Appendix

Collection Details - November 2018 to October 2019

Collections			Stations	
No.	**Bottle No.**	**Date**	**No.**	**Name**
1	Cht 11	1/11/2018	3	Chittur
2	Chl 11	1/11/2018	4	Chulliyar
3	Kap 11	1/11/2018	6	Kalpathy
4	Kan 11	1/11/2018	5	Kannadi
5	Maz 11	1/11/2018	7	Malampuzha
6	Man 11	15/11/2018	2	Mayannur
7	Kam 11	15/11/2018	8	Karimpuzha
8	Kod 11	15/11/2018	1	Koodallur
9	Muk 11	15/11/2018	9	Mukkali
10	Seek 11	15/11/2018	10	Seenkara
11	Kan 12	12/12/2018	5	Kannadi
12	Cht 12	12/12/2018	3	Chittur
13	Chl 12	12/12/2018	4	Chulliyar
14	Maz 12	12/12/2018	7	Malampuzha
15	Kap 12	12/12/2018	6	Kalpathy
16	Kam 12	19/12/2018	8	Karimpuzha
17	Kod 12	19/12/2018	1	Koodallur
18	Man 12	19/12/2018	2	Mayannur
19	Muk 12	19/12/2018	9	Mukkali
20	Seek 12	19/12/2018	10	Seenkara
21	Cht 01	22/01/2019	3	Chittur
22	Chl 01	22/01/2019	4	Chulliyar
23	Maz 01	22/01/2019	7	Malampuzha
24	Kap 01	22/01/2019	6	Kalpathy
25	Kan 01	22/01/2019	5	Kannadi
26	Man 01	28/01/2019	2	Mayannur
27	Muk 01	28/01/2019	9	Mukkali
28	Seek 01	28/01/2019	10	Seenkara
29	Kam 01	28/01/2019	8	Karimpuzha
30	Kod 01	28/01/2019	1	Koodallur
31	Kod 02	13/02/2019	1	Koodallur
32	Man 02	13/02/2019	2	Mayannur
33	Kam 02	13/02/2019	8	Karimpuzha
34	Muk 02	13/02/2019	9	Mukkali
35	Seek 02	13/02/2019	10	Seenkara
36	Maz 02	22/02/2019	7	Malampuzha
37	Kap 02	22/02/2019	6	Kalpathy
38	Kan 02	22/02/2019	5	Kannadi
39	Cht 02	22/02/2019	3	Chittur
40	Chl 02	22/02/2019	4	Chulliyar
41	Cht 03	04/03/2019	3	Chittur
42	Kap 03	04/03/2019	6	Kalpathy
43	Kan 03	04/03/2019	5	Kannadi

44	Maz 03	04/03/2019	7	Malampuzha
45	Chl 03	04/03/2019	4	Chulliyar
46	Kod 03	19/03/2019	1	Koodallur
47	Man 03	19/03/2019	2	Mayannur
48	Kam 03	19/03/2019	8	Karimpuzha
49	Muk 03	19/03/2019	9	Mukkali
50	Seek 03	19/03/2019	10	Seenkara
51	Maz 04	3/04/2019	7	Malampuzha
52	Kap 04	3/04/2019	6	Kalpathy
53	Kan 04	3/04/2019	5	Kannadi
54	Cht 04	3/04/2019	3	Chittur
55	Chl 04	3/04/2019	4	Chulliyar
56	Kod 04	16/04/2019	1	Koodallur
57	Man 04	16/04/2019	2	Mayannur
58	Kam 04	16/04/2019	8	Karimpuzha
59	Muk 04	16/04/2019	9	Mukkali
60	Seek 04	16/04/2019	10	Seenkara
61	Chl 05	18/05/2019	4	Chulliyar
62	Cht 05	18/05/2019	3	Chittur
63	Maz 05	18/05/2019	7	Malampuzha
64	Kap 05	18/05/2019	6	Kalpathy
65	Kan 05	18/05/2019	5	Kannadi
66	Muk 05	28/05/2019	9	Mukkali
67	Seek 05	28/05/2019	10	Seenkara
68	Kam 05	28/05/2019	8	Karimpuzha
69	Kod 05	28/05/2019	1	Koodallur
70	Man 05	28/05/2019	2	Mayannur
71	Cht 06	18/06/2019	3	Chittur
72	Kap 06	18/06/2019	6	Kalpathy
73	Kan 06	18/06/2019	5	Kannadi
74	Maz 06	18/06/2019	7	Malampuzha
75	Chl 06	18/06/2019	4	Chulliyar
76	Kod 06	30/06/2019	1	Koodallur
77	Man 06	30/06/2019	2	Mayannur
78	Kam 06	30/06/2019	8	Karimpuzha
79	Muk 06	30/06/2019	9	Mukkali
80	Seek 06	30/06/2019	10	Seenkara
81	Maz 07	16/07/2019	7	Malampuzha
82	Chl 07	16/07/2019	4	Chulliyar
83	Cht 07	16/07/2019	3	Chittur
84	Kap 07	16/07/2019	6	Kalpathy
85	Kan 07	16/07/2019	5	Kannadi
86	Kod 07	28/07/2019	1	Koodallur
87	Man 07	28/07/2019	2	Mayannur
88	Kam 07	28/07/2019	8	Karimpuzha
89	Muk 07	28/07/2019	9	Mukkali
90	Seek 07	28/07/2019	10	Seenkara
91	Chl 08	18/08/2019	4	Chulliyar

92	Cht 08	18/08/2019	3	Chittur
93	Maz 08	18/08/2019	7	Malampuzha
94	Kap 08	18/08/2019	6	Kalpathy
95	Kan 08	18/08/2019	5	Kannadi
96	Kam 08	25/08/2019	8	Karimpuzha
97	Muk 08	25/08/2019	9	Mukkali
98	Seek 08	25/08/2019	10	Seenkara
99	Kod 08	25/08/2019	1	Koodallur
100	Man 08	25/08/2019	2	Mayannur
101	Kod 09	18/09/2019	1	Koodallur
102	Man 09	18/09/2019	2	Mayannur
103	Kam 09	18/09/2019	8	Karimpuzha
104	Muk 09	18/09/2019	9	Mukkali
105	Seek 09	18/09/2019	10	Seenkara
106	Chl 09	22/09/2019	4	Chulliyar
107	Cht 09	22/09/2019	3	Chittur
108	Kan 09	22/09/2019	5	Kannadi
109	Kap 09	22/09/2019	6	Kalpathy
110	Maz 09	22/09/2019	7	Malampuzha
111	Cht 10	15/10/2019	3	Chittur
112	Kap 10	15/10/2019	6	Kalpathy
113	Kan 10	15/10/2019	5	Kannadi
114	Maz 10	15/10/2019	7	Malampuzha
115	Chl 10	15/10/2019	4	Chulliyar
116	Kod 10	27/10/2019	1	Koodallur
117	Man 10	27/10/2019	2	Mayannur
118	Kam 10	27/10/2019	8	Karimpuzha
119	Muk 10	27/10/2019	9	Mukkali
120	Seek 10	27/10/2019	10	Seenkara

