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Variation in phytoplankton diversity and its relation with water quality index of the Budhi Gandak River at Khagaria Bihar India

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Abstract
The phytoplankton diversity of river Budhi Gandak of Khagaria (Bihar) in relation to certain physico-chemical factors was studied. A total of 81 genera of phytoplankton, belonging to four groups – chlorophyceae, cyanophyceae, bacillariophycae and euglenophyceae were found in the river water. The phytoplankton density in different seasons was in order of winter > summer > monsoon. The species belonging to bacillariophyceae were dominant. A significant positive correlation was established in between total density of phytoplankton and various physico- chemical factors such as TDS and conductivity. The species diversity of phytoplankton ($\bar{H}$) varied from 0.3 to 2.8, the relative abundance of algal species indicate *Navicula subtilissima*, *Melosira granulata* and *Synedra ulna* as indicator of the pollution of the river. On the basis Shannon Weiner index river water was moderate to heavily polluted condition. WQI were in the range of poor category in monsoon season almost at all the three sites.

Keywords: phytoplankton, species diversity, water quality index

1. Introduction
Phytoplanktons are important component of ecosystem, which respond to ecosystem alterations rather rapidly. They are photosynthetic prokaryotes that float, drift, or weakly swim in the water column and major contributors of biomass and primary productivity in water ecosystems and form the basic link in the food chain of all aquatic animals. Therefore, quality and quantity of consumers of food chain depends upon qualitative quantity of phytoplanktons. Some of the species of phytoplankton are important to access the health of water body. The biological analysis of River water, especially the phytoplankton analysis will describe clearly about the pollutant materials impact on the aquatic life and a decrease in biological diversity not only at the time of sampling, but also the condition at a previous time point. Under this work the influence of physico-chemical parameters of water on phytoplankton occurrence and their diversity characteristics were studied. It is also possible to use these minute organisms as an indicator in biomonitoring system for determining the quality of water body using Shannon-Weiner diversity index [1]. Budhi Gandak River is one of the major and significant tributary of the Ganga in North Bihar. The origin of Budhi Gandak is at the West Champaran near Ramnagar and Bagaha. It is a rain fed river and flows through West Champaran, East Champaran, Muzaffarpur, Samastipur, Begusarai and flows into the Ganges near Khagaria (12 km upstream of Bariarpur in Munger district). The present study is an attempt to characterize quality of river water on the basis of species diversity index ($\bar{H}$) of algal diversity and water quality index (WQI) of physico-chemical data. The environmental status of any river anywhere indicates the environmental status of that region in the world. Therefore, the objective of the present study was to find out ecological status of River Budhi Gandak and some clues for river water management in future. Aquatic quality assessment is the overall process of evaluation of the physical, chemical and biological nature of the water in relation to human health and health of the ecosystem. In India many researchers have worked on the limnological study of the River Budhi Gandak [2, 3, 4, 5, 6].

2. Materials and methods
2.1 Study Area
Budhi Gandak River flows by the side of the Khagaria town. Three sampling sites were selected for the physico-chemical and biological (phytoplankton) assessment of water quality of Budhi Gandak River at Khagaria: Site I (Vidyadhar Ghat: 25°29'41.9" N 86°27'49.9" E) in upstream, Site II (Cremation Ghat: 25°30'04.4" N 86°28'55.3" E) 3 km downstream of site I, and Site III (Sansarpur Ghat: 25°30'19.8" N 86°30'33.2" E) 3 km downstream of Site II. Northern side of the river has more anthropogenic activities. So, water samples were collected from northern bank of the river in the present study (April 2012 to March 2013). Sterilized and clean plastic bottles of 2 liter capacity were used for the collection of water samples. Water quality parameters were analyzed following Standards methods [7].

2.2 Phytoplankton collection and identification
Water containing natural population of algae were collected in glass bottles from the surface by using plankton net (45 mm pore size). 125 mL of the samples were preserved with 5 mL of 4% formaldehyde in the field for microscopic examination. The collections were deposited in the Environmental Biology Research Laboratory of T.M. Bhagalpur University, Bhagalpur. Camera Lucida drawings were made under appropriate magnification. Identifications were made following [8, 9, 10, 11, 12, 13, 14, 15]. Phytoplankton diversity was deciphered by Shannon formula as follows Species diversity,

$$(\bar{H}) = -\sum\left(\frac{ni}{N}\right)\log\left(\frac{ni}{N}\right) \text{ Or } -\sum PilogPi$$

Where,
Pi= Importance Probability for each species i.e. ni/N,
Ni= Importance Value for each species i.e. number of individuals in each sample and N= Total of importance values i.e. number of individuals.
The WQI of river water has been calculated considering relative weights of 9 water quality parameters [16, 17].

