PHYTOPLANKTON ASSESSMENT OF TWO RIVERS RECEIVING PETROCHEMICAL EFFLUENT FROM NRL, ASSAM, (INDIA)

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ABSTRACT

Anassessment has been made on phytoplankton diversity ofthe two riversKaliani and Dhansiri receiving oil refinery effluent from NRL. A total of 25 genera of phytoplankton belonging to Bacillariophyta, Chlorophyta, Cyanophyta, Cryptophyta and Euglenophytahave been recorded. The mean annual percentage composition of 49% Chlorophyta> 16% Cyanophyta> 13% Bacillariophyta =Euglenophyta> 9% Cryptophyta. The mean seasonal variations of phytoplankton abundance were pre monsoon 35% > post monsoon 29% > winter 20% > monsoon 16 %. The Chlorophyta was dominant taxa for all the four seasons and Cryptophyta was the least common taxa. The Shannon-Wiener index found highest in S3(1.45) and lowest (1.15) in the point of effluent discharge (S6).

Keywords: Phytoplanktondiversity, Petrochemical Effluent, Community Structure, Assam

I INTRODUCTION

Phytoplankton is one of the most essential characteristics of the aquatic ecosystem for maintaining its stability and a means of coping with any environmental change [1]. These are very sensitive to the environment they live in and any alteration in the environment leads to the change in their communities in terms of tolerance, abundance, diversity and dominance in the habitat [2] and [3]. Over the last few decades, there has been much interest in the processes influencing the development of phytoplankton communities, primarily in relation to physico-chemical factors[4] and [5].Phytoplankton are more sensitive to pollution than other organisms [6] and used for water quality characterization[7].The aim of the study was to assess the phytoplankton diversity of the two rivers Kaliani and Dhansiri receiving oil refinery effluent from NumaligarhRefinery Limited. River Dhansiri is a major south bank tributary to theBrahmaputra flowing through Golaghat District. The Kalian is a tributary of Dhansiri and the Dhansiri is a perennial source of water located within 5-kms radial distance from the NRL. They receive effluent from the refinery and reported to be contaminated since its operation from the year, 2001.

II MATERIALS AND METHODS

The study was conducted from March 2012 to February 2014 on a seasonal basis – pre-monsoon (March-May), monsoon (June-August), post monsoon (September-November) and winter (December-February).

Phytoplankton samples were collected with No. 25 µ plankton net up to depth of 0.5 meter. A known volume (25 lit.) of water was strained through plankton net to assess the quality of the plankton. A total of 10 sampling stations were selected, 5 upstream ofKalianiand 5 downstream ofKaliani and Dhansiri rivers with reference to point of effluent discharge. The sample, after collection was fixed in 4% formalin for further study.Identification was followedby several worker[8], [9] and [10]. The total number of phytoplankton per liter of water was estimated by the following formula:

$$N = \frac{A \times C}{L}$$

Where, A = Average number of plankton counted per ml concentrated sample, C =Volume of concentrated sample in ml, L = Volume of original water in liter passed through the plankton net, N = Total number of plankton per liter of original water.

Some physico-chemical parameters were analyzed as per standard procedures [11]. Community structure was analyzed by using the Shannon-Wienerdiversity index,Pielou's Evenness index(E), Margalef diversity index (M), maximum diversity possible(Hmax) and Simpson's Diversity Index (D).

III RESULT

3.1Physico-Chemical Parameters

Annual mean fluctuations of the physicochemical parameters in ten sampling stations of the two rivers from March, 2012 to February, 2014 have been shown in the Table 1. DO found highest in S1 with a mean annual value of 8.73±1.09mg/l and the lowest (4.24±0.23mg/l) in S6. DO found highest in winter season (8.2 mg/l) with10 mg/l inS1 and lowest with 3.7 mg/l found in monsoon season in S6. Some of the parametersshowed higher valuesin monsoon season such as, turbidity(46.98 NTU) with an annual mean of 62.30±23.45NTU in S6, conductivity (150.6µS/cm) with an annual mean of 446.21±35.86µS/cm in S6, FCO2 (5.07mg/l) with an annual mean 5.21±.38mg/l in S6, TDS (59.71mg/l) with an annual mean of 108.97±25.53mg/l in S6, temperature(31.05°C) with an annual mean of 22.44±8.82°C in S10, water current(0.82m/s) with an annual mean of 0.51±0.21m/s in S1; in winter season on the other hand some parameters showed highest value – alkalinity(54.98mg/l)with an annual mean of 69.03±36.77mg/l in S6; total hardness (49mg/l) with 68.26±36.05mg/l in S6, calcium hardness(26.72mg/l) with an annual mean of 43.41±17.90mg/l in S6, pH(7.17) with annual mean of 6.95±.26 in S5, Chloride (7.32mg/l) with an annual mean of 24.19±18.17mg/l in S6.