Monthly values of physico chemical parameters

Temperature	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	25.65±0.35	31.5±0.36	29.1±0.62	30.57±0.47	31.23±0.31	29.6±0.44	29.2±0.26	28.53±0.38	25.87±0.23	26.75±0.07
Dec	28.63±0.15	30.97±0.32	26.53±0.32	28.83±0.31	28.63±0.15	28.53±0.38	27.07±0.15	30.27±0.40	27.53±0.55	25.93±0.49
Jan	29.7±1.13	28.67±0.86	27.5±0.4	28.67±0.4	27.93±0.15	27.87±0.35	28.53±0.35	29.2±0.14	28.35±0.35	27.9±0.14
Feb	29.5±0.42	28.75±0.07	30.4±0.28	29.7±0.14	31.9±0.42	32.45±0.07	31.35±0.48	30.89±0.28	29.7±1.41	30.4±0.14
Mar	30.8±0.61	31.77±0.25	33.03±0.59	32.77±0.75	30.83±0.80	32.63±0.47	33.87±0.31	34.3±0.2	35.33±0.57	31.87±0.25
Apr	31.05±0.07	31.93±0.81	33.4±0.56	32.1±0.79	34.97±0.21	34.27±0.06	34.37±0.12	33.15±0.21	30.85±0.49	31.55±0.35
May	32±0.14	32.27±0.45	34.07±0.15	30.4±0.56	32.17±0.93	34.07±0.15	32.5±0.44	34.0±0.28	32.4±0.42	32.6±0.14
Jun	30.8±0.1	31.27±0.06	30.1±0.1	29.7±0.2	31.43±0.38	31.57±0.21	32.13±0.25	30.4±0.1	27.97±0.06	27.93±0.06
Jul	28.97±0.15	29.77±0.40	28.7±0.17	28.33±0.12	29.27±0.35	28.97±0.31	29±0.53	26.83±0.35	25.57±0.38	25.4±0.36
Aug	28.7±0.14	28.4±0.42	28.3±0.14	29.65±0.21	28.25±0.49	29±0.42	29.05±0.21	25.73±0.15	23.33±0.21	23.23±0.25
Sep	29.8±0.1	28.6±0.61	29.63±0.12	29.87±0.42	32±0.36	31.13±0.25	31.6±0.2	27.6±0.46	25.23±0.57	25.77±0.45
Oct	28.43±0.15	28.63±0.12	29.03±0.67	29.27±0.15	29.87±0.83	29.87±0.57	29.13±0.25	26.9±0.2	26±0.14	26.2±0.28

pH	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	8.25±0.21	8.36±0.03	8.02±0.26	8.32±0.08	8.41±0.06	8.43±0.038	8.43±0.03	8.39±0.014	8.23±0.04	8.22±0.02
Dec	8.33±0.06	8.30±0.35	8.27±0.05	8.32±0.02	8.59±0.02	8.42±0.04	8.6±0.02	8.1±0.1	8.33±0.15	8.1±0.1
Jan	8.25±0.07	8.36±0.04	8.35±0.05	8.0 ±0.21	8.40±0.03	8.5±0.02	8.83±0.04	8.65±0.04	8.35±0.04	8.25±0.06
Feb	8.43±0.06	8.55±0.07	8.55±0.07	8.7±0.14	8.1±0.1	8.4±0.14	8.05±0.07	8.3±0.14	8.35±0.07	8.2±0.14
Mar	9.43±0.06	9.36±0.05	8.5±0.08	8.35±0.07	8.3±0.36	8.77±0.07	9.15±0.13	8.13±0.15	8.33±0.06	8.17±0.06
Apr	8.46±0.04	8.4±0.09	8.45±0.07	8.6±0.04	8.37±0.07	8.87±0.04	8.72±0.07	8.3±0.01	8.59±0.014	8.48±0.014
May	8.61±0.02	8.69±0.03	8.54±0.05	8.87±0.17	8.75±0.07	8.96±0.04	8.91±0.03	8.86±0.08	8.92±0.03	8.62±0.02
Jun	8.7±0.1	9.5±0.2	8.7±0.1	8.5±0.1	8.83±0.06	8.97±0.12	9.23±0.06	8.83±0.15	8.93±0.15	8.6±0.1
Jul	8.37±0.12	9.5±0.52	8.6±0.1	8.37±0.06	8.77±0.06	8.83±0.12	8.97±0.31	8.67±0.15	8.9±0.1	9.03±0.05
Aug	7.87±0.16	7.65±0.07	8.05±0.49	8.6±0.42	8.45±0.35	8.45±0.07	8.8±0.14	7.7±0.01	7.47±0.42	8.2±0.01
Sep	7.73±0.15	7.7±0.2	8.97±0.15	8.5±0.2	9.17±0.06	9.27±0.15	9.33±0.06	8.43±0.05	8.63±0.06	8.67±0.05
Oct	8.73±0.23	8.6±0.26	8.97±0.05	8.77±0.12	8.63±0.06	8.67 ±0.23	9.13±0.12	8.8±0.1	8.5±0.14	8.65±0.04

EC	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	286±1.41	302.67±36.3	599.33±6.52	281.33±4.16	645.33±2.5	1262.3±6.0	1374±13.4	64.67±0.58	49.33±1.15	50.5±3.54
Dec	296.67±0.58	202±47.57	548.33±6.11	678.33±11.3	505.67±2.8	734.33±7.7	1127.3±9.8	68.67±3.06	54.33±3.21	57±2
Jan	296.5±3.54	299.67±6.43	396.67±3.51	666.33±8.02	496.3±15.1	569±56.35	775.33±2.3	66±4.24	52±4.24	52±1.41
Feb	365.5±0.70	286.5±0.70	382±9.89	392±8.49	495±2.83	392.5±7.78	620±2.83	59.5±0.70	51±1.41	55.5±0.70
Mar	182.33±3.06	302.33±2.51	367.33±3.21	689±3	503±34.87	145.33±1.5	266.33±1.1	80.33±1.53	58±1	67.67±1.15
Apr	182±1.41	261.33±20.9	304.33±16.1	525.67±8.14	301±6.25	726.5±4.95	837.67±9.2	68±1.41	63±2.83	58.5±0.71
May	168.5±4.95	145.33±7.37	432.67±6.51	492.67±16.9	419±18.36	625±25.71	681.67±7.2	78.5±2.12	54.5±2.12	61±2.83
Jun	144±1.73	300.33±2.31	397.67±5.03	464.67±8.33	413±4.58	176.67±1.1	558.33±9.0	65±3.46	58±4	52.67±6.02
Jul	128±2.65	216±27.87	508±61.59	674.33±3.21	481.33±1.1	444±1	559.67±8.3	49±2.65	20±1	20.33±0.58
Aug	159.5±2.12	165.67±7.78	280.5±12.02	568±11.31	171±18.38	614±28.28	726±39.59	49.67±1.15	28.5±1	31.33±0.58
Sep	239±7.21	175.33±3.51	475.67±25.6	676.5±4.95	572±2	398.33±2.0	733.33±7.5	51±1	34.33±3.21	32±1
Oct	239.33±17.7	239.33±17.7	328.33±2.52	510.33±7.23	378±13.08	672.33±2.8	693±4.58	54±1	38.5±0.70	32±2.83

TDS	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	100±2.83	119.33±41.19	308.33±37.09	134.67±1.53	315.67±0.58	623.33±5.03	684±6.56	30.67±0.58	25.33±0.58	27±1.41
Dec	144±1	106.33±20.50	266.33±3.51	325.67±1.15	246±1.73	357±4.58	560.67±7.57	32.67±1.15	25.33±1.54	26.67±1.53
Jan	137.5±2.12	148.33±6.66	190.33±2.08	326.33±2.08	83.67±1.15	185.33±11.37	383.67±1.15	36±2.83	27.5±2.12	30.5±2.12
Feb	176.67±1.15	137±1.41	132.5±6.36	188±1.41	241.5±2.12	189±2.12	301.5±0.70	27±1.41	24.5±0.70	26.5±0.70
Mar	87±1	145.33±1.53	177±2	334.67±4.04	244±15.72	292.67±31.79	431.67±5.51	38.33±0.58	27.67±0.58	31.67±1.15
Apr	83.5±2.12	167±28	148±7	264.67±19.35	143.67±3.06	261.33±3.06	458.67±8.02	34±2.83	25±2.83	24.5±4.95
May	80.5±2.12	81.67±8.74	219.67±30.44	234.67±9.07	227±37.40	356±47.16	483.67±10.79	37±1.41	23.5±2.12	28.5±0.71
Jun	68.33±0.58	145.33±1.15	174.67±2.08	264.33±3.21	191.67±1.53	199.33±0.58	291±3	31.33±0.58	18.33±0.58	18.67±0.58
Jul	60.67±1.15	108.67±10.02	243±26.85	232±6.24	107.67±10.59	313±2.65	375.33±4.73	23.33±1.53	9.33±0.58	9.33±0.58
Aug	79.5±6.36	80.5±0.71	156.5±12.02	88±9.89	131±9.89	292±7.07	327.5±40.31	23.33±0.58	43.67±1.53	15.67±1.15
Sep	115.33±3.51	91.67±9.29	263.33±43.88	236.67±8.33	278±1	193.67±2.08	356±4.58	24.67±1.15	16.33±1.53	23.9±2.89
Oct	115±7.81	90.33±12.66	158.33±1.53	259.33±9.07	332±8.72	309.67±2.52	367±33.05	25.67±0.58	22.5±2.12	20.5±2.12