3. Results and discussion

3.1 Physico-chemical Assessment

Temperature was higher in monsoon, moderate in summer and lower in winter. It varied from 18°C to 31.2°C with maximum (31.2°C) during monsoon at site III and minimum (18°C) during winter at site I. High temperature in monsoon might be due mixing of town wastes in river from catchment area during rainfall. The similar results were also observed [18]. The pH of the water in all studied months was within the WHO Standard of 6.85-8.5. The pH was high at all the three sites during winter followed by summer and monsoon [19]. Turbidity varied from 8.7-58.37 NTU. It was higher (32.42-58.37 NTU) during rainy season at all the three sites followed by summer and winter. Higher turbidity in river water might be due to growth of phytoplankton, human activities such as construction, and agriculture, which lead to high sediment levels due to storm water runoff. The observed TDS values were lower (183.27mg/L) at site III during monsoon and higher at site I during summer (247.1mg/L). Conductivity values were minimum (363.8mg/L) at site III during rainy season and maximum (511.8mg/L) at site I during summer. Total hardness values were higher during winter, moderate during monsoon and lower during summer at all the three sites. Total hardness values varied from 187.5 mg/L- 246 mg/L. Similar observation was also found [20]. Dissolved oxygen is an important limnological parameter indicating level of water quality and organic pollution in the water body. It was higher (8.01-8.71 mg/L) during winter, moderate (6.71- 7.17mg/L) during summer and lower (4.9-6.30 mg/L) during monsoon at all the three sites. The result was very similar to results [21]. Free CO_2 values were found to be maximum (53.5-76.5 mg/L) during summer in water samples of almost all studied sites. The higher value of CO_2 in summer months might be due to decomposition of organic matter by microbes in the bottom. Total alkalinity of river water was minimum (33.6 mg/L) at site II during monsoon and maximum (51.7 mg/L) at site III during winter. The higher values of alkalinity during winter indicate greater ability of the river water to support algal growth and other aquatic life in this season. High phosphates value (0.071 mg/L) was observed during monsoon at site III and minimum (0.045 mg/ L) at site I during summer. Nitrate value was higher (0.055- 0.065 mg/L) at all the three sites during summer and lower (0.037- 0.038 mg/L) during winter; monsoon values were almost similar to winter values. Chloride value at site I (8.96 mg/ L) during monsoon was higher than other sites and also higher than that of winter values. WQI results indicated river water in good category (63.45- 89.99) at all the three sites in summer and winter and at site II in monsoon, and in poor category (105.55- 122.03) in monsoon at sites I and III (fig 2). Therefore, river water is not suitable for human consumption in monsoon season. It might be due to mixing of town wastes and agricultural wastes in the river due to overflowing of river during rainy season.

3.2 Biological (Phytoplankton Assessment)

Four algal groups were observed as Chlorophyceae (green algae), Bacillariophyceae (diatoms), Cyanophyceae (blue green algae) and Euglenophyceae. Rivers apparently favour species of diatoms and the same has been documented in the present study. A total of 81 algal species (Table 1) belonging to 48 genera under 21 orders were recorded at 3-sampling stations of the river during the study period, represented by four major groups, Bacillariophyceae (38 species), Chlorophyceae (25 species), Cyanophyceae (14 species) and Euglenophyceae (4 species). Bacillariophyceae (diatoms) were dominant followed by Chlorophyceae, Cyanophyceae and Euglenophyceae. Euglenophytes were poor in distribution.
Maximum density (1173 Unit/L) of phytoplankton was observed at Site III and minimum (31 Unit/L) at Site II. Maximum density of phytoplankton was recorded during winter and summer months in Budhi Gandak River. It was evident that winter months were most productive whereas the monsoon months were least, which was mainly due to dilution of phytoplankton cell density during periods of high seasonal precipitation.
In the present study, a significant positive correlation was established in between total density of phytoplankton and various physico- chemical factors such as TDS and conductivity at 5% level and negative correlation with turbidity and phosphate at 5% level (Table 2). During study period Bacillariophyceae contributed 45.8% to 100% of the total phytoplankton density at site I. At site II, maximum and minimum percentage compositions were 100% and 40.9% respectively. At site III, higher and lower compositions were 100% and 40.9% respectively. The Bacillariophycean density fluctuated from 62 U/L to 679 U/L, 19 U/L to 519 U/L and 43 U/L to 957 U/L at sites I, II and III respectively. A total of 38 species of Bacillariophyceae were recorded from Budhi Gandak River. The recorded species included *Epithemia zebra* and *Rhopaldia gibba* belonging to order Rhopalodiales*; Caloneis silicula, Navicula grimmi, N. minima, N. mutica, N. subtilissima, Gyrosigma acuminatum, G. kuetzingii, Pinnularia brebsonni* and *Stauroneis parvula* of order Naviculales; *Cymatopleura solea* and *Surirella subsalsa* of order Surirellales; *Nitzschia obtusa, N. acicularis, N. irremissa* and *N. vasnii* belonging to order Bacillariales; *Fragillaria leptostauron, F. capucina, Synedra acus* and *S. ulna* of order Fragilariales and *Gomphonema acuminatum, G. balatoneis, G. gracile, G. lanceolatum, G. parvulum, G. sphaerophorum, G. subapicatum, Cymbella bharatensis, C. pussila, C. tumida, Anomoeoneis exilis* and *Rhoicosphenia sp.* belonging to order Cymbellales. Order Eunotiales (*Eunotia major*), Melosirales (*Melosira granulata*) and Mastogloiales (*Achnanthes lapponica*) were represented by only one species each. Thalassiophysales comprised two species, *Amphora ovalis* and *Amphora normanii*. The enhanced growth of diatoms showed significant positive correlation with TDS, conductivity and TH and negative correlation with water temperature at 5% level.
Chlorophyceae were second in position with regard to number of species after Bacillariophyceae. A total of 25 species were

