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Phytoplankton as index of water quality with reference to industrial pollution

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Abstract: *In this paper Shannon-Weaver (SI-3.58-4.07, SII-3.1-3.72, SIII-1.64-2.25, SIV-2.54-2.95 and SV-3.09-3.23) diversity index was applied to surface phytoplankton to study the water quality status of river Bhadra receiving Mysore paper mill and Iron and steel mill effluent. A total of 45 species of phytoplankton belonging to 5 classes were recorded and study indicated that the phytoplankton diversity (Chlorophyceae-19 species, Bacillariophyceae-16 species, Cyanophyceae-07 species, Euglenophyceae-2 species and Chrysophyceae-1 species) did not reveal the same type of water quality (water temperature 24.62-27.32°C, pH-7.08-7.25, electrical conductivity-67.49-201.94 μmhos/cm, dissolved oxygen-4.13-5.98 mgl^{-1}, chloride-12.30-40.85 mgl^{-1}, calcium-6.49-23.74 mgl^{-1}, total hardness 28.98-76.65 mgl^{-1}, magnesium-4.69-15.92 mgl^{-1}, total alkalinity-77.26-86.53 mgl^{-1}, BOD-1.88-4.01 mgl^{-1}, COD - 16.53-45 mgl^{-1}, phosphate-0.001-0.53 mgl^{-1}, sodium-2.70-7.46 mgl^{-1} and potassium-2.37-7.88 mgl^{-1}). The investigation emphasized the need of phytoplankton community as index of water quality polluted by industrial effluents at the downstream stretch of the Bhadra river.*

Key words: *Bhadra river, Shannon- Weaver index, Phytoplankton, Industrial pollution*
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Introduction

Various species diversity indices respond differently to different environmental and behavioral factors of biotic communities and therefore, recent investigations have been directed to species diversity indices. Bhadra river is one of the important perennial rivers of the district Shimoga and it connects the river Tunga in Kudli and flows as Tunga Bhadra river. The knowledge of river phytoplankton in India is fragmentary, though a number of contributions are available (Singh and Srivastava, 1988; Misra *et al.,*1999; Sridhar *et al.,* 2006). In a water body there usually occur a seasonal qualitative fluctuations in planktonic population in tropical and temperate climates (Jhingran, 1980; Tiwari and Chauhan, 2006). In Bhadra river of tropical region, no such study has been reported so far. In the present communication, an attempt was made to study the phytoplankton diversity index in Bhadra river, Karnataka.

Materials and Methods

Phytoplankton samples were collected as per standard methods (APHA , 2005) from predetermined sampling stations [S.I- bypass bridge (upstream of river Bhadra before the entry of industrial effluents and domestic sewage from Bhadravathi town), S.II- railway bridge (after the release of MPM effluent to the river Bhadra, 0.5 km away from the point source of pollution), S.III- new bridge (after the addition of VISL industrial effluent and domestic sewage from the Bhadravathi town), S.IV- Nagathi belagalu (Nearly 10 kms away from the Bhadravathi town), S.V- Holehonnur (before river Bhadra joins river Tunga in Kudli] from the point of upstream stretch to effluent outfall along with the downstream stretch, arbitrarily designed in five sectors in three different seasons, premonsoon, postmonsoon and monsoon for two years (2004-2005). The collected samples were fixed in 4-5% formaldehyde and brought to laboratory for analysis. Counting and identification were done as per APHA (2005), Trivedy and Goel (1986) and Pillai (1986). Species diversity index was calculated following Shannon-Weaver (1949) formula- $H = -\sum Pi \ln Pi$.

Where, Pi = Ni/N represents the proportion of species in the community,
Ni = number of individuals of a species i, N = total number of individuals.

Results and Discussion

The physico-chemical complexes of different sampling stations are appended in Table 1. The water quality analysis of Bhadra river showed that Station I was unpolluted and station II was comparatively less polluted as compared to Stations III and IV. Stations III and IV were found to be highly polluted because of influx of industrial effluents, sewage and domestic wastes. Station V, also receiving sewage, had lesser pollution load compared to Stations III and IV. The likely pollutants in the river are lignin compounds, cellulose, chloralkali, dyes, fillers, heavy metals and other organic compounds from pulp and paper, iron and steel industries and domestic wastewater.