Nitrate	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	0.004±0.0007	0.06±0.002	0.015±0.005	0.014±0.002	0.039±0.009	0.02±0.002	0.018±0.0038	0.0317±0.01	0.056±0.039	0.044±0.01
Dec	0.004±0.0001	0.008±0.007	0.052±0.004	0.021±0.0025	0.045±0.006	0.04±0.013	0.04±0.003	0.023±0.002	0.002±0.001	0.002±0.001
Jan	0.003±0.0035	0.05±0.003	0.034±0.0076	0.054±0.012	0.069±0.0035	0.03±0.004	0.029±0.005	0.022±0.001	0.005±0.001	0.02±0.007
Feb	0.003±0.0007	0.053±0.007	0.05±0.013	0.061±0.001	0.048±0.009	0.06±0.007	0.055±0.009	0.003±0.001	0.0055±0.01	0.001±0.001
Mar	0.48±0.03	0.47±0.03	0.029±0.006	0.031±0.005	0.015±0.004	0.05±0.003	0.005±0.001	0.38±0.15	0.207±0.045	0.224±0.176
Apr	0.335±0.035	0.321±0.021	0.249±0.003	0.264±0.005	0.268±0.006	0.25±0.008	0.29±0.019	0.405±0.021	0.24±0.057	0.035±0.004
May	0.47±0.014	0.548±0.05	0.456±0.015	0.43±0.069	0.53±0.033	0.495±0.02	0.616±0.023	0.52±±0.014	0.525±0.021	0.49±0.014
Jun	0.256±0.015	0.089±0.006	0.045±0.005	0.043±0.004	0.042±0.006	0.02±0.004	0.067±0.023	0.234±±0.01	0.02±0.01	0.033±0.01
Jul	0.043±0.032	0.0525±0.01	0.053±0.012	0.063±0.007	0.042±0.003	0.05±0.013	0.066±0.007	0.035±0.007	0.055±0.007	0.061±0.001
Aug	0.033±0.012	0.023±0.006	0.041±0.002	0.049±0.005	0.038±0.0014	0.05±0.001	0.064±0.0035	0.006±0.004	0.023±0.005	0.008±0.002
Sep	0.085±0.013	0.072±0.013	0.069±0.016	0.086±0.017	0.0956±0.012	0.092±0.03	0.092±0.0015	0.084±0.011	0.094±0.011	0.124±0.011
Oct	0.184±0.016	0.289±0.012	0.247±0.039	0.187±0.014	0.241±0.004	0.243±0.05	0.347±0.023	0.874±0.020	0.12±0.014	0.205±0.021

Phosphate	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	0.14±0.01	0.13±0.008	0.02±0.006	0.03±0.008	0.038±0.01	0.038±0.004	0.14±0.029	0.13±0.03	0.14±0.017	0.18±0.04
Dec	0.168±0.02	0.164±0.005	0.04±0.01	0.03±0.005	0.039±0.004	0.05±0.006	0.04±0.005	0.13±0.03	0.15±0.01	0.15±0.005
Jan	0.09±0.003	0.06±0.014	0.04±0.007	0.029±0.006	0.044±0.004	0.031±0.004	0.058±0.031	0.07±0.056	0.2±0.008	0.14±0.006
Feb	0.21±0.014	0.21±0.05	0.302±0.027	0.312±0.35	0.25±0.02	0.21±0.005	0.137±0.07	0.19±0.025	0.18±0.02	0.18±0.003
Mar	0.09±0.10	0.04±0.011	0.31±0.037	0.38±0.05	0.29±0.09	0.39±0.08	0.21±0.02	0.15±0.04	0.2±0.001	0.51±0.61
Apr	0.13±0.007	0.12±0.03	0.10±0.008	0.198±0.003	0.16±0.08	0.19±0.08	0.19±0.01	0.18±0.014	0.14±0.006	0.16±0.0007
May	0.15±0.014	0.131±0.007	0.15±0.02	0.23±0.002	0.13±0.009	0.13±0.006	0.18±0.005	0.14±0.014	0.17±0.014	0.18±0.014
Jun	0.15±0.01	0.12±0.005	0.083±0.02	0.19±0.07	0.12±0.003	0.18±0.001	0.19±0.008	0.15±0.03	0.09±0.02	0.05±0.04
Jul	0.19±0.012	0.143±0.007	0.12±0.02	0.08±0.006	0.076±0.002	0.13±0.007	0.18±0.01	0.19±0.005	0.14±0.03	0.15±0.03
Aug	0.12±0.02	0.015±0.003	0.14±0.02	0.044±0.003	0.053±0.006	0.094±0.001	0.13±0.004	0.09±0.05	0.16±0.02	0.19±0.005
Sep	0.02±0.004	0.13±0.178	0.03±0.006	0.03±0.007	0.029±0.005	0.03±0.006	0.041±0.003	0.03±0.006	0.03±0.003	0.034±0.007
Oct	0.02±0.001	0.02±0.002	0.04±0.001	0.019±0.002	0.04±0.001	0.029±0.007	0.12±0.02	0.01±0.008	0.031±0.002	0.037±0.003

Silicate	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	0.09±0.002	0.058±0.02	3.07±0.17	1.67±0.02	2.88±0.03	3.23±0.05	3.42±0.09	0.25±0.07	0.28±0.23	0.35±0.078
Dec	1.37±0.11	1.29±0.09	2.56±0.11	3.67±0.03	2.09±0.05	2.71±0.02	1.87±0.12	1.12±0.12	1.34±0.06	1.41±0.07
Jan	1.16±0.02	1.37±0.09	1.72±0.15	3.48±0.57	1.77±0.11	1.57±0.038	1.89±0.025	1.12±0.06	1.26±0.04	1.56±0.049
Feb	1.31±0.08	1.09±0.029	1.26±0.014	0.57±0.07	1.64±0.160	1.67±0.11	2.09±0.04	1.42±0.36	1.69±0.03	1.71±0.007
Mar	0.42±0.12	0.48±0.046	1.24±0.003	1.87±0.09	0.59±0.03	0.77±0.09	1.78±0.003	0.76±0.02	0.87±0.023	0.88±0.077
Apr	0.37±0.06	0.39±0.05	1.17±0.03	1.56±0.01	0.73±0.03	0.21±0.003	1.27±0.008	0.67±0.03	0.61±0.09	0.61±0.045
May	0.69±0.05	0.62±0.02	1.30±0.019	1.21±0.03	1.3±0.03	1.13±0.07	1.33±0.03	0.57±0.06	0.67±0.03	0.69±0.03
Jun	0.63±0.031	0.63±0.11	1.51±0.03	1.74±0.18	0.49±0.37	1.43±0.021	1.88±0.005	0.63±0.03	0.32±0.005	0.35±0.02
Jul	0.49±0.02	0.73±0.04	1.24±0.059	1.31±0.04	1.189±0.077	1.20±0.04	1.73±0.04	0.4±0.026	0.14±0.02	0.16±0.01
Aug	0.47±0.23	0.79±0.02	1.30±0.03	1.14±0.013	1.42±0.006	1.24±0.002	1.28±0.019	0.55±0.017	0.47±0.25	0.27±0.03
Sep	0.42±0.04	0.62±0.06	0.28±0.01	0.42±0.04	0.27±0.02	0.59±0.08	0.86±0.18	0.52±0.03	0.27±0.02	0.54±0.04
Oct	0.25±0.001	0.29±0.08	0.39±0.02	0.52±0.02	0.38±0.02	0.43±0.03	0.54±0.03	0.24±0.01	0.26±0.002	0.49±0.03

