Global Journal of Science Frontier Research
Biological Sciences
Volume 12 Issue 5 Version 1.0 Year 2012
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

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GJSFR-C Classification : FOR Code: 060299

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Strictly as per the compliance and regulations of :

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Manoj Kr Saikia[α] & Pooja Lohar[σ]

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I. Introduction

Industrialization is considered as cornerstone of development. It is a yardstick for placing countries in the League of Nations and index of its political stature (FEPA, 1991). It brought about prosperity, comfort, health and wealth of mankind through industrial revolution and rapid utilization of natural resources, but also threatened the ecological security of the globe with consequent damage to ecosystem by generating huge waste and pollutants as by product of industrial development. Every day about two million tons of sewage, industrial wastes and agricultural wastes are discharged in to world's water (UN-WWAP, 2003). It is estimated that industry alone is responsible for dumping of 300-400 million tons of heavy metals, solvents, toxic sludge and other waste into waters each year (UNEP, 2010). A recent survey indicates that about 70% industrial waste in developing countries are dumped untreated into waters where they contaminate the existing water quantities (UN-Water, 2009).Water pollution as global concern (UNEP, 2000) and a threat to aquatic ecosystem has been stated in the Ministerial Declaration of the 2nd World Water Forum (WWF, 2000) summit. In India, almost every river system is now polluted to a considerable extent (Martin, 1998; Mahajan, 1988) due to the release of untreated or partially treated effluents in to natural water bodies. Survey conducted by National Environmental Engineering Research Institute (NEERI), Nagpur, highlighted that nearly 70% of water in India is polluted (Martin, 1998). Thermal and Steel plants are the highest contributors to annual industrial wastewater discharge. Pulp and Paper industry occupy the rank next to steel and thermal, and it is among the 20 high polluting industries (Bajpai and Bajpai, 1997). The Pulp and Paper industries consumed around 905.8 million m^3 of water and discharged around 695.7 million m^3 of waste water annually (NPC, New Delhi, 2006) which indicate the seriousness of the problems caused by this sector.

Natural water maintains a wide variety of aquatic life including fish, bacteria, algae and protozoa, all of which maintain a dynamic equilibrium with the environment. Excessive deposition of chemical nutrients into natural waters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solids (TS), P^H, conductivity etc impairs the water quality as well as endangers aquatic life (Mallin and Cahoon, 2007). They can alter the physico-chemical and biological nature of receiving water body in a number of ways (Sangodoyin, 1991). Pollutants may cause *'Physical Effects' 'Eutrophication' 'Toxicity'* and *Toxicity to* an organism through '*Bioaccumulation*'.

Water system in India is greatly polluted by paper mill effluents. During the past few decades, this activity has experienced a significant boost worldwide, and it is expected to increased by 77% from 1995 to 2020 (OECD, 2001). Pulp and paper mill liberates heavily loaded waste in to surrounding environment (Anonymus, 1999; Baruah and Das, 2001) which are mainly arising out from *pulping* and *bleaching* process. Broad categories of effluents from pulp and paper industry are 8 (eight) types of effluents: *1] Colouring substance, 2] Turbidity and Sediments, 3] Oxygen Consuming substance, 4] Nutrients, 5] Malodorous substances and those affecting taste, 6] Acidity/alkalinity, 7] Chlorate and 8] toxic substances* (Duncan, 1989). The effluents influence environment by imparting large BOD, toxicity and color. The lignosulphonate components of the waste may inhibit the growth of phototrophic plankton, algae and plants by reducing the transmission of sun light in water (Poole et al., 1977). Other ecologically important physical parameters such as *increased conductivity, PH, temperature, high suspended particulate matter,*

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dissolved particulate matter sometimes impair the oxygen balance of the water body and sediments. The excess of *nitrogen (N)* and *phosphorus (P)* nutrients in the effluents may support eutrophication process which might lead to anoxic condition (Poole et al., 1977).

Algae comprise one of the most diverse plant groups and contribute to approximately 50% of global photosynthetic activity and over 70% of the world's biomass (Andersen, 1996). They are considered to be the first group of organisms to appear and colonize on earth 2.5Gaλ (= Years X 109λ) ago and have broad habit range from polar region to tropical coral reef (South and Whittick, 1987). Algae are very sensitive to the environment. Any alteration in the environment leads to the change in algal communities in terms of tolerance, abundance, diversity and dominance in their habitat. Algae encountered in a water body reflect the average ecological condition of the water body and therefore, they may be used as an indicator for assessment and evaluation of water quality of diverse habitats (Dwivedi 2010, Saikia et al, 2010 &2011).