In Bhadra river, 45 species of phytoplankton have been identified and station wise distribution has been given in Table 2. Based on the percentage composition, the algae belonging to Chlorophyceae (40%) were dominant followed by Bacillariophyceae (29.49%), Cyanophyceae (15.50%), Euglenophyceae (10.0%) and Chrysophyceae (5.01%) at Station I. At Station II also the Chlorophyceae (36%) were dominant followed

Table - 1: Physico-chemical parameters (Mean ± SD) of Bhadra river water among the studied stations (values in the parenthesis represent the range of the respective parameter)

Parameters	S I	S II	S III	S IV	S V
Water temp.	24.62 ± 1.097 (23 – 26.5)	26.26 ± 1.640 (24 – 29.5)	27.06 ± 1.499 (24.5 – 30)	27.16 ± 1.314 (25 – 30.5)	27.32 ± 1.610 (25 – 31)
pH	7.25 ± 0.302 (6.8 – 8)	7.12 ± 0.159 (6.8 – 7.4)	7.08 ± 0.120 (6.8 – 7.2)	7.18 ± 0.167 (6.9 – 7.5)	7.22 ± 0.190 (6.9 – 7.5)
Electrical conductivity	67.49 ± 14.520 (36 – 95.6)	186.89 ± 77.502 (91.2 – 357)	201.94 ± 79.001 (98.5 – 365)	176.11 ± 61.052 (99.8 – 290)	131.68 ± 47.348 (65 – 200)
Dissolved oxygen	6.26 ± 0.773 (4.5 – 7.4)	4.21 ± 1.507 (1.1 – 6.6)	4.13 ± 1.570 (1.1 – 6.5)	5.80 ± 0.751 (3.8 – 7.1)	5.98 ± 0.759 (4 – 7)
Chloride	12.30 ± 3.744 (6.2 – 18.01)	32.27 ± 14.506 (9 – 55)	40.85 ± 16.679 (14.8 – 68)	33.44 ± 15.211 (12 – 60.2)	22.04 ± 13.137 (7.25 – 58)
Calcium	6.49 ± 2.160 (4.05 – 13)	17.62 ± 8.155 (6 – 32)	23.74 ± 11.817 (7.75 – 46)	19.69 ± 9.151 (8 – 35)	13.80 ± 6.612 (5 – 30)
Total hardness	28.98 ± 6.850 (20 – 44)	68.45 ± 25.100 (31.5 – 110.6)	76.65 ± 23.704 (46 – 115)	72.50 ± 22.218 (37.5 – 110.6)	48.59 ± 18.224 (24 – 80)
Magnesium	4.69 ± 1.524 (3 – 9.08)	13.10 ± 6.358 (4 – 23.15)	15.92 ± 8.314 (6.2 – 34)	15.18 ± 7.958 (5 – 28)	9.52 ± 6.022 (2.89 – 24.3)
Total alkalinity	86.53 ± 14.924 (68 – 112)	81.79 ± 15.622 (48 – 110)	77.26 ± 16.625 (46 – 100)	80.38 ± 18.176 (48 – 102)	85.43 ± 18.317 (49 – 110)
BOD	1.88 ± 0.445 (1.2 – 2.8)	4.01 ± 1.957 (2.2 – 8.7)	3.84 ± 2.074 (1.6 – 8.8)	2.46 ± 0.744 (1.2 – 3.7)	2.19 ± 0.713 (1.2 – 4.1)
COD	16.53 ± 5.980 (8 – 26)	39.29 ± 27.984 (12 – 136)	45.00 ± 61.822 (8 – 280)	40.35 ± 57.022 (15 – 260)	34.53 ± 40.710 (8 – 190)
Phosphate	0.001 ± 0.001 (0.001– 0.006)	0.45 ± 0.312 (0.1 – 1)	0.53 ± 0.282 (0.28 – 1.2)	0.43 ± 0.237 (0.15 – 0.86)	0.34 ± 0.223 (0.1 – 0.9)
Sodium	2.70 ± 0.251 (2.18 – 3.15)	7.46 ± 0.437 (6.8 – 8.2)	7.25 ± 0.801 (6.5 – 9.6)	5.70 ± 1.261 (4.24 – 8.2)	6.46 ± 1.111 (5 – 9.15)
Potassium	2.37 ± 0.263 (2 – 2.92)	5.96 ± 0.733 (4.6 – 7.4)	7.88 ± 1.764 (4.6 – 9.97)	6.12 ± 1.423 (3.85 – 9.6)	6.51 ± 1.521 (3.9 – 10.5)