recorded from river during study period and they contributed in the range of 4.1% at site I to 40.4% at site II of the total phytoplankton density. The density of Chlorophyceae varied from 19 U/L to 333 U/L, 6 U/L to 86 U/L and 6 U/L to 154 U/L at Sites I, II and III respectively,

During the study period, the recorded Chlorophycean taxa included *Spirogyra hyalina, S. arta, S. rivularis, S. teodersci, Zygnema gangeticum* and *Zygogonium indicum* belonging to order *Zygnematales*, and *Desmidium baileyi, Onychonema filiformae, Cosmarium punculatum, C. venustrum* and *Closterium kuetzingii* belonging to order Desmidiales. Oedogoniales was represented by *Oedogonium gracilis, O. pisanum, Cladophora sp., Chlorella conglomerate, C. vulgaris, Pectodictyon cubicum, Scendesmus armatais, S. obliqus, S. quadricauda, Pediastrum duplex, P. ovatum, Oocystis incrassata* and order Chlorococcales was represented by *Actinastrum hantzschii*. Volvocales was mainly represented by *Volvox aureus*.

Chlorophyceae population had positive correlation with TDS, conductivity, HCO_3, total akalinity and chloride and negative correlation with phosphate, values being significant at 5% level.

Cyanophyceae were third after Bacillariophyceae and Chlorophyceae in term of abundance. A total of 14 species of Cyanophyceae was recorded in Budhi Gandak River in the present study. Cyanophytes contributed 1.7% to 21.2%, 2.1% to 26.9% and 3.7% to 36% at sites I, II & III respectively, its density varied from 6 U/L to 117 U/L, 12 U/L to 43 U/L and 31 U/L to 74 U/L at sites I, II and III respectively, the density was observed maximum in summer months and minimum in winter months.

The members recorded were *Spirulina major* and *S. subtilissima* belonging to order Spirulinales; *Rivularia hansgiri, Nostoc calcicola, Nostoc muscorum, Anabaena circinalis* and *Calothrix pusca* to order Nostocales; *Gloetrichia raciborskii, Lyngbya martesiana, Oscillatoria curviceps, O. limosa* and *O. princeps* to order Oscillatoriales, *Polycystis flos-aquae* to order Chroococcales, and *Merismopaedia elegans* to order Synechoccales.

It was also positively correlated with chloride at 5% significance level

In the present study, percentage composition of Euglenophyceae varied from 1.7% to 5.6%, 4.4% to 19.4% and 1.6% to 20.3% at sites I, II and III respectively. Its density ranged from 6 U/L to 49 U/L, 6 U/L to 31 U/L and 12 U/L to 31 U/L at sites I, II and III respectively.

Recorded euglenophycean members were *Euglena acus, E. oxyuris, E.viridis, Phacus orbicularis* belonged to order Euglenales. Euglenophyceae density was positively correlated with conductivity, nitrate and chloride at 5% level of significance.

