicate samples were collected within a distance of five meters. A composite sample was prepared by mixing replicate samples together. All the samples were properly sealed and transported to the laboratory for further analysis.

Water analysis

The p^H was determined using p^H meter using Orion combination p^H electrode. Dissolved oxygen in the sample is estimated by Winkler's modified Iodide-Azide method (**APHA**, ***AWWA and WPCF, 1985)***.

The water samples for heavy metal analysis were filtered immediately, using 0.45 µm membrane filter mounted on a Pyrex filter holder with the filtrate acidified to p^H 2 with AR grade HNO_3 to keep the metals in solution. The samples were digested at controlled temperature. Detection and estimation of heavy metals was done on Jobin-Yvon Inductively Coupled Plasma spectrophotometer (ICP).

Plankton Analysis

Analysis of phytoplanktons was done by centrifuging 15 ml. samples at 2000 rpm for ten minutes. Estimation was made by Lacky's drop count method using high- power magnification in microscope. Then samples were examined under light microscope and identified by standard methods (**Desikachary 1959, Palmer 1980**). Analysis of zooplankton was done by concentrating the samples by centrifuging the samples at 2000 rpm. for 10 minutes and the counting of zooplanktons was done in Sedgewick Rafter Cell (S-R Cell) of 1 ml capacity and various forms are identified as per **Ward and Whipple (1959), Battish (1992) and Tonapi (1980).**

Diversity Index

The Shannon Weaver Diversity Index (SWDI) was calculated using formula given by Shannon and Weaver.

$$S.W.I. = -\sum(Ni/N) \times \ln(Ni/N)$$

Where, Ni = Number of i^{th} species;

N = Total number of individuals

Palmer's pollution index *(PPI)* has been given by **C. M. Palmer (1969 and 1980)** for biological evaluation of the level of organic pollution in the water bodies. Palmer reviewed the literature and allotted pollution ratings to specific indicator algal species. The summation of all the ratings of the indicator species recorded in the water samples gives the value of PPI. The value of PPI ranging from 0-15 indicates the absence of organic pollution; 15-20 indicates probable presence of organic pollution and more than 20 indicates the presence of very high organic pollution in the water sample.

Results and Discussion

Thermal plants create or use steam in the process of creating electricity requires water for cooling. This water typically comes from adjacent water bodies or groundwater sources and is discharged back into the water body at significantly higher temperatures. By altering the temperature in the "mixing zone," the discharges of thermal wastewater can both negative and positive effects on aquatic life. On the plus side, the warmer temperature water may create more favorable feeding and breeding conditions for certain species located near the power plant's water source. However, when the power plant is suddenly shut down for routine maintenance or unplanned outage, the resulting wide swing to colder temperatures can be lethal to sensitive fish populations.

The reservoir selected for the present investigation is made up of 5-6 small water-bodies connected with each other which form a wetland ecosystem, which receive wastewater from the thermal plant at one end and provide water for various purposes viz., ***Boiler blow down, Coal pile run-off*** cooling towers, ***Boiler cleaning*** and other industrial use at the downstream location. A variety of fish species like *Catla catla*, Cirrhina *mrigala*, and *some* weed fish species and avifauna were observed to thrive in this wetland. Diverse macrophytes like, *Ipomea aquatica, Ipomoea indica, Hydrilla verticillata*, *Ceratophyllum*, *Nelumbo nucifera,* were observed as dense weeds in the shallow areas of the reservoir. Thus this wetland was productive and significant from biological point of view. It is also an important recreational spot for the local people, tourists and pilgrims as there is a temple situated near the reservoir indicating the cultural value of this wetland.