All the parameters are in mgl^{-1} except temperature (°C), electrical conductivity ($\mu mhoscm^{-1}$)

by Bacillariophyceae (25%), Cyanophyceae (21%), Euglenophyceae (15.01%) and Chrysophyceae (2.99%). Whereas, at Station III Cyanophyceae (32.35%) were abundant followed by Bacillariophyceae (25.70%), Chlorophyceae (24.99%) and Euglenophyceae (16.95%). At Station IV, phytoplankton belonging to Cyanophyceae (33%) were dominant followed by Euglenophyceae (24%), Chlorophyceae (22%) and at Station V, Chlorophyceae (50.26%) were dominant followed by Bacillariophyceae (18.09%), Cyanophyceae (16.0%) and Euglenophyceae (15.74%). Evidently in polluted zones, percentage of Cyanophyceae and Euglenophyceae was higher when compared to Chlorophyceae and Bacillariophyceae. The present observations are in conformity with earlier finding (Kiran *et al.,* 2006).

A number of workers have reported many algal species as indicators of water quality (Naik *et al.,* 2005; Nandan and Aher, 2005; Zargar and Ghosh, 2006). Zargar and Ghosh (2006) in a study on Kadra reserviour of Karnataka listed several algal forms belonging to Chlorophyceae, Cyanophyceae, Euglenophyceae and Bacillariophyceae as indicators of water pollution. The Bhadra river is subjected to acute pollution due to addition of industrial effluents, fertilizers from agricultural lands and domestic sewage. Progressive enrichment of water with nutrients leads to mass

Table - 2: Occurrence of different classes of phytoplankton in Bhadra river

Phytoplankton	S I	S II	S III	S IV	S V
Chlorophyceae					
Spirogyra sp	+	-	-	+	+
Ulothrix sp	+	-	-	-	-
Zygnema sp	+	-	-	-	-
Microspora sp	-	-	+	+	+
Cosmarium moniliforme	+	+	-	-	+
Closterium lunula	-	+	-	-	-
Mougeotia sp	-	-	-	-	+
Chaetophora sp	-	-	+	+	-
Scenedesmus quadricauda	-	-	+	-	+
Gonatozygon sp	-	-	-	+	-
Cosmarium reniform	-	-	-	-	+
C.constactum	-	-	-	-	+
C.tumidum	+	-	-	-	+
Pachycladon sp	-	-	-	-	+
Staurastrum sebaldi	-	-	-	-	+
Tetraedon sp	+	-	-	-	+
Selenastrum gracile	-	-	+	-	-
Sirogonium sp	-	-	-	+	-
Ankistrodesmus falcatus	-	-	-	+	+
Bacillariophyceae					
Melosira granulata	+	-	+	+	+
Synedra ulna	-	+	+	+	+
Amphora cofformis	+	-	-	+	+
Cymbella tumida	+	+	-	-	+
Gomphonema sp	+	+	+	+	+
Navicula cryptocephala	+	-	-	-	+
Navicula palea	-	-	-	-	+
Fragillaria sp	+	+	-	-	-
Pinnularia major	-	-	+	-	-
Nitzschia sp	+	-	-	-	-
Surirella sp	-	+	-	-	-
Tabellaria sp	-	+	-	-	-
Gyrosigma attenuatum	+	-	-	-	-
Cyclotella meneghniana	-	+	+	+	+
Navicula sp	-	+	+	+	+
Cocconeis placentula	-	+	-	-	+
Cyanophyceae					
Ocillatoria limosa	+	+	+	-	-
Phormidium sp	+	-	-	-	-
Anabaena sp	-	-	-	+	-
Microcystis aeruginosa	-	-	-	+	-
Arthrospira sp	-	-	-	+	-
Nostoc sp	-	-	+	-	-
Aphanocapsa sp	-	-	-	+	-
Euglenophyceae					
Euglena limnophylla	-	-	-	+	+
Phacus nordstedti	-	-	+	+	-
Chry sophyceae					
Dinobryon sp	+	+	-	-	-

+ = Present - = Absent

production of algae, in turn this increases productivity and other undesirable biotic changes (Ahmad, 1996).