Table1. Annual mean fluctuations of the physico-chemical parameters of the two rivers Kaliani and Dhansiri

Parameters	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10
DO(mg/l)	8.73±1.09	8.55±1.10	8.39±1.10	8.18±1.01	7.84±.99	4.24±.23	5.88±.55	6.69±.73	7.14±.78	7.51±.89
Turbidity(NTU)	18.39±13.41	19.09±13.54	19.93±13.59	20.90±14.25	26.84±22.33	62.30±23.45	47.20±16.96	36.48±14.75	34.53±13.82	34.08±14.06

Total Hard.(mg/l)	19.67±2.44	19.6±2.36	20.45±3.09	19.55±2.67	21.26±9.57	68.26±36.05	46.89±24.83	38.63±18.91	27.99±11.57	26.05±9.88
Alkal.(mg/l)	23.55±2.93	23.62±3.06	23.8±2.93	24.01±3.011	25.30±9.27	69.03±36.77	49.53±25.64	42.89±20.26	30.54±12.16	29.80±11.20
Conduct. (μS/cm)	61.21±8.97	62.42±7.83	62.04±8.019	63.25±7.76	61.38±8.	446.21±35.8	215.29±42.97	153.04±38.46	115.67±31.46	88.04±9.05
Calcium hard.(mg/l)	13.68±3.65	13.33±3.28	13.63±2.94	14.03±5.64	14.68±6.28	43.41±17.90	31.35±15.51	24.74±9.79	20.89±6.72	20.34±6.57
Velocity (m/s)	0.51±0.21	0.50±0.21	0.50±0.21	0.49±0.21	0.49±0.20	0.48±.20	0.47±.20	0.47±.20	0.47±.20	0.47±.20
Chloride (mg/l)	0.98±.49	0.96±.44	0.91±.43	1.23±.49	1.19.60	24.19±18.17	12.37±6.73	3±2.59	1.95±1.27	1.37±.63
pH	6.89±.25	6.92±.27	6.94±.27	6.94±.26	6.95±.26	6.62±.14	6.76±.18	6.90±.32	6.89±.32	6.91±.32
TDS(mg//l)	31.06±3.90	31.47±3.81	31.31±3.81	31.45±3.77	31.12±3.89	108.97±25.53	77.25±12.02	61.39±16.49	46.6±12.61	42.39±6.16
FCO_2(mg/l)	4.16±.39	4.34±.32	4.41±.36	4.44±.32	4.51±.34	5.21±.38	5±.34	4.83±.37	4.79±.37	4.79±.39
Wat. temp.(^{0}C)	20.86±8.54	21.08±8.53	21.21±8.58	21.36±8.58	21.60±8.64	22.03±8.55	22.13±8.54	22.18±8.68	22.24±8.78	22.44±8.82
Depth(m)	2.2±.88	2.19±.87	2.22±.97	2.30±.92	2.41±.93	2.72±1.16	3.81±1.38	3.87±1.37	3.91±1.26	4.05±1.37

3.2 Biological Parameters

A total of 25 phytoplankton taxa were collected of which 3 Bacillariophyta, 15 Chlorophyta, 4 Cyanophyceae, 2 Cryptophyta and 1 Euglenophyta. Bacilaiophyta includes *Asterionella, Fragillaria and Diatoma*; Chlorophyta includes *Ankistrodesmus ,Chlorella, Cosmarium, Eudorina,Desmidium, Haematococcus, Odogonium, Pediastrum, Selenastrum, Spirogyra, Ulothrix, Vaucheria*; Cyanophyta incudes *Anabaena,Gloeotrichia, Nostoc, Oscillatoria*; Cryptophyta includes *Cryptomonus and Rodomonus*; Euglenophyta includes a single genera-*Euglena*. The seasonal abundance of different phytoplankton taxa in the two years are tabulated separately in (Table2 and Table3). The total numbers of phytoplankton collected were 468 and 484 in the sampling years 2012-2013 and 2013-2014 respectively.