The water sample was turbid at station # 1, but became clear gradually at subsequent sampling locations due to settling of suspended matter, especially the ash particles which are imparting the turbidity to water. The rate of sedimentation might have been enhanced due to resistance of water- flow offered by submerged and emergent macrophytes in the reservoir in the reservoir basin. The temperature of the reservoir water was observed to be high (32°C) near wastewater disposal point at station #1. This is the upper tolerable limit for most of the aquatic flora and fauna. The temperature of water gradually lowered down to 25° C at station # 2 and 22°C at all the other stations. The water was alkaline with higher p^H i.e. 8.25 at station #1 and alkaline condition gradually decreases to p^H 7.9 at station #5. Dissolved oxygen concentration was low at station #1 i.e. 2.5 ppm. It showed gradual improvement in the subsequent sampling stations (Table 1). Waste water disposed off at temperature 4-5^0 C above the prevalent surface water temperature, which can harm the local aquatic biota. In order to avoid such thermal pollution, this power plant dispose off the effluent by means of a long and open channel, due to which the temperature of the effluent comes down to the level of that of the surface water by the time it reaches the receiving body. Therefore, no loss of fisheries and other aquatic biota was observed due to thermal pollution by this power plant.

The heavy metal concentration was also observed to be high at station #1, especially of copper (0.66 ppm), zinc (1.98 ppm) and nickel (28.0 ppm) and its gradual decrease at downstream stations. Copper was not present in toxic amount at stations 3, 4 and 5. The concentration of nickel did not vary significantly at different sampling locations. Thermal wastes are known to have favorable as well as adverse effects on the flora and fauna of aquatic ecosystems. However, the same depends on the nature and degree of the waste being discharged. In this case it was observed to favour the growth of planktons especially the *Diatoms,* both qualitatively and qualitatively. Most other heavy metals act as a source of trace nutrients at micro quantities and may stimulate the growth and vigor of flora and fauna in the water body. The concentration of various heavy metals at different stations is shown in Table 2.

Biodiversity of planktons at different sampling locations is the indicator of the hostile and favorable growth conditions prevailing there. The conditions at station #1 appear to be unfavorable for the growth of biotic components due to high temperature and the concentration of different heavy metals. However, the toxicity of heavy metals and water temperature was found decreasing considerably at subsequent downstream locations. The phytoplankton count was observed to be varying from 15175 - 20486 algae/ml in the reservoir water. Biodiversity of phytoplankton was increased from station #2 to station #3 and #5, while station #4 showed the minimum count.

Algal growth is dependent on sunlight and nutrient concentrations. An abundance of algae is indicative of nutrient pollution (De Lange, 1994). Moreover algae are sensitive to some pollutants at levels which may not visibly affect other organisms in the short term or may affect other communities at higher concentrations. In all, *forty-six* genera belonging to four different algal groups i.e. *Chlorophyceae, Cyanophyceae, Bacillariophyceae* and *Euglenophyceae* were recorded. The members of *Bacillariophyceae* were dominant and represented by twenty species. The dominant Diatom genera were *Navicula, Synedra, Stauroneis, Nitzschi*a. *Cyanophyceae* was represented by six species. The percenage composition of *Bacillariophyceae* was highest at all the stations. It may be due to high amount of trace elements especially aluminium and silica in the water body. The occurrence of *Bacillariophyceae* members in the large numbers recorded in this study is the agreement with the results of **Shrivastava *et al.*, (1996) and Patrick (1973)** described that diatom flora gives a good idea of the quality of water. The Shannon Weaver diversity index (SWDI) was observed ranging between 3.31 and 3.63. The SWDI values clearly indicate that the plankton diversity was very high. A higher diversity index within a narrow range showed greater stability i.e. resistance to adverse environmental conditions **(Staub *et al.*, 1970).** But it is interesting to note that the Palmers pollution intex was also very high i.e. 32 to 36. This shows that the water was highly contaminated. Such a condition is observed when there is high micronutrient load as well as high consuming capacity of the biological organisms. In this reservoir, many hydrophytic plants such as *Hydrilla, Nymphea, Ceratophyllum* and *Chara* were distributed in very large numbers, which in turn utilize the organic pollutants and produce oxygen, which makes the ecosystem well balanced and stabilized. A large count of *Bacillariophyceae* is an indication of pollution due to thermal power plant, which contain large amount of silica, aluminium and other heavy metals.