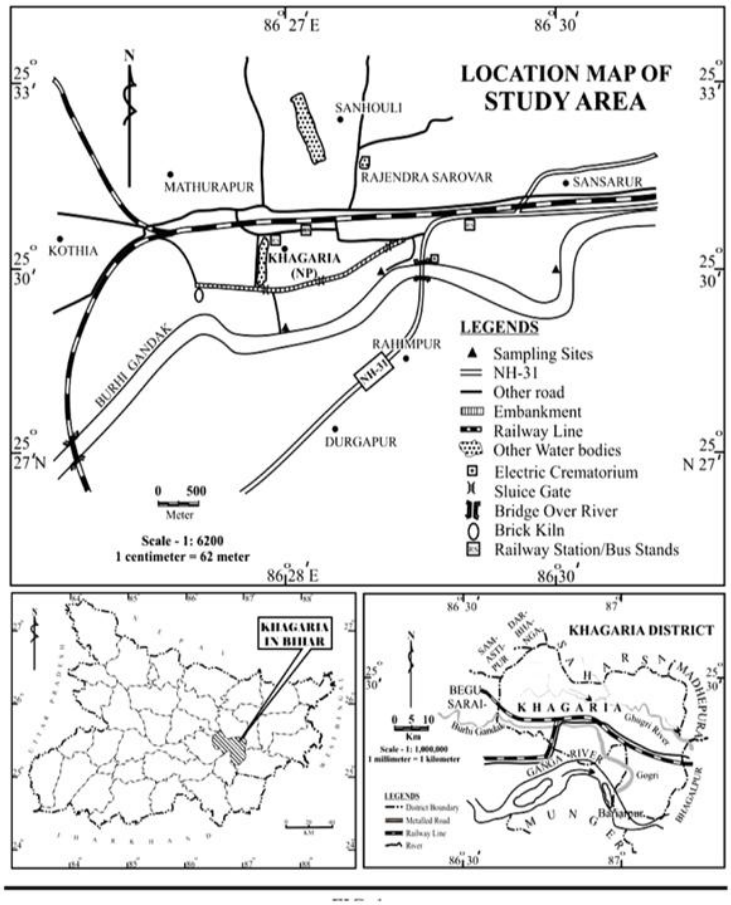

Fig 1: Location Map of Study Area (River Budhi Gandak near Khagaria)

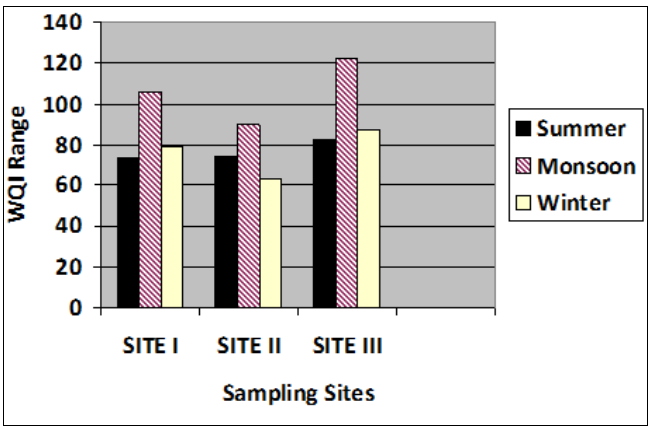

Fig 2: WQI Graph Sheet

3.3 Species diversity and species richness of phytoplankton (Shannon-Weiner Index)

Shannon-Weiner index of species for phytoplanktonic algal forms of River Budhi Gandak, its evenness and richness computed for 3-research sites (Table 3). Species diversity values varied from 0.3 - 2.8, evenness varied from 0.4 - 1.0 and richness ranged from 1.6 - 28.8. A general picture of monthly species diversity variations seemed to be increasing from winter to summer months and the monsoon values were comparatively lower to summer and winter values, probably because of the presence of lower number of species during rains. Both species richness and species evenness showed relatively higher values during summers and winters. The present study illustrates species diversity varying in a range of 0.3 – 2.8 indicating instability of the River Budhi Gandak and its tendency for mesotrophic to eutrophic nature.

In a clean water community diversity is high while in the polluted waters diversity is low. Species diversity values suggest that all the 3-sites under investigation fall under moderately polluted zone in summer and winter months and heavily polluted in monsoon months as per the scale [22]. However, according to scale [23], site I and II of the river had light polluted condition in summer and winter months and moderate polluted condition in monsoon, whereas site III had moderate pollution condition in summer and monsoon months and light polluted in winter months during present study.

Navicula subtilissima (49 individuals) at site I, *Melosira granulata* (21 individuals) at site II and *Synedra ulna* (97 individuals) at site III were dominant species in the present study, their relative abundance being 26.2, 75 and 53 respectively.