Table2. Seasonal abundance of phytoplankton taxa during 2012-2013

Phytoplankton		**Abundance (ind/l)**					
		Pre monsoon	**Monsoon**	**Post monsoon**	**Winter**	**Total**	**Mean±STD**
Bacillariophyta	1.*Asterionella*	5	1	5	3	14	3.5±1.91
	2.*Fragillaria*	12	2	8	3	25	6.25±4.65
	3.*Diatoma*	6	5	3	3	17	4.25±1.50
	Sub total	23	8	16	9	56	14±6.98

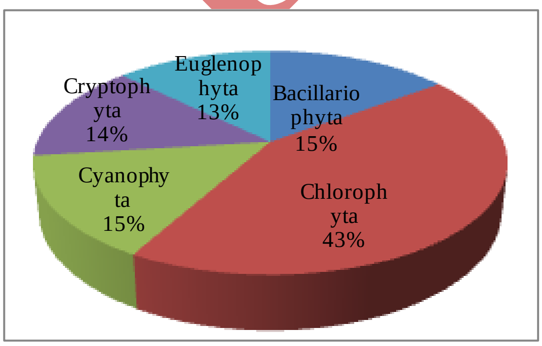
Chlorophyta	4.*Ankistrodesmus*	1	0	5	1	7	1.75±2.22
	5.*Chlorella*	7	0	2	1	10	2.5±3.11
	6.*Closterium*	0	7	5	0	12	3±3.56
	7.*Cosmarium*	6	2	4	0	12	3±2.58
	8.*Eudorina*	2	3	6	4	15	3.75±1.71
	9.*Desmidium*	7	5	3	2	17	4.25±2.22
	10.*Haematococcs*	1	0	6	5	12	3±2.94
	11.*Odogonium*	9	6	11	6	32	8±2.45
	12.*Pediastrum*	0	0	4	1	5	1.25±1.89
	13.*Selenastrum*	3	7	4	2	16	4±2.16
	14.*Spirogyra*	5	0	10	6	21	5.25±4.11
	15.*Ulothrix*	10	0	6	1	17	4.25±4.65
	16.*Vaucheria*	1	2	4	5	12	3±1.83
	17.*Volvox*	9	8	5	2	24	6±3.16
	18.*Zygonema*	8	0	8	3	19	4.75±3.95
	Sub total	69	40	83	39	231	57.75±21.4
Cyanophyta	19.*Anabaena*	9	0	0	4	13	3.25±4.27
	20.*Gloeotrichia*	4	6	10	10	30	7.5±3.00
	21.*Nostoc*	3	0	5	3	11	2.75±2.06
	22.*Oscillatoria*	8	4	6	4	22	5.5±1.91
	Sub total	24	10	21	21	76	19±6.16
Cryptophyta	23.*Cryptomonus*	14	2	5	2	23	5.75±5.68
	24.*Rodomonus*	10	0	7	2	19	4.75±4.57
	Sub total	24	2	12	4	42	10.5±9.98
Euglenophyta	25.*Euglena*	22	7	14	20	63	15.75±6.75
	Sub total	22	7	14	20	63	15.75±6.75
Total		162	67	146	93	468	117±44.50