DO	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nov	7.15±0.07	7.5±1.27	7.55±0.07	7.9±0.14	7.35±0.21	7.55±0.07	7.85±0.07	7.47±1.23	8.53±0.37	8.45±0.07
Dec	7.93±0.49	5.27±1.01	7.13±0.15	7.93±0.66	7.9±0.1	5.93±0.42	8.03±0.25	7.43±1.05	8.6±0.69	7.77±0.51
Jan	6.85±0.07	7.47±0.15	7.77±0.5	6.6±0.75	8.53±0.25	6.2±0.56	6.73±0.31	7.1±0.14	8.5±0.14	7.7±0.14
Feb	6.05±0.21	6.9±0.14	7±0.14	7.45±0.07	6.45±0.63	7.2±0.14	6.75±0.21	6.1±0.42	7±0.28	7.2±0.42
Mar	7.07±0.12	7.2±0.3	7.17±0.15	7.76±0.55	7.13±0.12	6.93±0.15	6.67±0.49	6.83±0.12	5.8±0.26	5.1±0.1
Apr	6.4±0.14	6.9±0.1	7±0.17	7.07±0.05	6.87±0.15	7.17±0.06	6.7±0.2	6.8±0.14	6.75±0.49	6.85±0.07
May	5.8±0.1	7.15±0.21	7.45±0.07	7.45±0.21	6.9±0.14	7.2±0.14	6.7±0.28	7.1±0.14	7.05±0.21	6.7±0.14
Jun	6.1±0.28	7.1±0.14	5.8±0.14	7.2±0.14	7.25±0.07	7.2±0.14	6.15±0.28	6.97±0.14	7.35±0.07	6.6±0.98
Jul	5.7±0.28	8.05±0.35	5.75±0.21	7.1±0.28	6.6±0.42	7.35±0.35	5.75±0.21	5.9±0.42	6.6±0.42	6.25±0.49
Aug	5.75±0.64	7.5±0.3	6.97±0.12	7.05±0.07	7.15±0.07	7.27±0.31	6.37±0.12	6.33±0.85	7±0.4	6.53±0.25
Sep	7.07±0.45	6.9±0.14	6.76±0.25	6.07±0.25	6.97±0.32	6.37±0.20	5.9±0.1	5.93±0.25	6.73±0.31	6.8±0.92
Oct	5.5±0.51	7.5±0.1	6.47±0.30	5±0.28	6.5±0.45	6.47±0.58	5.87±0.55	6.07±0.15	6.65±0.21	6.9±0.28

List of papers published/Communicated

- K. K. Seena, Ignatius Antony & P. V. Anto (2019). Seasonal influences on phytoplankton diversity in tributaries of river Bharathapuzha, Palakkad District, Kerala, *Indian Hydrobiology*. 18(1 & 2), 252–264.
- Seena K. K., Ignatius Antony & Anto P.V. (2018). Review Microalgae:- A Potential Source, *International journal of Research and Analytical Reviews*. 5(3), 484-494.

Conference paper

- Seena K. K., Ignatius Antony, (2019). Phytoplankton diversity indices of Kalpathy, River, Palakkad, *Albertian Journal of Multidisciplinary Research.* 1(1), 111-115.
- Seena K. K., Ignatius Antony & Anto P.V. The seasonal oscillation of physico-chemical parameters and phytoplankton distribution from South West Coast of India (Bharathapuzha river basin), *Brazilian Journal of Botany*.
- Seena K. K., Ignatius Antony, Anto P.V. & Dhanya Jose. First new report of *Micrasterias laticeps* var. *acuminata* Willi Krieger from south Southwest Coast of India (Bharathapuzha river basin), *Limnology*.

List of paper presentations

- Fresh water algal diversity and physico-chemical parameter study from Chittur river, Kerala on national conference on Vistas in biodiversity, biology, biotechnology and nanotechnology of algae at Madras Christian College, Chennai from 20/09/2018-22/09/2018
- Micro algal diversity from Chittur river, Palakkad on national seminar "Plant-microbe Interactions" Sree Neelakanta Government Sanskrit College, Pattambi from 05/12/2018-06/12/2018
- Phytoplankton diversity indices of Kalpathy river, Palakkad on international seminar on "Albertian Knowledge Summit-an International conference on multidisciplinary research" at St.Alberts College, Eranakulam on 14/01/2019
- Ecological assessment of Chittur river using phytoplankton diversity on national seminar "Species The Passion V" Air Pollution At St.Thomas, College, Thrissur from 26/06/2019 to 27/06/2019
- Seasonal variation of phytoplankton diversity in two tributaries of river Bharathapuzha, Palakkad District" on national conference on bioprospecting of algae:- resources, conservation and utilization - Central University of Kerala from 01/08/2019-02/08/2019

Indian Hydrobiology, 18(1 & 2): 252–264, 2019

Seasonal Influences on Phytoplankton Diversity in Tributaries of River Bharathapuzha, Palakkad District, Kerala

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Abstract

The present paper determines the current biological and ecological state of phytoplankton diversity in three tributaries of Bharathapuzha viz., Chittur, Kalpathy and Kannadi Rivers. The phytoplankton sampling was done during three different seasons i.e. pre-monsoon, monsoon, and post-monsoon of the year 2018–2019. Environmental characteristics, Phytoplankton diversity and seasonal fluctuations were investigated from November 2018–August 2019. Eighty-one species were observed during the present study which constituted 40 species of Bacillariophyceae, 25 species of Chlorophyceae, 8 species of Euglenophyceae, 6 species of Cyanophyceae,1 species each of Xanthophyceae and Dinophyceae. Comparing the population, the abundance of each group of phytoplankton was in the order of Bacillariophyceae > Chlorophyceae > Euglenophyceae > Cyanophyceae > Dinophyceae and Xanthophyceae. Species richness and evenness high in pre-monsoon season, while species diversity in all the stations high in post-monsoon. The present study resulted in identification of 12 pollution tolerant algal genera namely *Oscillatoria, Gomphonema, Cyclotella, Cymbella, Melosira, Navicula, Nitzschia, Synedra, Phacus, Euglena, Closterium and Scenedesmus.* Temperature and pH showed marked increase in Pre-monsoon season. BOD was also noted high along with pH and temperature. TDS and conductivity level observed high during the period of post-monsoon. Higher values of nitrate and silicate were recorded in dry season. Dissolved oxygen was observed low in pre-monsoon while the highest value in monsoon season. Pollution indices analyses indicated, the organic pollution and river and eutrophic in nature of the river.

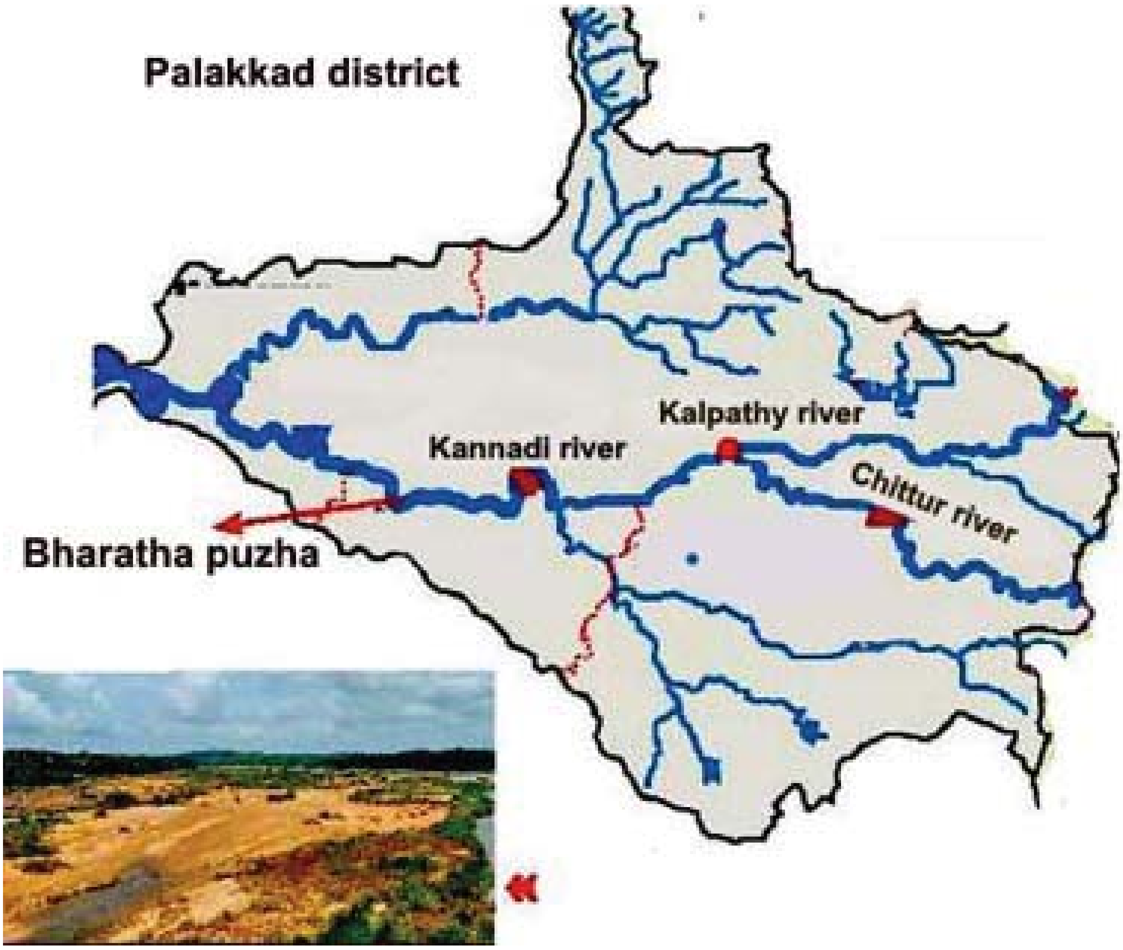
Key words: Phytoplankton, diversity index, Physico-chemical parameters, Seasonal changes.