The results on the relative abundance of algal species indicate *Navicula subtilissima*, *Melosira granulata* and *Synedra ulna* as indicator of the pollution of River Budhi Gandak. Thus the present study indicates that species diversity of phytoplankton may be used as a biological tool for monitoring the pollutional load of the river water.

Table 1: Phytoplankton species in river Budhi Gandak (April, 2012 – March, 2013)

Number	Phytoplanktons	SITE I	SITE II	SITE III
	CHLROPHYCEAE			
1.	*Actinastrum hantzschi* Lagerheim	-	+	+
2.	*Oedogonium gracilis* (Wittr.) Taffany	+	+	+
3.	*Oedogonium pisanum* Wittrock.	+	+	+
4.	*Chlorella vulgaris* Beijerinck	+	+	-
5.	*Chlorella conglomerata* Artari.	-	+	-
6.	*Cosmarium venustrum* Breb.	-	+	+
7.	*Cosmarium punculatum* (Nordst.) Borgesen.	+	-	+
8.	*Oocystis incrassata* W.et.G. S. West.	+	-	-
9.	*Pediastrum duplex* Meyen var. *genuinum* (A.Braun)	-	+	-
10.	*Pediastrum ovatum var. simplex* (Ehr) A. Braun	-	+	-
11.	*Scenedesmus quadricauda VAR.longspina* (CHOD.)	+	-	-
12.	*Scendesmus armatais* (Chod.)G.M. Smith	-	-	+
13.	*Scendesmus obliqus* (Turp.) Kuetz.	+	+	-
14.	*Spirogyra hyalina* Cleve.	+	+	+
15.	*Spirogyra teodoresci* Transeau.	+	+	+
16.	*Spirogyra arta* Jao	+	+	+
17.	*S. rivularis* Hassall	+	-	+
18.	*Volvox aureus* Ehr. (Smith)	+	+	-
19.	*Zygnema gangeticum* Rao.	+	+	+
20.	*Zygogonoium indicum* (Randhawa) Transeau.	+	-	-
21.	*Onychonema filiformae* (Ehr) Roy and Biss	-	-	+
22.	*Desmidium baileyi* (Ralfs) Nordst Var. indicum.	+	-	-
23.	*Cladophora kuetzingianum* Grun.	+	-	-
24.	*Pectodictyon cubicum* Traft.	-	+	-
25.	*Closterium kuetzingii* Breb	+	-	-
	BACILLARIOPHYCEAE			
1.	*Epithemia zebra* (Ehr)Kuetz.	+	-	-
2.	*Eunotia major* (W. Smith) Rabh.	+	-	-
3.	*Caloneis silicula* (Ehr) Cleve.	+	+	+
4.	*Cymatopleura solea* (Breb.) W. Smith.	+	+	+
5.	*Navicula grimmi* Krasske.	+	+	+
6.	*Navicula subtilissima* Cl.	+	+	+