II. Statement of the Problem

Goswami (1998) reported that Nagaon Paper Mill (NPM) established in 1985 in jagiroad, Assam (India) has been affecting the air, water and soil quality of adjoining areas through the disposal of solid, liquid and gaseous emission. Mainly the problem arises from the disposal of effluents in to nearby Land or wetland system. Among various wetlands of Assam, Elenga Beel was identified by CPCB, New Delhi as most polluted one due to influential of paper mill effluents. The beel is to be called as the gate of effluents to neary by wetlands of entire district of Morigaon. *Elenga Beel* is located between $92^0 3'51''$ E-$92^0 17'7''$ longitude & $26^0 8'2''$ – $26^o 11'41''$N latitude. Two drains carrying PME drains to Elenga Beel which after traveling at a distance of 25 km downstream meets River Kolong/Kopili a tributary of mighty river Brahmaputra. The confluence of paper mill effluents in the nearby fresh water bodies conglomerates the entire aquatic biota and reported to cause gradual environmental degradation their by affecting the crops, livestock's and aquatic life of the district (Anonymus, 1999; Bora, 1998). The impact of paper mill effluents on aquatic bodies has been assayed to a certain extent (Bhattacharyya and Ahmed, 1995; Baruah and Das, 2001; Kalita et al, 2002), but information on toxicity and effect of Nagaon Paper Mill effluent on algal flora was very limited. The toxicity of pulp mill effluents demonstrated many times in literature were mostly on lethal and sub-lethal effect fish populations. Only few papers have reported toxic effect of these wastes on other members of aquatic communities. Considering above study undertaken.

III. Methodology

The algal and water quality samples were collected from predetermined sample sites prepared by Arc.9.3 GIS software as shown in the *Figure-2* were analyzed as per methodology of APHA (1989), Trivedy and Goel (1986), Golteman et al.(1978), Greenberg et al.(1985).The numerical counting and identification of algae was done following Lackey's (1938) ,Desikachay (1959) Prescott (1951); Smith, (1950). The statistical analysis of *Pearson correlation* and *ANOVA* of water samples corresponding to sample sites and seasons was done using *SPSS 9.0*.

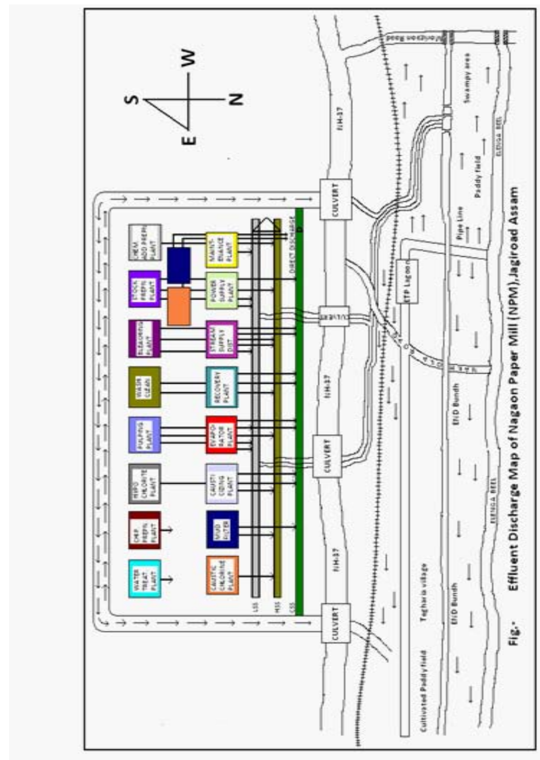


Figure1: Effluents discharge map of NPM.