Nandan and Aher (2005) has showed the algal genera, *Euglena*, *Oscillatoria, Scenedesmus, Navicula, Nitzschia* and *Microcystis* which are the species found in organically polluted waters. Similar genera were also recorded in the present study. The epilethic and epiphytic algae are excellent indicators of water pollution (Round, 1965). In this study, occurrence of *Phormidium, Oscillatoria* and *Ulothrix* as epilethic algae and *Gomphonema* as epiphytic were recorded in the present study. The algae like *Microcystis aeruginosa* was used as the best single indicator of pollution and it was associated with the highest degree of civic pollution (Nandan and Aher, 2005). In the present study, similar phytoplankton was also recorded in Station IV.

In the current study, the occurrence of *Oscillatoria* was indicating pollutants of biological origin which agreed with the observations of Gadag *et al.* (2005). The pollution level was observed to increase in the down stream stretch of Bhadra river from Station I onwards as it was confirmed by using Shannon-Weaver index (Table 3). The abundance of *Navicula, Oscillatoria* and *Euglena* were maximum at Station IV and V indicating the highest degree of organic pollution. Unpolluted Station (S I) is characterized by abundance of green algal flora followed by Cyanophyceae and flagellates, as it was supported by earlier workers (Verma and Mohanty, 1994; More and Nandan, 2000; Nandan and Aher, 2005; Tas and Gonulal, 2007).

Phytoplankton count also registered higher value during non-rainy months. This result gains support from the similar observations of Kamat (2000) and Singh *et al.* (2002). It is reported that excessive growth of certain algal genera, *viz*., *Scenedesmus, Anabaena, Oscillatoria* and *Melosira* indicate nutrient enrichment of aquatic bodies (Kumar, 1990; Zargar and Ghosh, 2006). Although these plankters were present in the Bhadra river, their density varied.

The seasonal variation of species diversity index in 5 studied sectors is given in Table 3. The index is based on the principle that in clean water, the species diversity is high while, in polluted water the diversity becomes low. The Shannon-Weaver diversity index proposed as diversity index greater than (>4) is clean water; between 3-4 is mildly polluted water; between 2-3 is moderately polluted water and less than 2(<2) is heavily polluted water. The index computed in the present analysis showed that phytoplankton species diversity ranged from 3.58-4.07 in site I representing clean water (higher the Shannon-Weaver index lesser the degree of pollution), 3.10-3.72 in Station II indicating mildly polluted water; 1.64-2.25 in site III indication heavily polluted water, 2.54-2.95 Station IV indicating moderately polluted water and 3.09-3.23 in Station V showing mildly polluted nature of the river.

Table - 3: Seasonal variation of species diversity index (Shannon and Weaver, 1949) in different sectors of the Bhadra river

Year	Season	S I	S II	S III	S IV	S V
2004	Pre-monsoon	4.05	3.1	1.78	2.75	3.15
	Post-monsoon	4.07	3.72	2.2	2.78	3.11
	Monsoon	3.58	3.20	1.91	2.95	3.09
2005	Pre-monsoon	3.96	3.21	2.25	2.54	3.10
	Post-monsoon	3.94	3.62	1.64	2.9	3.20
	Monsoon	3.89	3.63	1.88	2.88	3.23

Index: > 4 clean water, 3–4 = Mildly polluted water, 2–3 = Moderately polluted water, < 2 = Heavily polluted water

In the present investigation, based on physico-chemical parameters, pollution load was higher at S II to S IV Station. Hence, Shannon-Weaver index values observed to be lower (Table 3) in Station II, III and IV. This index was maximum at Station I since the water is unpolluted due to absence of human anthropogenic activities. Comparatively, Station V is moderately polluted when compared to Station III and IV because of self-purification of river.

This study revealed that the water quality parameters, such as temperature, pH and phosphate play a decisive role in altering the phytoplankton distribution. Human anthropogenic activities are the main causative agents in the increase of nutrients (phosphate, chloride and calcium) level in the river that supports the growth of *Microcystis aeruginosa* whose presence in water will render it unfit for drinking.

It is summarized from the results that river Bhadra which is one of the most productive riverine system of Karnataka is polluted at downstream stations. The results show that the improvement of diversity index from Station IV onwards up to the Station V, was due to the decline in pollution level. This observation agreed with the report of Khan (1991) in respect of diatom community in tropical river, polluted by urban and industrial wastes. The findings of this investigation clearly revealed that in respect of industrial effluent pollution, phytoplankton perhaps were more tolerant to pollution. The study emphasizes the necessity of using phytoplankton as effective and appropriate method of biomonitoring for evaluation of river water quality.

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