In all, twenty-one different zooplankton species belonging to seven different groups viz. Protozoa, Rotifera, Cladocera, Copepoda, Ostracoda, Oligocheta, and *Diptera* were recorded in the reservoir water. The members of *Cladocera* and *Copepoda* groups were observed to be dominant. Total of these organisms varied from 4100 to 5690 per cubic meter of water sample. The SWDI values varied from 2.57 to 3.42, which indicate medium to high diversity and rich supply of nutrients. The occurrence of *Ostracoda* group indicates the enriched status of reservoir water. The members of *Diptera* group were recorded from two stations only. The above situations indicate that the maximum impact of the thermal power plant effluents was observed at effluent disposal point in the reservoir having maximum water temperature (32^o C), p^H 8 .2 and dissolved oxygen level at 2.5 mg /L.

The phytoplankton count in the reservoir is comparable to the level present in mesotrophic water that is low level of medially polluted water **(Leithe, 1975).** Shannon Weaver Diversity Index values ranging from 3.31 to 3.63 also indicate medially enriched status of the reservoir (Table 3). Shannon Weaver Index is sensitive to all the physico-chemical conditions, which brings about the inhibition in the growth of flora and fauna. In the present investigation, heavy metal toxicity and mineral organic nutrient enrichment are the two factors mainly affecting the development of phytoplankton flora. Shannon Weaver Diversity Index thus shows the overall impact of these factors on the growth of phytoplanktons and zooplanktons. Palmers Pollution Index ranged from 32-36, indicating presence of high organic pollution. In spite of the presence of very high organic pollutants, the phytoplankton density was comparatively less. This was due to the impact of the toxicity of heavy metals on the growth of phytoplanktons. Similarly, the utilization of nutrients by the dense growth of macrophytes in the reservoir resulted in attenuating the availability of nutrients for the growth of phytoplanktons. The presence of organic pollution indicator species in the reservoir viz., *Euglena, Oscillatoria, Merismopeida, Chlorella, Chlamydomonas, Scenedesmus, Navicula* and *Nitzschia* supports these observations.

Dominance of *Bacillariophyceae* in the reservoir water may be attributed to the higher level of silica in the water. Silica is the essential requirement for the growth and dominance of diatoms. It was observed that the diatoms could tolerate heavy metal toxicity in the prevailing conditions. The next dominant algal group was *Chlorophyceae*. The lowest percentage composition was of *Cyanophyceae* or blue green algae. These results indicate that green algae showed average tolerance to heavy metals, while blue green algae were sensitive to the heavy metal toxicity.

Zooplanktons were also sensitive to the heavy metal toxicity in the reservoir water. Shannon Weaver Diversity Index based on zooplanktons was low at station #2 and #4 and high at station #3 and # 5 (Table 4). The reduction in the diversity may be attributed to the higher concentration of heavy metals at station 2 and 4 especially Aluminium, as indicated by higher percentage composition of organic pollution indicator group i.e. *Protozoa* and *Rotifera.* On the other hand, *Cladocera* was found to be dominant and *Copepoda* and *Rotifera* were subdominant groups in the zooplankton population.

Thus from the above results it appears that the reservoir is a rich and productive wetland system supporting macrophytes, planktons, fish and a large number of birds in the area. Apart from its ecological function, it plays an important role in detoxifying and purifying thermal power plant wastewater discharge into the reservoir and restoring the reservoir water quality suitable for industrial use again. The reservoir water appears to be clean near the water intake point. The physio-chemical changes in dissolved oxygen and p^H also indicates the improvement in the quality of water.

Water slurry is used to take the ash from the power plant to the ash pond for disposal. There are two impacts associated with the ash pond decant. The first point is that this water slowly seeps into the ground while carrying with it the ash leachate. The water may contain harmful heavy metals like boron, which have a tendency to leach out over a period of time. Due to this the ground water gets polluted and may become unsuitable for domestic use. The second factor affecting the water environment is the release of ash pond decant into the local water bodies. Such release of ash pond decant tends to deposit ash all along its path thereby causing fugitive dust nuisance when it dries up. Also when such water mixes with a water body, it increases the turbidity of the water body thereby decreasing the primary productivity. This is harmful to the fisheries and other aquatic biota in the water body.