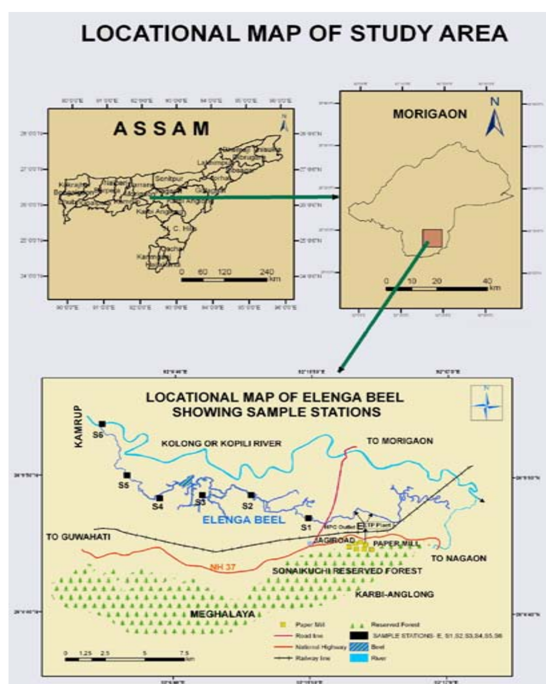


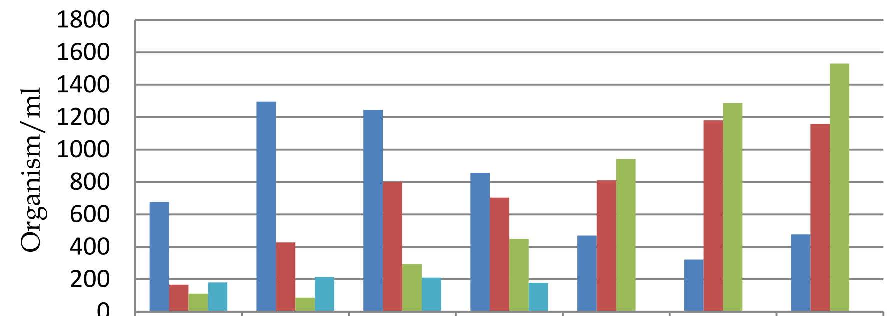
Figure 2 : Location Map of Study Area.

Table 1 : Number (org/ml) of total phytoplankton's encountered from different sample stations of Elenga Beel.

Taxa	E	S1	S2	S3	S4	S5	S6	Annual average Org/ml
Cyanophyceae	676	1296	1244	857	470	322	477	5342
Chlorophyceae	167	427	800	704	810	1180	1159	5247
Bacillariophyceae	112	87	294	449	941	1287	1531	4701
Euglenophyceae	181	214	210	179	0	0	0	784
Total	1136	2024	2548	2189	2221	2789	3167	16074

Figure 3 : Thee yearly average (A) and Seasonal mean (B) value of different algal groups .

[A]



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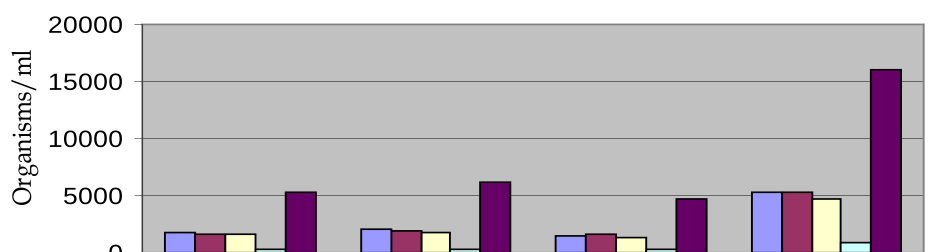
[B]



	W	S	R	Total
Ctanophyceae	1702	2110	1520	5332
Chlorophyceae	1653	1979	1603	5235
Bacillariophyceae	1594	1794	1286	4673
Euglenophyceae	286	301	247	834
Total	5235	6183	4656	16074

Table 2 : Physico-Chemical characteristics of Effluents and water quality of different sample Station of Elenga Beel (Annual mean and ± SD).