Introduction

Phytoplanktons constitute the primary producers in both freshwater and marine ecosystems and have substantial role in calcification, silicification and nitrogen fixation (Baliarsingh *et al.*, 2012; Singh and Swarup, 1980). Facts on taxonomy of phytoplankton are vibrant to study the community dynamics in spatio-temporal scale (Gameiro *et al.*, 2007). Documentation to lively environment is a valuable thing as species composition and density of phytoplankton are sensitive to environmental changes. Varied human actions in river ecosystems can affect in alteration of water quality (leading to eutrophication), and introduction of non-native species. As a result, blooms of both non-toxic or toxic phytoplanktons arise, influencing the seasonal patterns of dominant phytoplankton community structure, thereby distressing or polluting physical, chemical and biological characteristics of water bodies. Pollution in rivers depends on the number of people living on its banks, their cultures and commercial growth. Pollution of the major rivers of India through discharge of industrial effluents and domestic sewage are the major threat in recent times (Singh *et al.*, 2007). The physicochemical aspects of river water were reported by (Gurumayum *et al.,* 2002; Deshmukh and Ambore, 2006; Santhosh, 2007; Eknath, 2013). Several scientific papers reported the existing status of Indian rivers that are in a dangerously deteriorated situation due to pollution (Biswas and Konar, 2000; Kumari and Rani, 2008; Singh *et al.*, 2007; Yazdandoost *et al.*, 2001a,b). The river water resources in Kerala State are subjected to substantial stress due to changes in riverine ecology (Joy *et al.*, 1990; Koshy and Nayar, 2001; Sankar *et al.*, 2002; Harilal *et al.*, 2004; Joseph and Tessy, 2010; Thomas and Paul, 2015; Sreenisha and Paul, 2016). The water quality is fluctuating hastily due to human activities. This anthropogenic pollutant influx are the crucial sources of change in water quality that led the scientific community for systematic monitoring (Baliarsingh *et al.*, 2012). The phytoplankton due to its importance in ecosystem requires regular study under such fluctuating environment. We focused this study as a first attempt in this river to explore the phytoplankton composition simultaneously with seasonal changes. The outcome of this study will certainly useful for environmental monitoring and impact assessment work.

Study area

Bharathapuzha river or 'Nila' River, the second largest river in Kerala State, with a total length of about 209 km, with a large basin of 6186 sq. km. The average catchment area of the river Bharathapuzha is 1828 mm. The river originates from Aanamalai Hills at Tamil Nadu in the Western Ghats and flows through Coimbatore district of Tamil Nadu, and Palakkad, Malappuram and Thrissur districts of Kerala and finally empties into the Arabian Sea at Ponnani. The major land utilization of Bharathapuzha basin includes forest (26%), cultivated area (52%), fallow (8%) and barren and cultivable land (5%). The major portion of crop is rice followed by coconut and rubber. It is popular for its geo-physical value as well as its cultural and historical significance. The river valley is considered as the frame of civilization in Kerala and have significant role in the cultural formation of Keralites. Nearly one-eighth of the total population in the state depends on the river for various resources. The main tributaries of Bharathapuzha river are Gayathripuzha,



Map 1: Map of Palakkad district showing Bharathapuzha River with sampling sites.

Chitturpuzha, Kalpathipuzha and Thuthapuzha. From the confluence of Kalpathipuzha and Chitturpuzha at Parali, the river acquires the name Bharathapuzha. Three tributaries selected for the current study, Station 1 (Chittur river), Station 2 (Kalpathy river) and station 3 (Kannadi river) (Map 1). Kannadi river along with the kalpathy and Gayathrpuzha irrigate a major portion of the Palakkad district. Station-1 lies on latitude 10.746972°N and longitude 76.6652°E, has a lot of anthropogenic activities around it. Station-2 lies on latitude 10.7471136°N and longitude 76.3935686°E, is characterized by various cultural worships on the banks of this river. Station-3 lies on latitude 10.918532°N and longitude 76.430962°E with dominant grass vegetation and heavy construction.

Materials and methods

The present research work was carried out on fixed sampling points during three seasons such as pre-monsoon, monsoon and post-monsoon of year 2018–2019. Phytoplankton samples were collected from surface and stored in polythene bottles after preservation in 4% formalin. After concentrating the sample by sedimentation method, 1 ml of sample was taken and examined with a Sedgwick rafter counting chamber under a compound microscope with different magnifications. The average count was taken to get the relative number of organisms per ml of original water sample. For taxonomic identification, standard literature and monographs were referred. Identification of phytoplankton organisms was done by consulting published works of Prescott (1962), Sarode and Kamat (1979), Philipose (1967) and Fritsch (1935). Diversity indices were used for the ecological data analysis using Past and Sigma Plot. Simultaneously with algal sampling, Temperature, pH, Conductivity, TDS, Nitrate, Phosphate, Silicate, DO, BOD and algal abundances are assessed for each sample. This analysis was useful to obtain quantitative information on the relationship between species and environmental variables.

Results and discussion

In Bharathapuzha, algae are studied from three selected tributaries namely Chittur, Kalpathy and Kannadi. Physical, chemical and biological lines are frequently considered as basic monitoring methods, for proper water management systems (Rosenberg and Resh, 1993). The taxonomic analysis of algal diversity in tributaries of Bharathapuzha revealed 81 species belonging to 6 algal classes among which Bacillariophyceae prevailed, then Chlorophyceae and Euglenophyceae (Table 1). Among algae, *Synedra, Gomphonema*, *Navicula* and *Scenedesmus* succeeded in all stations. As on (Table 2), total of 36 genera and 81 species belongs to Chlorophyceae (11 genera, 25 species; Plate 1, figs. A–H; Plate 3, fig. H) Bacillariophyceae (13 genera, 40 species; Plate 2, figs A–H; Plate 3, figs. A–E) Cyanophyceae (6 genera, 6 species), Euglenophyceae (4 genera, 8 species; Plate 3, fig. F) Xanthophyceae (1 genus, 1 species) and Dinophyceae (1 genus, 1 species; Plate 3, fig. G). Acccording to the species sensitivity towards pH, all species in study area belongs to alkaliphiles because of their resistance in high pH. Algal indicators of organic pollution according to Wang *et al.* (2014) and Watanabe *et al.* (1986), assigned to 4 species with a prevalence of *Synedra ulna, Cyclotella meneghiniana, Trachelomonas volvocina* and *Pinnularia viridis.* By comparing the details of all three study stations, more algal species seen in Station 1 and Station 3, but least number of species and high diversity observed in station 2. Dominant group included the members of the Bacillariophyceae occur in Station 1, followed by Station 2, next domoinant group is Chlorophyceae in both stations (Fig. 1). By analysing seasonal variations, high dominance of species seen in pre-monsoon, then monsoon season (Fig. 2). Cyanophyceae, Englenophyceae, Xanthophyceae and Dinophyceae counts were low compared to the observations in Bacillariophyceae and Chlorophyceae groups.

pH in all study stations varies from 8.2–9.4, highly alkaline. Conductivity and TDS show marked increase in Post-monsoon season. At the same time, pH is observed high in pre-monsoon. Concentrations on nitrate and silicate high at pre-monsoon,

Table 1: Composition and abundance of Phytoplankton.