7.	*Navicula mutica* Kuetz. v. producta Grun.	+	-	+
8.	*Navicula minima Grun. V. atmoides* (Grun.)Cleve	-	-	+
9.	*Nitzschia obtusa* N.Smith V. Scapelliformis. Grun. F. parva Hustedt	+	+	+
10.	*Nitzschia acicularis* W. Sm.	+	-	+
11.	*Nitzschia irremissa* Cholonky	+	+	+
12.	*Nitzschia vasnii Gandhi.*	-	+	-
13.	*Rhopaldia gibba* (Ehr.) O. Muell.	+	+	+
14.	*Synedra acus* Kuetz.	+	+	+
15.	*Synedra ulna v. biceps* (Kutz.) Schonfeldt.	+	-	+
16.	*Gomphonema gracile* Ehr. f turris(Ehr.) Hustedt.	+	-	+
17.	*Gomphonema parvulum* (Kuetz.) Grun.	+	+	+
18.	*Gomphonema subapicatum* Fritsch et. Rich.	+	+	+
19.	*Gomphonema lanceolatum Ehr.*	+	-	+
20.	*Gomphonema balatoneis (*Pant.) Gandhi	+	-	-
21.	*Gomphonema sphaerophorum Ehr.*	-	+	+
22.	*Gomphonema acuminatum Ehr. v turris Her*	+	-	+
23.	*Melosira granulata* (Ehr)Ralfs V. angustissima O. Muell.	+	-	+
24.	*Gyrosigma acuminatum* (Kuetz.) Rabh.	+	+	+
25.	*Gyrosigma kuetzingii* (Grun.) Cleve.	+	-	+
26.	*Cymbella pussila Grun.*	+	-	+
27.	*Cymbella tumida (Breb.) V. H.*	+	-	+
28.	*Cymbella bharatensis* sp. nov.	+	-	+
29.	*Pinnularia brebsonni(Kuetz.)* Cleve.	+	-	+
30.	*Anomoeneis exilis (Kuetz., Grun.)* Cleve.	+	-	+
31.	*Fragillaria leptostauron (Ehr)*Hustedt	+	-	+
32.	*Fragillaria capuciana Desmaziers* var. courtailensis krish.	+	-	+
33.	*Achnanthes lapponica* (Hustedt)	+	-	-
34.	*Amphora ovalis* Kuetz. v. pediculus Kuetz.	+	+	+
35.	*Amphora normanii* Rabh.	+	+	+
36.	*Stauroneis parvula* Grun. V. prominula Grun.	+	-	+
37.	*Rhoicosphenia sp.*	+	-	-
38.	*Surirella subsalsa W. Smith.*	-	-	+
	CYANOPHYCEAE			
1.	*Spirulina major* Kuetz.	+	+	+
2.	*Spirulina subtilissima Kuetz. ex Gomont.*	-	-	+
3.	*Rivularia hansgiri* Schmidle.	+	+	-
4.	*Gloetrichia raciborskii* Woloszynska.	+	-	-
5.	*Nostoc calcicola* Breb.ex Born. Et Flah.	+	+	+
6.	*Notoc muscorum* Ag. ex Bornh. Et Flah.	+	+	-
7.	*Lyngbya martensiana* Menegh. Ex. Gomont	+	+	+
8.	*Anabaena circinalis* (Kuetz.) Rab.	+	+	-
9.	*Merismopaedia elegans*	+	+	-
10.	*Oscillatoria limosa* Ag.ex Gomont	+	-	+
11.	*O. princeps*	-	-	+
12.	*Oscillatoria curviceps* Ag. ex Gomont.	-	+	-
13.	*Polycystis flos-aquae* (Wittr.) Kirchin.	+	+	-
14.	*Calothrix pusca* (Kuetz.)	-	-	+
	EUGLENOPHYCEAE			
1.	*Euglena acus* Ehr	+	+	+
2.	*Euglena oxyuris* Schmarda var. minor Deft.	+	+	+
3.	*Euglena viridis* Ehr.	+	-	-
4.	*Phacus orbicularis* Hubner.	+	+	+

Table 2: Correlation between physico-chemical variables and phytoplankton density of River Budhi Gandak (April, 2012 - March, 2013)

	WT	**pH**	**Depth**	**Turbidity**	**TDS**	**Cond.**	**TH**	**DO_2**	**Free CO_2**	**HCO_3^-**	**TA**	**PO_4-P**	**NO_3-N**	**Cl^-**	**WQI**
Total Density	-0.33	-0.27	-0.10	-0.47*	0.59*	0.55*	0.41	0.17	0.30	0.68#	0.68#	-0.50*	0.28	0.34	-0.39
Chlorophyceae	-0.02	-0.30	-0.16	-0.36	0.49*	0.52*	0.22	-0.08	0.29	0.47*	0.47*	-0.49*	0.45	0.50*	-0.34
Bacillariophyceae	-0.50*	-0.21	-0.02	-0.45	0.57*	0.48*	0.48*	0.32	0.26	0.71$	0.71$	-0.42	0.11	0.16	-0.34
Cyanophyceae	0.18	-0.17	-0.39	-0.39	0.34	0.38	0.07	-0.21	0.23	0.30	0.30	-0.43	0.39	0.50*	-0.42
Euglenophyceae	0.18	-0.37	-0.06	-0.26	0.42	0.51*	0.11	-0.15	0.36	0.32	0.32	-0.45	0.57*	0.59*	-0.25

Significant at *5%, #1&and $. 01 level. WT= Water temperature, TDS= Total Dissolved Solids, Cond. = Conductivity, TH= Total Hardness, DO_2= Dissolved Oxygen, Free CO_2= Free CO_2, HCO_3^-= Bicarbonates, TA= Total Alkalinity, PO_4-P= Phosphates, NO_3-N = Nitrates, Cl^-= Chloride, WQI= Water Quality Index.