Table3.Seasonal abundance of phytoplankton taxa during 2013-2014

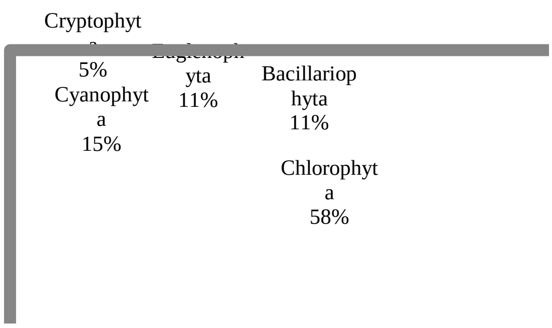
Phytoplankton		**Abundance (ind/l)**					
		Pre monsoon	**Monsoon**	**Post monsoon**	**Winter**	**Total**	**Mean±STD**
Bacillariophyta	1.*Asterionella*	6	2	6	5	19	4.75±1.89
	2.*Fragillaria*	8	3	4	2	17	4.25±2.63
	3.*Diatoma*	12	3	8	6	29	7.25±3.77
	Sub total	26	8	18	13	65	16.25±7.8
Chlorophyta	4.*Ankistrodesmus*	2	0	4	1	7	1.75±1.71
	5.*Chlorella*	5	0	3	2	10	2.5±2.08
	6.*Closterium*	4	0	2	1	7	1.75±1.71
	7.*Cosmarium*	5	7	4	2	18	4.5±2.08
	8.*Eudorina*	2	2	3	0	7	1.75±1.26
	9.*Desmidium*	6	0	5	1	12	3±2.94
	10.*Haematococcus*	3	0	5	5	13	3.25±2.36
	11.*Odogonium*	14	2	10	6	32	8±5.16
	12.*Pediastrum*	2	0	0	0	2	0.5±1.00
	13.*Selenastrum*	6	8	7	2	23	5.75±2.63
	14.*Spirogyra*	3	2	6	2	13	3.25±1.89
	15.*Ulothrix*	6	8	9	4	27	6.75±2.22
	16.*Vaucheria*	4	4	6	5	19	4.75±0.96
	17.*Volvox*	3	13	7	0	23	5.75±5.62
	18.*Zygonema*	9	0	11	7	27	6.75±4.79

	Sub total	74	46	82	38	240	60±21.29
Cyanophyta	19.*Anabaena*	7	0	5	3	15	3.75±2.99
	20.*Gloeotrichia*	4	4	4	5	17	4.25±0.50
	21.*Nostoc*	3	0	4	4	11	2.75±1.89
	22.*Oscillatoria*	11	9	7	5	32	8±2.58
	Sub total	25	13	20	17	75	18.755.06
Cryptophyta	23.*Cryptomonus*	12	3	4	3	22	5.5±4.36
	24.*Rodomonus*	11	3	7	4	25	6.25±3.59
	Sub total	23	6	11	7	47	11.75±7.80
Euglenophyta	25.*Euglena*	20	9	13	15	57	14.25±4.57
	Sub total	20	9	13	15	57	14.25±4.57
Total		168	82	144	90	484	121±41.71

Among the Bacillariophyta, the genera *Fragillaria*showed the highest abundance in the year 2012-2013 with a mean and standard deviation of 6.25±4.65, but during the sampling year 2013-2014, *Diatoma* showed the highest abundance with a mean and standard deviation of 7.25±3.77. Among the taxa of Chlorophyta, *Odogonium* showed highest abundance for both the sampling years with 8±2.45 and 8±5.16for both the sampling years. *Gloeotrichia* with 7.5±3 in 2012-2013 and *Oscillatoria* with 8±2.58 in 2013-2014 showed highest abundance amongCyanophyta; *Cryptomonus* with 5.75±5.68 in 2012-2013 and *Rodomonus*with 6.25±3.59 in 2013-2014 showed highest abundance among Cryptophyta. *Euglena* -the single most taxa of Euglenophyta showed highest abundance with 15.75±6.75 in sampling year 2012-2013. The mean seasonal abundance of different phytoplankton taxa are showed in the Fig.1 The Bacillariophyta showed an increasing abundance with 11% in monsoon<12% in monsoon=winter<15% in pre monsoon. The Chlorophyta showed fluctuations with increasing order of 42% in winter<43% in pre monsoon<57% in post monsoon<58% in monsoon; Cyanophyta with 14% in post monsoon<15% in both pre monsoon & winter<21% in winter; Cryptophyta with 5% in monsoon< 6% in winter<8% in post monsoon< 14% in pre monsoon and Euglenophyta with 9% in post monsoon< 11% in monsoon< 13% in pre monsoon< 19% in winter. The mean annual percentage composition were 49%Chlorophyta>16%Cyanophyta> 13% Bacillariophyta=Euglenophyta> 9% Cryptophyta(Fig.5). Thus Chlorophyta was dominant taxa for all the four seasons and Cryptophyta was least common taxa (Fig.2). variation of phytoplankton density of the two rivers- with a decreasing density- pre monsoon 35%> post monsoon29% >winter20%> monsoon 16% (Fig.3). In pre monsoon highest density 22.5ind/lit was found in S4 and lowest density 4ind/lit was found in S6(Fig.4). The lowest density in monsoon season with 4ind/lit in S6.