Sl. No.	Name of the species	*Pre-monsoon	*Monsoon	*Post-monsoon
	Chlorophyceae			
1	*Scenedesmus hystrix* Lagerheim	8	6	4
2	*Scenedesmus quadricauda* (Turnip) Bebisson	12	10	6
3	*Scenedesmus dimorphus* (Turnip) Kuetzing	4	–	–
4	*Scenedesmus bijugatus* (Turnip) Kuetzing	12	–	–
5	*Scenedesmus acuminatus* (Lagerheim) Chodat	25	–	18
6	*Pediastrum duplex* Meyen	8	13	4
7	*Pediastrum tetras* (Corda) Hansgirg	16	8	–
8	*Pediastrum integrum* Naegeli	12	10	8
9	*Cosmarium granatum* Breb.*ex* Ralfs	16	12	–
10	*Cosmarium retusiforme* (Wille) Gutw.	28		18
11	*Cosmarium blyttii* Wille	2	–	10
12	*Closterium calosporum* Wittr.	6	–	–
13	*Closterium intermedium* Ralfs	5	–	4
14	*Euastrum spinulosum* Delp.	6	4	–
15	*Cosmarium portianum* Arch.	12	8	–
16	*Pediastrum simplex* Meyen	8	6	1
17	*Staurastrum crenulatum* (Nag.) Delp.	12	8	4
18	*Golenkinia radiata* Chodat	9	–	3
19	*Pandorina morum* (Mull.) Bory	25	12	4
20	*Cosmarium medioscrobiculatum* West & West	8	–	–
21	*Micrasterias sp.*	–	–	8
22	*Cosmarium auriculatum* Reinsch	4	6	–
23	*Arthrodesmus sp.*	16	–	6
24	*Closterium validum* West & West	8	6	–
25	*Tetraedron sp.*	6	2	8
	Bacillariophyceae			
26	*Cymbella tumida* (Breb.) Van Heurek.	32	28	36
27	*Gomphonema gracile* Ehr.	24	28	32
28	*Gomphonema subapicatum* F.E.Fritsch & M.F.Rich	28	22	10
29	*Gomphonema parvulum* (Kuetz.) Grun.	29	24	8
30	*Rhopalodia gibba* (Ehr.) Muell.	24	16	18
31	*Gomphonema subventricosum* Hustedt	24	18	–
32	*Cymbella hungarica* (Grunow) Pantocsek	21	–	–
33	*Nitzschia closterium* W. Smith	32	28	16
34	*Nitzschia obtusa* W. Smith	39	26	19
35	*Synedra ulna* (Nitz.) Ehr.	52	29	38
36	*Pinnularia acrosphaeria* Rabenhorst	–	21	–

Table 1: (Continued)

Sl. No.	Name of the species	*Pre-monsoon	*Monsoon	*Post-monsoon
37	*Navicula pupula* Kuetz.	28	18	10
38	*Cymbella laevis* Nageli	19	9	16
39	*Gomphonema lanceolatum* Ehr.	25	–	–
40	*Navicula rhynchocephala* Kuetz.	29	5	8
41	*Nitzschia intermedia* Hantzsch	–	–	14
42	*Cymbella osmanabadensis* Sarode & Kamat	5	–	–
43	*Navicula cuspidata* Kuetz.	38	27	37
44	*Cyclotella glomerata* H.Bachmann	28	12	8
45	*Pinnularia braunii* (Grun.) Cleve	28	18	–
46	*Pinnularia sudetica* (Hilse) Hilse	18	22	22
47	*Gomphonema montanum* (J.Schumann) Grunow	30	21	3
48	*Pinnularia divergens* W.Smith	–	15	12
49	*Gyrosigma acuminatum* (Kuetz.) Rabh.	13	8	4
50	*Synedra acus* Ehrenberg	37	28	–
51	*Cymbella tumidula* Grunow	24	14	16
52	*Cyclotella meneghiniana* Kuetz.	15	–	–
53	*Melosira granulata* (Ehr.) Ralfs	50	23	29
54	*Navicula mutica* Grunow	8	5	–
55	*Surirella tenera* Gregory	–	17	18
56	*Gyrosigma distortum* (W.Smith) Griffith & Henfrey	23	12	–
57	*Surirella capronioides* Gandhi	18	–	9
58	*Pleurosigma salinarum* (Grunow) Grunow	14	8	8
59	*Nitzschia hungarica* Grunow	6	–	5
60	*Surirella robusta* Ehr.	26	18	5
61	*Navicula halophila* (Grun.) Cleve	16	8	–
62	*Pinnularia hartleyana* Greville	8	–	14
63	*Pinnularia viridis* (Nitz.) Ehr.	28	16	18
64	*Hantzschia sp.*	18	6	4
65	*Fragilaria intermedia* Grun.	18	–	12
	Euglenophyceae			
66	*Strombomonas fluviatilis* (Lemm.) Defl.	26	16	18
67	*Phacus longicauda* (Ehr.) Dujardin	19	16	–
68	*Euglena acus* Ehr.	26	12	16
69	*Phacus acuminatus* Stokes	–	6	–
70	*Euglena oblonga* Schmitz.	24	17	3
71	*Trachelomonas armata* (Ehr.) Stein.	14	7	5
72	*Trachelomonas dubia* (Swiremend) Defl.	36	16	18

(Continued)

Table 1: (Continued)

Sl. No.	Name of the species	*Pre-monsoon	*Monsoon	*Post-monsoon
73	*Euglena sp.*	–	25	18
	Cyanophyceae			
74	*Microcystis sp.*	21	8	16
75	*Spirulina sp.*	5	–	8
76	*Oscillatoria sp.*	18	16	24
77	*Aphanocapsa sp.*	–	6	16
78	*Chroococcus turgidus* (Kuetz.) Nag.	28	18	4
79	*Merismopedia glauca* Meyen		12	18
	Xanthophyceae			
80	*Centritractus belonophorus* (Schmidle) Lemmerm.	18	3	–
	Dinophyceae			
81	*Peridinium sp.*	36	28	26
	Total Taxa	**70**	**59**	**56**
	Total individuals	**1352**	**844**	**716**

Note: *Number of phytoplankton per ml in samples.

Table 2: Diversity of Phytoplankton in study area.

Sl. No.	Algal class	Station 1			Station 2			Station 3		
		No. of genera	No. of species	%	No. of genera	No. of species	%	No. of genera	No. of species	%
1	Chlorophyceae	6	13	24	5	8	20	9	11	25
2	Bacillariophyceae	11	31	58	9	18	46	8	21	48
3	Cyanophyceae	3	3	6	4	4	10	5	5	12
4	Euglenophyceae	3	4	8	4	8	21	3	5	11
5	Xanthophyceae	1	1	2	0	0	0	1	1	2
6	Dinophyceae	1	1	2	1	1	3	1	1	2
	Total	24	53		23	39		27	44	

it provides a proper baseline for algae development. BOD also high in pre-monsoon. Dissolved oxygen low in pre-monsoon while high value in monsoon. A persual of Table 3 shows all parameters except pH and Conductivity within permissible limit. Alkaline nature of water bodies and increased conductivity give information about the level of contamination especially due to anthropogenic activities. During post-monsoon season a high level of TDS and electrical conductivity along with rich species diversity are observed. This shows strong correlation between diversity along with chemical parameters.