Parameters	E	S-1	S-2	S-3	S-4	S-5	S-6
Temperature	30 ±4.00	29 4.00	29 3.00	28 3.60	27 3.60	27 2.64	26 3.00
PH	8.5	8.43	8.36	8.3	8.25	8.20	7.50
	±0.346	0.115	0.02	0.05	0.15	0.5	0.5
Conductivity.	1.34	1.31	1.29	1.22	1.10	1.09	0.90
mmho/cm	0.010	0.01	0.01	0.025	10.78	0.04	6.65
Total Suspended Solids	3.91	3.89	3.84	3.51	3.25	1.94	1.76
(TSS) mg/L	0.021	0.01	0.030	0.08	0.01	0.09	0.18
Total Dissolved	1311	1264	1240	1231	981	641	385
Solids(TDS)mg/mL	28.431	64.00	48.12	110.02	74.48	89.47	81.14
Total Solids(TS)	1761	1630	1563	1286	1007	729	367
	52.82	50.90	55.51	40.50	14.46	41.78	48.86
Turbidity,NTU	133	130	127	215	231	307	452
	4.725	6.00	7.09	4.041	31.37	18.90	42.25
Dissolve Oxygen(DO)	0.75	0.76	0.77	1.05	1.22	2.04	2.36
mg/mL	0.058	0.06	0.015	0.09	0.14	0.14	0.2
Biochemical Oxygen	396.33	388	370	315	262	206	167
Demand(BOD)mg/mL	2.516	7.57	10.00	10.14	21.77	13.45	0.13
Chemical Oxygen	553	493	423	376	302	241	147
Demand(COD)mg/mL	7.57	37.85	49.32	19.07	22.72	25.00	19.65
Alkalinity,mg/mL	322	315	303	287	208	192	161
	6.65	5.56	6.11	11.50	6.02	11.01	5.6
Total Nitrogen(TN) in ppm	4.68 0.02	4.14 0.15	4.84 0.011	5.07 0.01	3.75 0.02	2.62 0.20	2.04 0.2
Total phosphorus(TP) in	1.02	0.84	0.76	0.75	0.54	0.33	0.24
ppm	0.02	0.03	0.009	0.0025	0.04	0.06	0.4
Sulphate in ppm	168	158	137	117	108	94	83
	3.05	5.29	4.93	12.34	5.50	15.39	6.55
Total	610	586	514	264	303	204	156
Hardness in ppm	49.72	57.71	13.79	10.06	19.42	28.37	26.50

Table 3 : Phytoplankton's Correlation with different Physico-chemical parameters of effluents and water quality of Elenga beel.

Parameters		Cyanophyceae	Chlorophyceae	Bacillariophyceae	Euglenophyceae	Total Phytoplanktons
Temperature	Pearson Correlation	.530	-.722	-.856*	.703	-.821*
	Sig(2-tailed)	.221	.067	.014	0.078	.023
	N-7					
PH	Pearson Correlation	.477	-.721	-.834*	.659	-.769*
	Sig(2-tailed)	.280	.067	.020	.107	.043
	N-7					
E.Conductivity	Pearson Correlation	.699	-.836*	-.968**	.883**	-.786*
	Sig(2-tailed)	.080	.014	.000	.008	.036
	N-7					
TSS	Pearson Correlation	.745	-.859*	-.962**	.852*	-.771*
	Sig(2-tailed)	.055	.013	.001	.015	.043
	N-7					
TDS	Pearson Correlation	.705	-.846*	-.967**	.867*	-.791*
	Sig(2-tailed)	.077	.016	.000	.012	.034
	N-7					
TS	Pearson Correlation	.726	0.890**	-.988**	.894**	-.816*
	Sig(2-tailed)	.065	.007	.000	.007	.025
	N-7					
Turbidity	Pearson Correlation	-.700	.795*	.943**	-.815*	.750
	Sig(2-tailed)	.080	.033	.001	.026	.052
	N-7					

**** Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2 tailed).**

(Continued...)

Parameters		Cyanophyceae	Chlorophyceae	Bacillariophyceae	Euglenophyceae	Total Phytoplankton
DO	Pearson Correlation	-.736	.846*	.964**	-.848*	.772*
	Sig(2-tailed)	.059	.016	.000	.016	.021
	N-7					
BOD	Pearson Correlation	.776*	-.891**	-.994**	.918**	-.788*
	Sig(2-tailed)	.040	.007	.000	.004	.035
	N-7					
COD	Pearson Correlation	.655	-.941**	-.973**	.861*	-.879**
	Sig(2-tailed)	.110	.002	.000	.013	.009
	N-7					
Alkalinity	Pearson Correlation	.785*	-.863*	-.991**	.962**	-.757*
	Sig(2-tailed)	.036	.012	.000	.001	.049
	N-7					
TN	Pearson Correlation	.658	-.839*	-.902**	.684	-.691
	Sig(2-tailed)	.108	.018	.005	.090	.086
	N-7					
TP	Pearson Correlation	.646	-.949**	-.975**	.876*	-.888**
	Sig(2-tailed)	.117	.001	.000	.010	.008
	N-7					
Sulphate	Pearson Correlation	.688	-.943**	-.946**	.841*	-.851*
	Sig(2-tailed)	.101	.001	.001	.018	.015
	N-7					
T.Hardnes	Pearson Correlation	.704	-.869**	-.902**	.800*	-.756*
	Sig(2-tailed)	.078	.011	.005	.031	.044
	N-7					