A



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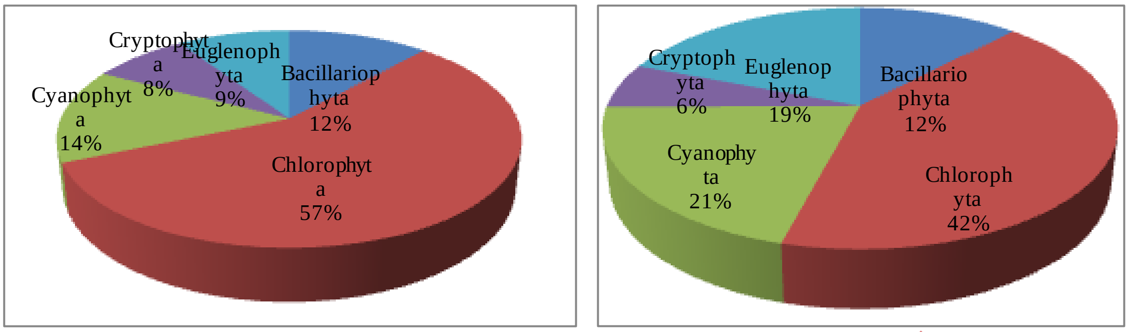
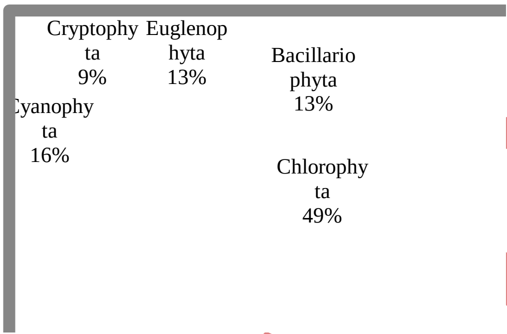


C D

Fig.1:Mean percent abundance of different phytoplankton taxa in four seasons (A) premonsoon, (B) monsoon (C) post monsoon and (D) winter



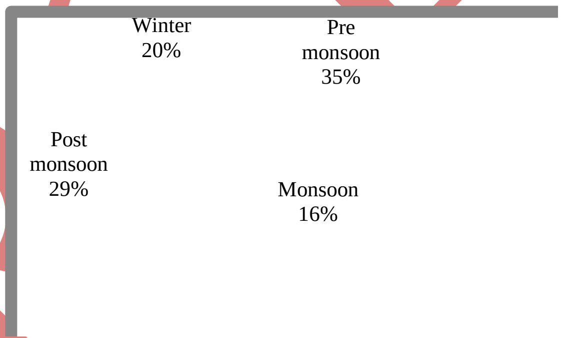
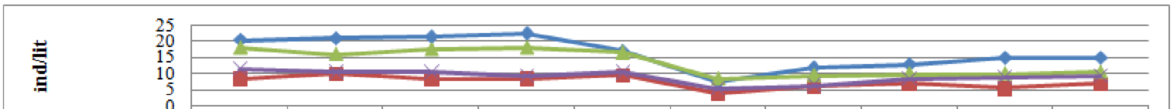


Fig.2: Mean annual percent composition of phytoplankton taxa; Fig.3: Mean seasonal percent density of phytoplankton



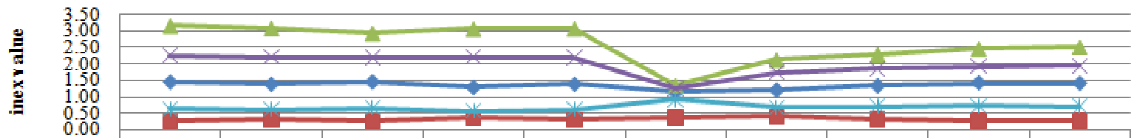
	1	2	3	4	5	6	7	8	9	10
Pre monsoon	20.5	21	21.5	22.5	17	7.5	12	13	15	15
Monsoon	8.5	10	8.5	8.5	9.5	4	6	7	5.5	7
Post monsoon	18	16	17.5	18	16.5	8.5	9.5	10	10	10.5
Winter	11.5	10.5	10.5	9.5	10.5	5.5	6.5	8.5	9	9.5