Table 3: Species Diversity ($\bar{H}$), Evenness (J^1), Richness (d) of Phytoplankton of River Budhi Gandak (April, 2012 – March, 2013)

	Site I			Site II			Site III		
Studied Months	**Species Diversity**	**Evenness**	**Richness**	**Species Diversity**	**Evenness**	**Richness**	**Species Diversity**	**Evenness**	**Richness**
APRIL	2.3	0.8	3.7	2.2	0.9	10.7	1.9	0.9	8.7
MAY	2.6	0.9	3.5	2.4	0.9	12.7	1.4	0.9	4.6
JUNE	2.7	1.0	4.0	1.6	1.0	4.4	1.8	1.0	5.7
JULY	1.4	0.9	4.7	1.3	1.0	3.4	1.0	0.7	3.5
AUG	0.3	0.5	1.6	0.9	0.8	2.6	1.6	1.0	4.6
SEPT	1.4	0.8	5.7	2.0	0.9	9.7	1.1	0.8	3.7
OCT	1.1	0.8	3.7	0.4	0.4	2.7	1.0	0.6	4.7
NOV	0.7	0.7	2.7	0.7	0.7	2.7	0.6	0.5	2.7
DEC	0.6	0.9	1.7	1.2	0.8	3.7	2.4	0.9	16.8
JAN	2.8	0.8	28.8	2.5	0.9	18.8	2.0	0.7	19.8
FEB	2.0	0.7	13.8	1.7	0.9	5.7	2.3	0.9	12.7
MARCH	2.7	0.9	18.8	2.4	1.0	11.7	1.4	0.9	4.6

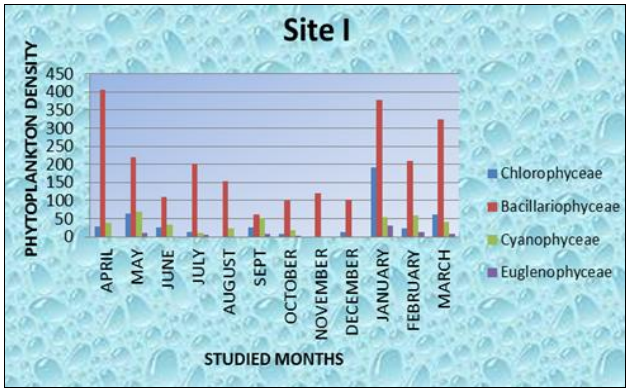

Fig 3: Phytoplankton density of River Budhi Gandak at site I (April, 2012 – March, 2013)

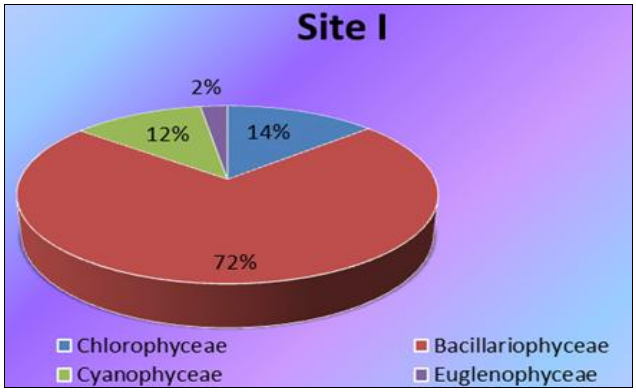

Fig 6: Percentage composition of phytoplankton density of River Budhi Gandak at site I (April, 2012 – March, 2013)

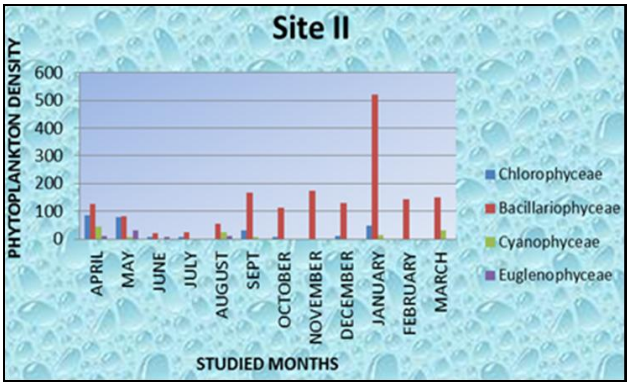

Fig 4: Phytoplankton density of River Budhi Gandak at site II (April, 2012 – March, 2013)

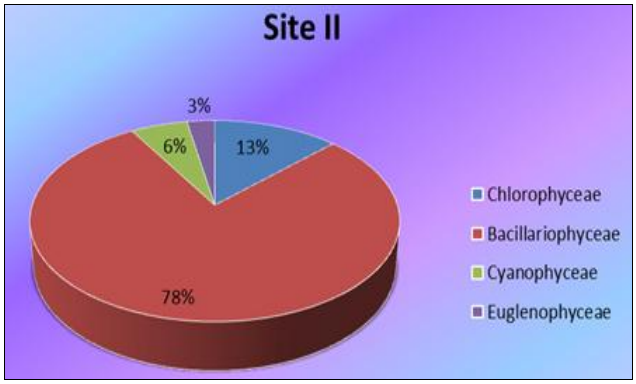

Fig 7: Percentage composition of phytoplankton density of River Budhi Gandak at site II (April, 2012 – March, 2013)