Table 4 : ANOVA for phytoplankton's abundance on seasons and stations (using SPSS.9.0)
ANOVA Summary for winter (W).

Source	SS	df	MS	F	P
Treatment [between seasons]	7091569	1	7091569	12.64	0.003
Within seasons	7851893	14	560849.5		
Total	14943462	15			

ANOVA Summary for summer (S).

Source	SS	df	MS	F	P
Treatment [between seasons]	6173982.5625	1	6173982.5625	10.42	0.006
Within seasons	8297362.375	14	592668.7411		
Total	14471344.9375	15			

ANOVA Summary for rainy(R)

Source	SS	df	MS	F	P
Treatment [between seasons]	8420153.0625	1	8420153.0625	15.34	0.001
Within seasons	7684153.375	14	548868.0982		
Total	16104306.4375	15			

ANOVA Summary for Seasons and Stations (combined effect)

Source	SS	df	MS	F	P
Treatment [between seasons and station]	10974184.125	3	3658061.375	10.67	<.0001 (not significant)
Within in seasons and station	9602081.75	28	342931.4911		
Total	20576265.875	31			

P<5% significant difference; P>5% not significant difference.

IV. Results and Discussion

The water body is an abandoned paleo-channel of Kopili River and therefore, elongated in nature and loaded by the effluents of Nagaon Paper Mill. The abundance of algal flora in *Elenga Beel* shows a wide displacement from those occurring in natural unpolluted water bodies. The plankton community of *Elenga beel* shows a departure from normal conditions. A horizontal variation of algal flora of different classes was observed at different sampling location and seasons. In the entire stretch of the *Beel* four groups of algae, namely -

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Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophycea was recorded. The data presented in *Table-1* and *Figure 2&3* showed that *Cyanophyceae* (33.17%), *Chlorophyceae* (32.56%), *Euglenophyceae* (29.07%) and *Bacillariophyceae* (5.18%) were present in the entire stretch of the Beel. The study revealed that physico-chemically station E and S1 has perfect positive correlation (r = 1.000) which did not allow large number of species to encounter. A significant decline of species number was recorded in these stations. Gradual increase of species number was observed in station S_2 to S_6 due to dilution of effluents. Phytoplankton's counts also registered higher during non-rainy season at all stations. The phytoplankton's count was comparatively higher in summer (39.57%) and low during rainy (28.50%) season [*Figure 2&3*]. This agrees with the findings of Sadguru *et al.* (2002) on Caveri River with reference to pollution. From the result presented in Figure 2&3, station E to S3 characterized with polluted water by PME which favours the growth of algal groups –*Cyanophyceae* and *Euglenophyceae*. The *Chlorophyceae* and *Bacillariophyceae* were dominating at station S4-S6 having low pollution nature of the Beel water. These agree with the finding of Sudhakar and Venkateswarlu (1991a) and Venkateswarlu (1969).

The variations of physico-chemical parameters greatly influence the variation of phytoplankton's population. In our study, during rainy season, phytoplankton's counts were declined along with the physico-chemical parameters. Similar observation has also been reported by Pundhir and Rana (2002). The occurrence of higher percentage of phytoplankton during summer is mainly due to the change in physical properties of water rather than chemical condition of the beel as supported by Davika *et al* (2006). The abundance of *Cyanophyceae* in paper mill effluents is attributed to favourable contents of oxidizable organic matter and less dissolved oxygen, high BOD and COD (Venkateswarlu, 1991; Boominathan, 2005; Vijayakumar et al. 2005). They suggest that *Cyanophyceae* grow luxuriantly with great variety and abundance in water with less DO and oxidizable organic matter. In the present study, the waste water from paper mill showed considerable amount of *nitrates* and *phosphates*, with increased level of BOD and COD along with very low DO and turbidity [*Table 2]*. This could be the reason for the flourishing growth of *Cyanophyceae* in paper mill effluents and their sequent decline in unpolluted or low organically polluted stations (S_5 and S_6).