Community structure analysis

Algal community can predict the status of pollution because of their quick response to the pollutants and Physicochemical properties. Hence this can be used

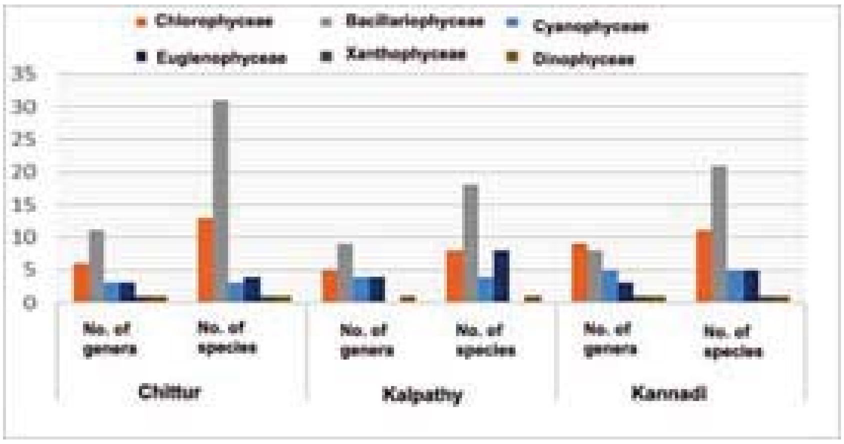


Fig. 1: Distribution of phytoplankton in three stations.

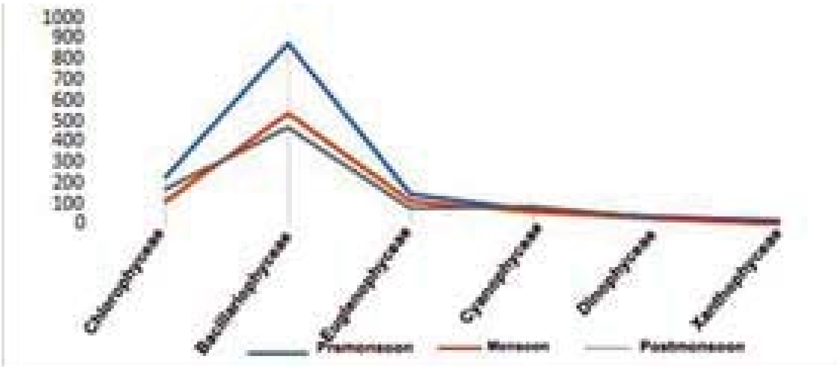


Fig. 2: Distribution of Phytoplankton during different seasons.

Table 3: Results of Physicochemical parameter analysis.

Sl. No.	Parameters	Station 1			Station 2			Station 3			Permissible limit (BIS)
		Pr-M	M	Po-M	Pr-M	M	Po-M	Pr-M	M	Po-M	
1	Temperature °C	30.2	29.1	27	34.2	31.6	28.2	33.5	31.5	28.6	–
2	pH	8.7	8.5	8.8	9.0	8.2	8.4	9.4	8.8	8.9	6.5–8.5
3	Conductivity	433	397.6	556	216	177	752	272	416	506	250
4	TDS (mg/L)	209	174.6	272	104	99	355	131	192	246	500
5	Nitrate(mg/L)	0.46	0.05	0.06	0.47	0.02	0.05	0.52	0.04	0.05	45
6	Phosphate(mg/L)	0.16	0.03	0.07	0.14	0.03	0.04	0.12	0.01	0.02	5
7	Silicate(mg/L)	2.45	1.29	1.53	2.72	0.44	1.05	2.12	1.25	0.64	
8	DO (mg/L)	5.7	7.5	6.6	6.5	7.5	6.4	7.0	7.6	7.1	–
9	BOD	0.8	0.1	0.6	1.9	0.2	0.9	0.4	0.3	0.5	–

Note: Pr-M-Pre-monsoon; M-Monsoon; Po-M-Post-monsoon.

to classify water bodies. According to Nygaard (1978), compound quotient values obtained from the study indicate the intensity of pollution. A compound quotient of value 6.5 in the present study indicates the Eutrophic nature of the entire study area. In 1965, Patrick suggested an idea to the pollution status of water bodies by evaluating algal community. Desmids, Bacillariophyceae,

Table 4: Ecological indices in different seasons.

Sl. No.	Diversity indices	Pre-monsoon	Monsoon	Post-monsoon
1	Taxa	70	59	56
2	Individuals	1352	844	71
3	Simpson	0.9815	0.9782	0.9736
4	Shannon	4.094	3.932	3.799
5	Mergalef	9.571	8.608	8.367

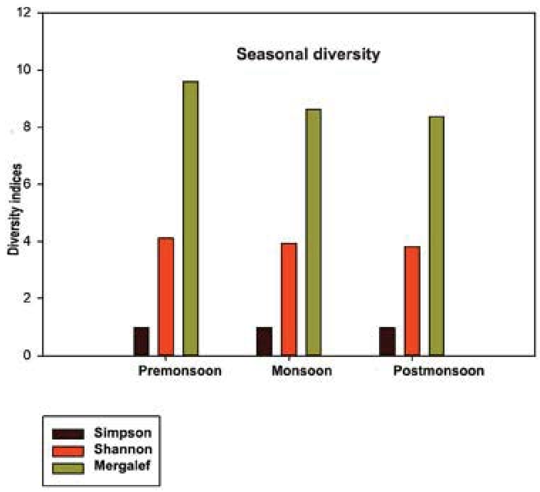


Fig. 3: Diversity profile in different seasons.

Table 5: Ecological indices in different stations.

Sl. No.	Diversity indices	Station 1	Station 2	Station 3
1	Taxa	38	17	29
2	Individuals	836	445	455
3	Simpson	0.9674	0.9272	0.9551
4	Shannon	3.496	2.712	3.218
5	Mergalef	5.499	2.624	4.575

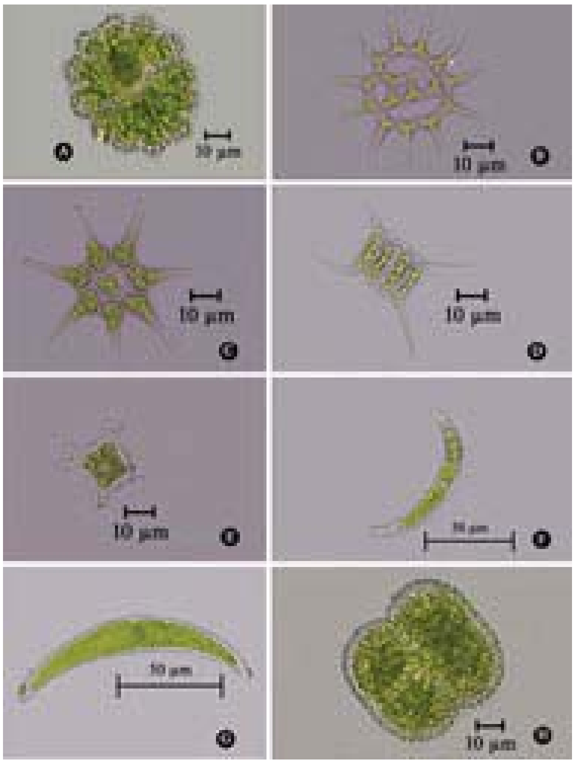


Plate 1: (A) *Euastrum spinulosum* Delp. (B) *Pediastrum simplex* Meyen (C) *Pediastrum integrum* Nageli (D) *Scenedesmus quadricauda* (Turnip) Bebisson (E) *Tetraedron* sp. (F) *Closterium calosporum* Wittr. (G) *Closterium intermedium* Ralfs (H) *Cosmarium* sp.

Cyanophyceae and Euglenophyceae are used to accomplish meaningful evaluation of degree of pollution. Index value is 3.71. By analysing Palmer index (1969), with a high value that is above 20 also indicates the density of pollution may be due to enrichment of nutrients and phytoplanktons. Prasad *et al.* (1988) emphasized the importance of biological survey in monitoring water quality, which is dependent on qualitative and quantitative composition of aquatic population. Among the species diversity profile in all the three stations and seasons, high in post-monsoon but total taxa and species richness high in pre-monsoon season and least in post-monsoon. Shannon and Mergalef indices also high in pre-monsoon (Table 4 and Fig. 3).