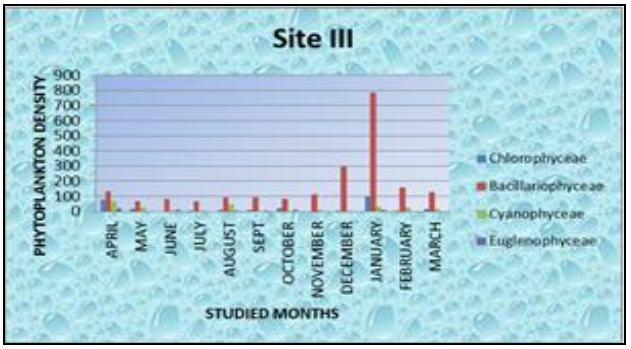

Fig 5: Phytoplankton density of River Budhi Gandak at site III (April, 2012 – March, 2013)

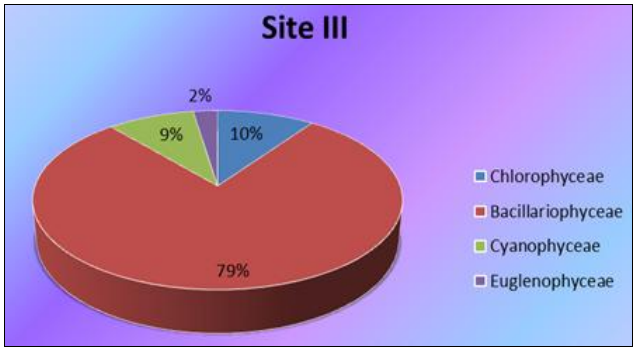

Fig 8: Percentage composition of phytoplankton density of River Budhi Gandak at site III (April, 2012 – March, 2013)

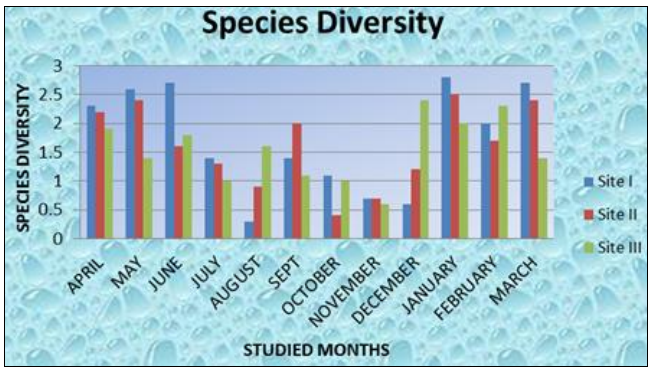

Fig 9: Species Diversity Index of River Budhi Gandak at three sites (April, 2012 - March, 2013)

4. Conclusion

The water quality of the River Budhi Gandak at Khagaria in Bihar has been assessed on the basis of results of analysis of river water samples for important physico-chemical parameters and algal data at three sites (upstream, downstream & one in between two). An attempt has been also made to investigate the impact of anthropogenic activities in the river which affects physico-chemical and biological quality of the river. The water quality analysis results in the present study indicated that most of the physico-chemical parameters investigated were within the WHO limits (1998) and BIS: 10500(2004-2005) for drinking water except that of turbidity which exceeded the permissible limit. WQI results suggested that the river water was in the poor category (105.55- 122.03) at sites I and III during monsoon, and might be classified under good category in winter (63.46) and summer (73.86- 82.45) months at site II.

Species diversity index (H) varied from 0.3 to 2.8, the different species diversity water quality scales suggest river water was in pollution stage in monsoon months. Therefore, results of water quality index and species diversity index on the basis of both physico-chemical and biological (phytoplankton) data respectively suggests the river water was poor and moderate to heavily polluted condition in monsoon months and good and light polluted in summer and winter months. The overall study suggests river water as unsuitable for human consumption during all three seasons. However, the river water is suitable for diverse uses like irrigation, recreation and other domestic uses except drinking. Quality of an aquatic ecosystem is depending on the physico-chemical characteristics of water and also on the biological diversity of the system. Therefore in this context present study will be helpful for water quality management system of various water bodies of interest.

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