The basic process of phytoplankton production depends on temperature, turbidity and nutrients (Sukumaran and Das 2002) and some others physico-chemical properties of the water body which provides converging lines of evidences for evaluation of polluted habitats of different origin. In the present study, *temperature*, *turbidity* and *nutrients* found to have significant correlation ($p < 0.01$ or $p < 0.05$) with phytoplankton's count [*Table 3*]. Water temperature was observed in the range from 26°C-30°C throughout the beel with slight variation with seasons. The water temperature recorded at station E-S_4 was higher than the temperature recorded at S_5 and S_6, which may be due to the effect of effluent entered in the water body. A comparison of algal population with water temperature in Elenga Beel revealed that higher temperature effect favours the growth of *Cyanophyceae (r=.530)* and *Euglenophyceae (r=.703),* while low temperature enhanced *Chlorophycean & Bacillariophyceae*. This observation agrees with the findings of Sudhakar and Venkateswarlu (1991) who also observed 27 unit's variation in algal number with a change of one unit of temperature. In the present study positive correlations of temperature with *Cyanophyceae* (r = 0.530) & *Euglenophyceae* (r = 0.703) and negative correlation with *Chlorophyceae* (r = -0.722) & *Bacillariophycea* (r = -0.856)[Table-3]was recorded which signify temperature effect on algae. Mittal and Senger (1989) also concluded that low temperature enhanced the growth of green algae. Gonzalves and Joshi (1946) observed positive correlation of temperature with *Cyanophyceae.*

Ellis (1937) opined that the tolerance level of most of organisms to alteration of pH is quite narrow. Hence, survival of aquatic organism under extreme condition creates serious problems. The annual mean value of pH of treated effluent of Nagaon Paper Mill released to Elenga *beel* was recorded as 8.5 indicating the enrichment of alkaline effluents. P^H was recorded high in summer (S) and low in rainy(R) season at all stations. The higher P^H showed positive correlation with *Cyanophyceae* (r = 0.477) & *Euglenophyceae* (r = 0.659) and negative correlation with *Chlorophyceae* and *Bacillariophyceae* [*Table 3]*. The higher values of pH affected the algal flora and enhanced the growth of blue green and *Euglenoides* which can survive well in alkaline water. This finding is in conformity with the findings of Kaushik *et al.* (1991) who observed similar abundance of algae in polluted water.

Depletion of DO affects the total system of a water body. In an aquatic ecosystem, flora and fauna can survive only in the presence of adequate dissolved oxygen. Singh and Singh (2001) noticed water quality degradation in Ami River due o changes in values of dissolved oxygen mainly due to the discharge of paper mill effluent. Medhi *et al.* (2011) also noticed low level of DO in Nagaon paper mill effluents. In the present study dissolved oxygen (DO) level was comparatively found to be low at all stations..The result indicates that low DO of paper mill effluent enhanced the abundance of *Cyanophyceae* and *Euglenophyceae* in highly polluted zone (E-S_3) whereas high DO influence *Chlorophyceae* and *Bacillariophyceae* in low organically polluted zone (S_4-S_6). Similar type observations were made by Saxena and Chauhan (1993) in river Yamuna and Reemol (2004) in Muvattupuzha River.

The increased level of BOD and COD indicate the nature of chemical pollution. High amount of BOD

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and COD cause oxygen depletion which leads to the suffocation of aquatic life (Verma *et al.*, 1984). These two parameters are interrelated and show inverse correlation with DO. In the present study the combined effect of BOD and COD is negatively correlated with total phytoplankton's count (r = -0.788 and r = -0.879) but showed positive correlation with *Cyanophyceae* (r=0.776; r=0.918) and *Euglenophyceae* (r = 0.655; r= 0.861) [*Table 4.2i & 4.2ii*]. This indicates that *Euglenophycean* and *Cyanophycean* algae can grow abundantly in paper mill effluents enriched water body having higher range of BOD and COD. Similar type observation was also reported by Venkateswarlu (1991) while working on Cyan bacterial diversity in paper mill effluent.