The result indicates that the fly- ash slurry was mainly responsible for the deterioration of the water quality of the wetland ecosystem coupled with hot water circulation. The deterioration of water quality due to enrichment of nutrients is also undesirable for the reuse, and recalculation of reservoir water in long run. For this fly- ash needs to be removed prior to disposal of wastewater for the protection of wetland ecosystem in this case and for sustainable use of wetland for industrial reuse of reservoir water and for maintaining the wetland functions that restore the water quality slowly.

Table: 1 Physico-chemical characteristics of wetland reservoir water

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°c)	32 (± 1.8)	25 (± 1.0)	22 (± 0.3)	22.2 (± 0.2)	22 (± 0.2)
pH	8.2 (± 0.2)	8.2 (± 1.0)	8.2 (± 0.2)	8.1 (±0.5)	7.9 (± 1.0)
Dissolved Oxygen (mg/L)	2.5 (± 1.4)	3.2 (± 1.0)	3.5 (± 0.5)	3.8 (± 0.8)	4.6 (±0.6)
Alkalinity (mg/L)	125	120	113	115	110
Nitrate (u/L)	160	155	156	120	110

(± Standard deviation)

Table: 2 Heavy metals in the reservoir water (concentration in ppm)

Heavy Metals	Station 1	Station 2	Station 3	Station 4	Station 5
Chromium	ND	ND	ND	ND	ND
Zinc	2.0	0.4	0.3	0.5	0.6
Lead	ND	ND	ND	ND	ND
Aluminium	14.5	13.3	12.5	13.9	12.4
Nickel	28	24.6	22.6	25.6	25.6
Cadmium	ND	ND	ND	ND	ND
Manganese	ND	ND	ND	ND	ND
Iron	200	175	169	128.8	120
Copper	0.7	0.4	ND	0.3	ND
Silica	180	171	169.6	173.0	170.8

ND = Not detectable

Table: 3 Community structure of phytoplankton and zooplanktons at various sampling Stations in the reservoir water

Sampling Station	Total Count/ml (Algae)	Total Count/m^3 (Zooplanktons)	Shannon Weaver Diversity Index For algae	Shannon Weaver Diversity Index For zooplanktons	Palmer's Pollution Index
1	-	-	-	-	-
2	18675	4100	3.63	3.04	32
3	19125	4320	3.56	3.09	32
4	15175	4340	3.50	2.57	34
5	20486	5690	3.31	3.42	36

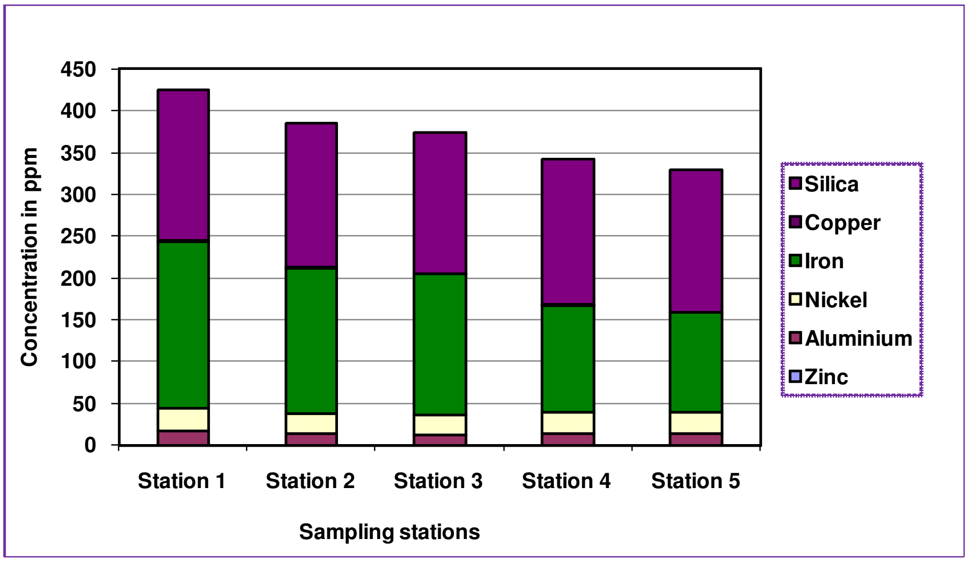

Figure 1. The heavy metal concentration in the wetland at different sampling location in ppm