Fig.4: Mean annual density of phytoplankton in ten sampling stations for 2012-2014

3.3 Diversity Indices

Species diversity is a measure of the diversity within an ecological community that incorporates both species richness and the evenness of species abundances. The diversity indices are shown in the Fig.5

The Shannon-Wiener index found highest in S3 with 1.45 and lowest in the point of effluent discharge (S6) with 1.15; Simpson's Diversity Index found highest in S7 with 0.40 and lowest inS3 with 0.27; Margalef diversity index found highest in sampling S1 with 3.17 and lowest in S6 with 1.35; Hmax found highest in S1 with 2.25 and lowest 1.25 in S6;Pielou'sEvenness index found highest in S6 with 0.92 and lowest in S4 with 0.58



	1	2	3	4	5	6	7	8	9	10
H	1.45	1.38	1.45	1.28	1.38	1.15	1.20	1.33	1.43	1.41
D	0.28	0.31	0.27	0.37	0.32	0.38	0.40	0.33	0.29	0.29
M	3.17	3.10	2.94	3.08	3.08	1.35	2.14	2.30	2.47	2.53
Hmax	2.25	2.22	2.18	2.22	2.20	1.25	1.75	1.85	1.93	1.95
E	0.64	0.62	0.67	0.58	0.63	0.92	0.69	0.72	0.74	0.73

Fig.5: Diversity indices of phytoplankton in ten sampling stations for 2012-2014

IV DISCUSSION

The low alkalinity found during the monsoon season might be due to dilution.[12] and[13] also reported similar findings in their study on Malayan rivers and the Halali Reservoir.The increased conductivity in monsoon season confirm the finding of [14] who observed an increase in conductivity in water bodies of Burdwan, West Bengal during monsoon which according to them is due to voluminous runoff carrying diverse types of electrolytes from the nearer as well as distant areas. The highest TDS in monsoon season may be attributed to the heavy rainfall resulting in soil erosion and several fold concentration of elements and minimum in winters due to minimum velocity which favored effective sedimentation and low level of water causing minimum silt. The cause of maximum DO in winter months may be due to the reduced rate of decomposition by decreased microbial activity at low temperature[15]. Higher value of pH observed in pre monsoon, post monsoon and winter comparative to monsoon season. Among the chemical parameters all the parameters were found highest in the point of effluent discharge, except DO and pH.The minimum DO (4.24±.23mg/l) found inS6 (point of effluent disharge) may be the result of the oilly effluents disharged from NRL, whih effect on gaining of DO from atmosphere in addition to reduce the primary producer – phytoplankton population. At the point of effluent discharge minimum pH(6.62±.14) was observed, which might ultimately leading to minimum phytoplankton growth with a mean annual density of 6.375ind/l. Only a few pollution tolerant taxa of phytoplankton were found in that sampling station-*Fragillaria,Euglena, Oscillatoria*etc. According [16] organic pollution tends to influence the algal flora more than many other factors in the aquatic environment such as water hardness, trophic status, light intensity, pH, DO (dissolved oxygen), rate of flow, size of water body and other types of pollutants. Higher pH values promote the growth of algae and results in bloom [17]. The seasonal variation of phytoplankton density of the two rivers with - pre monsoon 35%> post monsoon29% >winter20%>monsooon16 % may be attributed to the effect of some physic-chemical parameters. In monsoon season the high turbidity by influencing lightpenetration acts as a limiting factor for phytoplankton abundance[18].The optimum temperature in pre monsoon and post monsoon may be the cause of higher production of planktons. Green algae prefer water with higher concentration of dissolved oxygen [19]. The Chlorophyta was dominant taxa for all the four season. According to[20] dominance of Chlorophyta throughout the year indicates excess of nutrient such as Nitrogen and Phosphorus.

The H, D, M, Hmax values are lowest in theS6, with 1.15, 0.38, 1.35, 1.25 respectively indicating lower diversity. The higher value of Shannon-Wiener Index (H) indicated greater diversity of species, meaning larger food chain and more cases of inter-specific interactions and greater possibilities for negative feedback control which reduced oscillations and hence increases the stability of the community [21]. The E value was found highest inS6 with 0.92. Evenness indices indicate whether all species in a sample are equally abundant. This means that species evenness decreases with increasing size of the phytoplankton population and vice-versa.