Naturally, alkalinity helps to buffer pH changes which are important criteria for growth of aquatic organisms. In the present investigation, the values of alkalinity at different sites were high during summer season followed by steep fall during rainy period due to dilution of effluents. In the present study, the highest alkalinity (322mg/ml) was recorded at station E, while the lowest alkalinity (161mg/ml) was recorded at Stations S_6. . Similar results were observed by Jain *et al*, (1996) and Reemol (2004) in Cochin estuary. In our study negative correlation has been observed between total alkalinity and total phytoplankton population (r = -0.757), but alkalinity showed positive correlation with *Cyanophycean* (r = 0.785) and *Euglenophycean* (r = 0.962) algae respectively [*Table 3*]. This indicates that increase in total alkalinity due to paper mill effluent enhances the abundance of *Cyanophyceae* and *Euglenophyceae* while the population of other groups of algae decreases.

The Total dissolved solids (TDS) affect the water quality by increasing the density of water and thereby retarding the palatability of water. The values of TDS were found to be the highest at Station E (1311mg/ml) and the lowest at station S_6 (385 mg/ml). Seasonal variation showed higher values of TDS during rainy and summer seasons due to addition of runoff, sewage and effluents to the *beel*. The high level of TDS, especially from station E to station S_3 indicated the input of ionic substances along with NPM effluent. Spatial distribution of phytoplankton population showed that TDS has negative correlation with total phytoplankton density (r = - 0.791). However, TDS showed positive correlation with *Cyanophyceae* (r = 0.705) and *Euglenophyceae* (r = 0.867) [*Table 3*]. The higher value of TDS in rainy and summer season was observed by Gupta and Singh (2000), and Reemol (2004). In the present study, the total suspended solids (TSS) found to vary with sampling location and seasons. The highest amount (3.91mg/l) of TSS was recorded at station E and minimum at station S_6 (1.76mg/l). The highest amount of TSS discharged by Nagaon Paper Mill imparted brown colouration of water as well as reduced transparency particularly at sampling station E and S_1 reducing of photosynthetic activity, reduced growth of primary producers, reduces abundance and compositions. The study revealed a negative correlation (r = -0.771) of TSS with total phytoplankton count which of Clausen (1973) .

Investigation on conductivity (EC) revealed that its value decreases away from the effluent discharge site. The maximum value (1.340mhos/cm) was observed at station E and minimum value (0.90mhos/cm) at station S_6. The high value of conductivity at E indicated the presence of large amount of ionic substance in water but the lower level of conductivity in S_6 may be due to dilution or self purification properties of the water body. Trivedy and Goel (1984), Dutta and Baissya (1997) suggested that the water having conductivity more than 2.00 mhos/cm is unsuitable for plant growth. In our present study, conductivity was less than the prescribed limit. Hence it would not affect plant growth. A negative correlation of conductivity with total phytoplankton counts (r = -0.786) was observed in our study. However conductivity showed positive correlation with *Cyanophyceae* (r = 0.699) and *Euglenophycea* (r = 0.883) *[Table 3].*