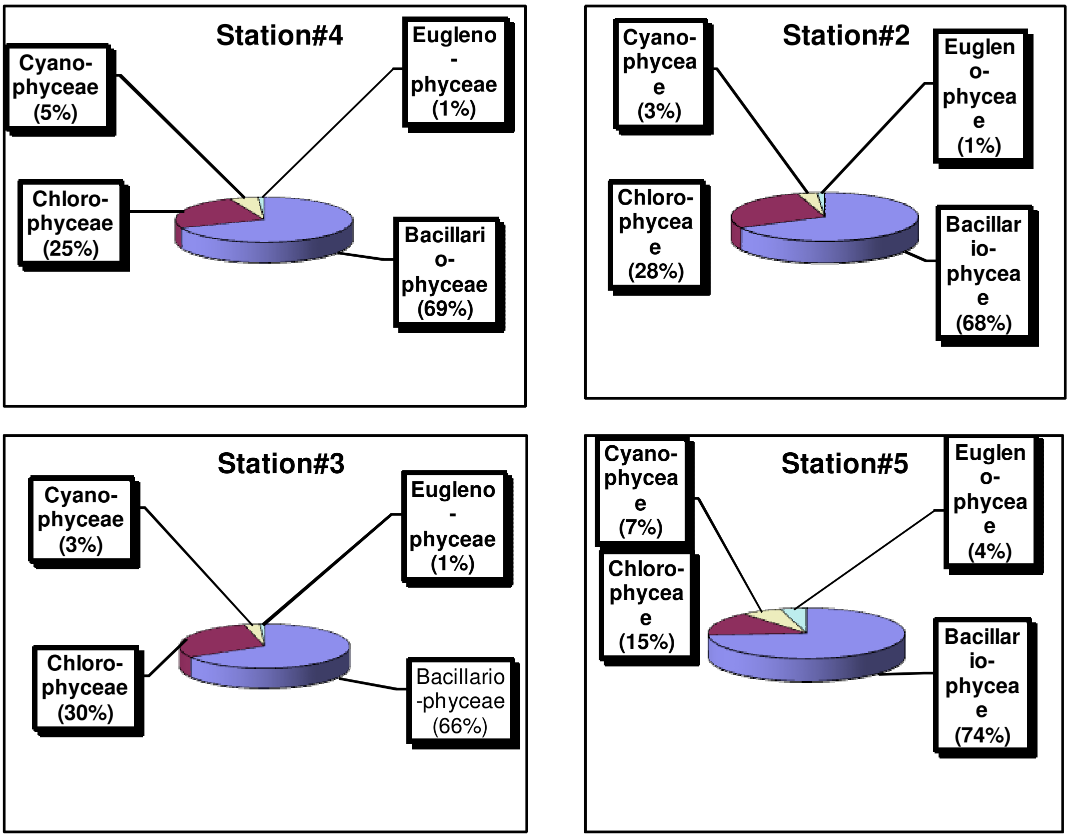

Figure 2: Per cent contribution of different algal groups at different sampling stations

Conclusion

From the basic biological data, various pollution indices like Palmers algal pollution index, and Shannon-Weaver index were calculated to quantify the water quality of the water bodies and diversity of phytoplanktons and zooplanktons. Forty-seven different species of phytoplankton represented by four different groups were recorded. It is observed that Shannon Weaver Diversity Index value ranges from **3.31 to 3.63,** while Palmer's Pollution Index value ranges from **32- 36.** The Diatoms were found in high concentration as compared to green algae and blue green algae. Twenty-one different zooplankton species represented by seven different groups were recorded. The enriched status of reservoir water was indicated by occurrence of Ostracoda group. The Shannon Weaver Diversity Index value for zooplanktons was recorded ranging between **2.57 to 3.42.**

The part of the wetland near the effluent disposal point of the thermal power plant was observed to be ecologically deteriorated because of increased temperature and concentration of heavy metals in the water due to leaching effects of fly- ash slurry. No algae, zooplankton and other biological components were recorded at the disposal point. However a gradual recovery of water quality was observed from disposal point to opposite point of the reservoir, from where water is taken for the reuse of thermal power plant for various purposes.

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