V CONCLUSION

Thus the findings showed the mean annual percentage composition of different phytoplankton taxa with 49%Chlorophyta>16%Cyanophyta>13% Bacillariophyta=Euglenophyta> 9% Cryptophyta. The mean seasonal variation of phytoplankton density of the two rivers- pre monsoon 35%> post monsoon29% >winter20%>monsoon 16%. The abundance and density were found minimum in all the seasons in the point of effluent discharge along with the lowest diversity indices such as H, D, M, Hmax. These results drawn from the study of physicochemical and biological parameters support the unexpected effect of refinery effluents from NRL. The proper effluent treatment plant is of immense importance to conserve the health of the two rivers – Kaliani and Dhansiri.

REFERENCES

[1] Hambright, K.D. and Zohary, T. (2000). Phytoplankton species diversity control through competitive Exclusion and physical disturbances.*Limnol.Oceanogr., 45(1): 110-122.*

[2]Amarsinghe, B. P. and Viverberg, J. (2002). Primary production in a tropical reservoir in SriLanka.*Hydrobiologia, 487: 85-93.*

[3] Elliott, J.A., Irish, A.E. and Reynolds, C.S. (2002). Predictingthe spatial dominance of phytoplankton in light limited andincompletely mixed eutrophic water column using the PROTECH model. *Fresh. Bio*.,47: 433-440.

[4]Akbay, N., Anul, N., Yerti, S., Soyupak, S. and Yurteri, C. (1999). Seasonal distribution of large phytoplankton in Keban dam reservoir.*Plank. Res., 21(4): 771-787.*

[5]Peerapornpisal, Y., Sonthichai, W., Somdee, T., Mulsin, P. and Rott, E. (1999). Water quality and phytoplankton in theMae KuangUdomtara Reservoir, Chiang Mai, Thailand. *J. Sci. Fac. Cmu., 26(1): 25-43.*

[6] Cairns, J.Jr. and Dickson, K. J. *Wat. Poll. Control Fed., 1971, 775*.

[7] Eva Willen. *Ambio, 2001, 30 (8).*

[8]Bellinger, E.G., Sigee, D.C.,2010. *Freshwater AlgaeIdentification and Use as Bioindicators*. A John Wiley & Sons, Ltd, Publication. *ISBN 978-0-470-05814-5.*

[9] Ward, H. B. and Whipple, G. C. *Freshwater Biology edited by W. T. Edmonson*. John Wiley &Sons., Inc. New York,*19591248 pp.*

[10]Desikachary, *Cyanophyta (Monograph*); ICAR, New Delhi, *1959, 686 pp*.

[11]APHA (1989): *Standard method for the experimentation of water and waste water*, American Public Health Association, New York.

[12]Bishop, J.E. (1973). Limnology of small Malayan river, Sungai Gomback.Dr. W. Junk Publishers, The Hague.

[13] Jain, S.M., Sharma, M. and Thakur, R. (1996). Seasonal variations in physico-chemical parameters of Halai reservoir of Vidisha district, India. *Indian Journal of Ecobiology. 8(3): 181-188.*

[14]Taheruzzaman, Q. and Kushari, D. P. (1995). Study of some physico-chemical properties of the different water bodies in Burdwan with special reference to effluents resulting from anthropogenic activities.*I.J.E.P., 15 (5): 344-349.*

[15] Prasad, B.B. and Singh, R.B. (2003). Composition, abundance and distribution of phytoplankton and zoobenthos in a tropical water body.*Nat. Envin. Pollut.Technol., 2: 255-258.*

[16] Palmer, C.M. *J. Phycol., 1969, 5:78-82*.

[17]Verma, J.P. and Mohanty, R.C. *Poll. Res., 1995, 14:233-242.*

[18]Munawar, M. (1972). Limnological studies of fresh water ponds of Hyderabad, India-II The biocoenose, distribution of unicellular and colonial phytoplankton in polluted and unpolluted environment.*Hydrobiologia. 3: 105-128.*

[19]Venkateshwarlu, V..*Hydrobiol.,1969, 34(3-4) :533-560.*

[20] Round, F.E. (1973). *The Biology of Algae.* 2nd edi., St. Martins Press, New York.

[21] Ludwik, J.A. and J.F. Reynolds: *Statistical ecology a primer on methods and computing A Wiley-Interscience Publication*. New York.pp.1-337 (1998).