Turbidity is an important physical parameter which has a significant bearing on productivity of aquatic ecosystem (Kuriyan, 1974). According to Trivedy and Goel (1986) turbidity of all water resources ranged between 18-31 NTU (Neptholometric Turbidity Unit). In the present study, lowest turbidity was recorded in station E (133NTU) and highest at Station S_6 (452NTU). It was less in summer and maximum in rainy. Turbidity increases in downstream station S_5 and S_6 as distance increases from the effluent discharge point. In the present study, turbidity has positive correlation with total phytoplankton counts (r = 0.750), but has negative correlation with *Cyanophyceae* (r = - 0.700) and *Euglenophyceae* (r = - 0.815) [*Table 3*]. The result indicated that decrease in turbidity of paper mill effluent may reduce the production of phytoplankton at upstream of the *beel*. Similarly increase in turbidity in downstream may increase the abundance of algae.The excess amount of nutrients (P and N) that are discharged into aquatic systems sometimes might cause eutrophication and this would lead to various changes in algal community structure (Parnell, 2003). Although pulp and paper mill effluents are deficient in nitrogen and phosphorus, urea and superphosphate were used in biological treatment to feed the microorganisms. As a result, the entry of N and P in waste water of pulp and paper mill effluents and their subsequent release into natural ecosystem may cause serious problem for aquatic flora and fauna. In the present study, the highest amount of total nitrogen (TN) (5.07ppm) was recorded in station S_3 and the lowest (2.04ppm) was recorded in station S_6. Similarly, the highest amount of total phosphorus (TP) (1.02ppm) was recorded at station E, while the lowest (0.24ppm) was recorded at station S_6. Higher concentration of nitrogen at station S_3 may be due to the mixing of agricultural sewage from the nearby agricultural field where plenty of fertilizers were used by the farmers for crop production along with effluent irrigation (Dutta and Baissaya, 1997; Medhi *et al*., 2011). Total phytoplankton count shows negative correlation with total Nitrogen ($r = -0.691$) and total Phosphorous ($r = -0.888$) has [*Table 3*]. The ratio of N/P was below 7 in polluted zones covering stations E to S_4 which stimulate *Cyanophycean bloom* and exhibited eutrophic nature of the Beel water. A positive correlation of TN ($r = 0.655$) and TP ($r = 0.646$) with *Cyanophycea* was noticed.

The pulp and paper mill waste water contains huge amount of sulphate because majority of pulp mill adopt sulphite processes. In our study the highest amount of sulphate was recorded in station E (168 ppm) and lowest was recorded in S_6 (83ppm). The highest amount sulphate (443mg/l) in NPM effluents was recorded by Medhi *et al.* (2011). But NPM now able to reduce sulphate up to permissible limit. In our study negative correlation ($r = -0.851$) between sulphate and total phytoplankton count was observed.

Hardness was recorded highest at station E (610ppm) and lowest in Station S_6 (156ppm). It was low at all stations during rainy season. Nerra *et al*. (2001) reported that hardness of water was an indication of water pollution. In our study hardness was found not to exceed the IS permissible limit 600ppm except station E. Medhi *et al.* (2011) also observed hardness of NPM below permissible limit. Hardness was found to be negatively correlated ($r = -0.756$) with total algal counts. From the result it was evident that the effluent and water quality of the Elenga beel were characterised by high temperature, P^H, Colour ,high range of oxidizable matter, sulphates, BOD,COD, TDS,TSS ,SS, EC, TN,TP. The effluent and water in some stations was highly depleted in Dissolved Oxygen and Turbidity. Most of parameters have showed positive and negative correlation, except E has perfect positive correlation with station S1 ($r=1.000$) i.e. these two are most similar. Phycologically also all sample sites (E-S6) have positive and negative correlation as evident from the *Table: 3* Phycologically station E, S1, S2, S3 have exhibited similar type of occurrences of algal flora in upstream of the beel where as in downstream stations S4, S5, S6 exhibited an another type occurance of algal flora. Thus both upstream and downstream stations were contrary to each other subject to pollution load. For determination of variance between phytoplankton abundance on seasons & stations ANOVA test was administered (*Table 4*) and statistically analysed. The analysis of variance for seven stations and seasons for phytoplankton's observed showed significant differences ($p<5\%$) between seasons and stations. But their combined effect on seasons and stations was not significant ($p <0.001$) *[Table-4]*.

Thus, from the foregoing discussion, it concluded that physico–chemical character together with algal abundance provides lines of evaluation of Elenga Beel as –*i] seasonal variation ii] high load of pollutants from paper mill and iii] relative adaptability and resistance of nuisance algal flora to pollutants.*

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Acknowledgement

I acknowledge the department of Biotechnology particularly NER-BPMC for providing infrustcture facillaties in the form of creation of Institutional Biotech Hub at Dhing College,Nagaon: Assam to carry out some laboratory experiments during this piece of research work. Also thankful to UGC, NERO for providing fellowship for pursuing research. I am thankful to all biotech hub partners/ JRF who directly or indirectly involved with this piece of work. Lastly I am thankful to prof. S.kalita & G.C.sarma of Gauhati University,Assam for providing necessary guidance and supervision.

Global Journal of Science Frontier Research (C) Volume XII Issue V Version I Year 2012

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