The diversity index of the phytoplankton among the sample stations showed that species richness and evenness highest in station 1 followed by station 3 and least in station 2 (Table 5). Least value of Simpson index signifies

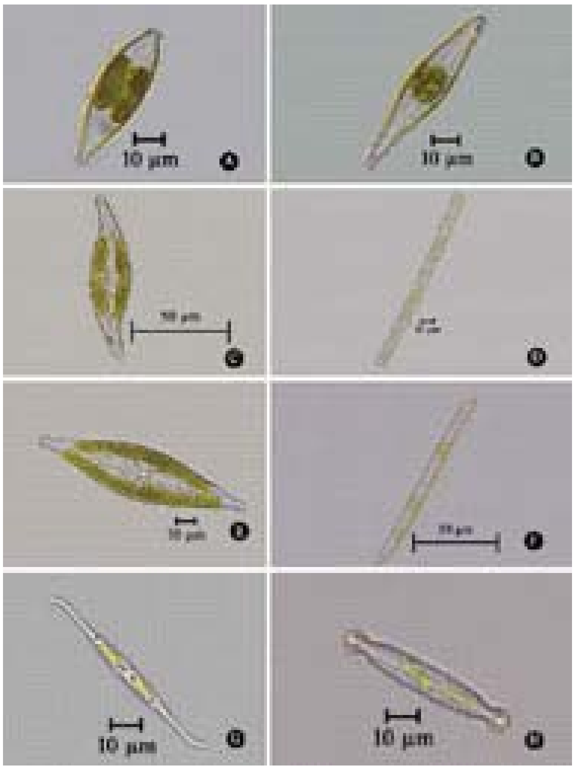


Plate 2: **(A)** ***Gomphonema montanum*** **(J. Schumann) Grunow (B)** ***Gomphonema gracile*** **Ehr. (C)** ***Gyrosigma distortum*** **(W. Smith) Griffith & Henfrey (D)** ***Melosira gramulata*** **(Ehr.) Ralfs (E)** ***Navicula cuspidata*** **Kuetz (F)** ***Nitzschia obtusa*** **W. Smith (G)** ***Nitzschia closterium*** **W. Smith (H)** ***Pinnularia braunii*** **(Grun.) Cleve.**

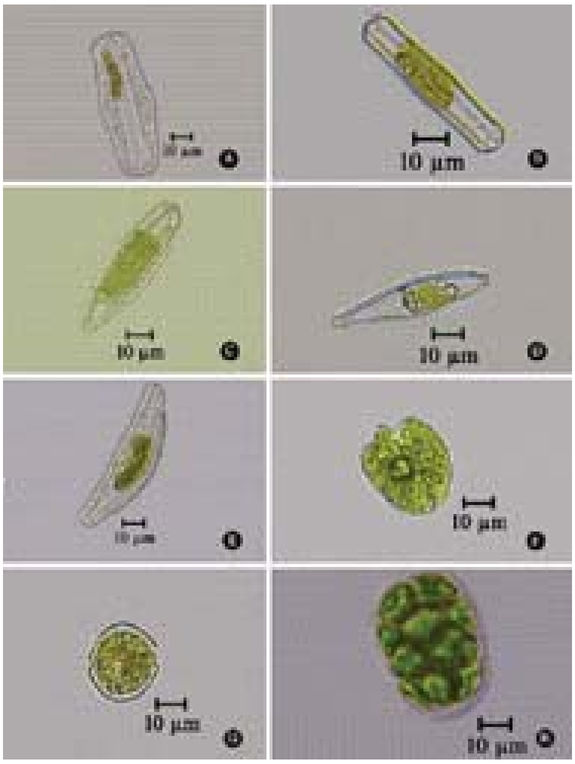


Plate 3: **(A)** ***Rhopalodia gibba*** **(Ehr.) Muell. (B)** ***Pinnularia acrosphaeria*** **Rabenhorst (C)** ***Surirella capronioides*** **Gandhi (D)** ***Gomphonema subapicatum*** **F.E. Fritsch & M.F. Rich (E)** ***Cymbella tumida*** **(Breb.) Van Heurek (F)** ***Phacus acuminatus*** **Stokes (G)** ***Peridinium*** **sp. (H)** ***Pandorina morum*** **(Mull.) Bory.**

that there is the low probability that any two individuals drawn at random from a population belong to the same species. This results in higher species diversity observed in station 2. Low Simpson dominance index results in higher diversity and *vice versa* (Ogbeibu, 2005). Like that a higher species diversity is observed in post-monsoon but species richness and evenness in pre-monsoon (Table 4). Generally low diversity observed in the study, represents a situation where most of the individuals belong to the same species. The cosmopolitan forms represent those found everywhere and most frequently encountered are *Synedra ulna*, *Melosira granulata* (Plate 2, Fig. D), *Scenedesmus quadricauda* (Plate 1, Fig. D), *Pediastrum simplex* (Plate 1, Fig. B), *Cymbella tumida* (Plate 3, Fig. E), *Navicula cuspidata* (Plate 2, Fig. E), *Euglena acus* (Plate 3, Fig. F) and *Peridinium sp.* (Plate 3, Fig. G). Other compositions that are recognized in this study are pre-monsoon and monsoon season. Dominance of Bacillariophyceae were found during pre-monsoon and Chlorophyceae during monsoon seasons. Simpson index value same in almost all the stations, facilitate to conclude that diversity was in same range. High species richness

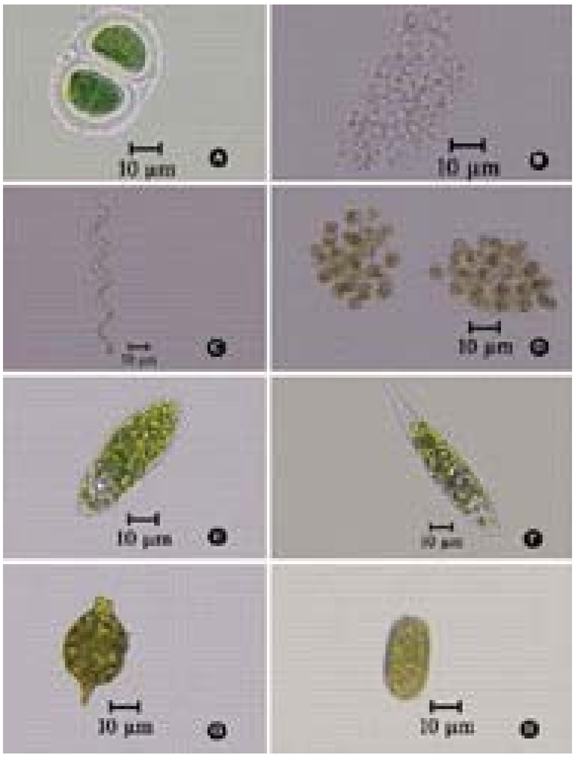


Plate 4: (A) *Chroococcus turgidus* (Kuetz.) Nag. (B) *Aphanocapsa* sp. (C) *Spirulina* sp. (D) *Microcystis* sp. (E) *Euglena* sp. (F) *Euglena acus* Ehr. (G) *Strombomonas fluviatilis* (Lemm.) Defl. (H) *Trachelomonas dubia* (Swiremend) Defl.

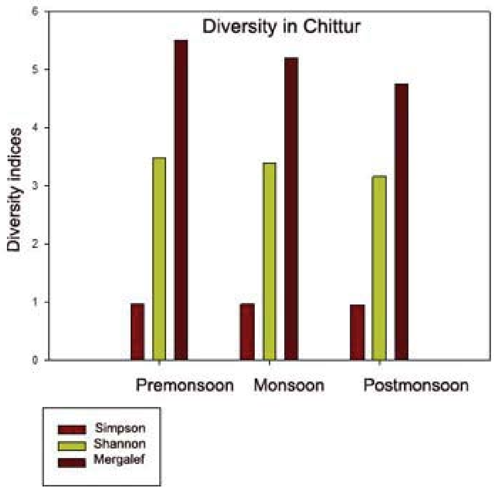


Fig. 4: Diversity profile in Chittur river.

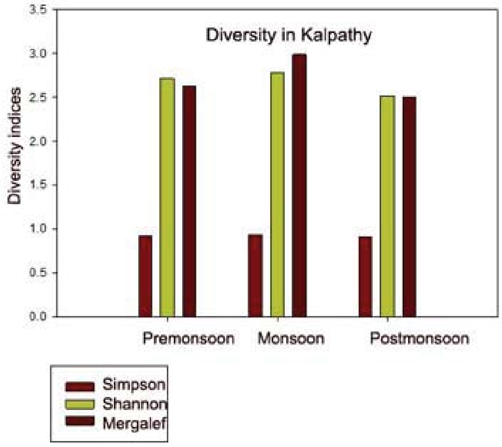


Fig. 5: Diversity profile in Kalpathy river.

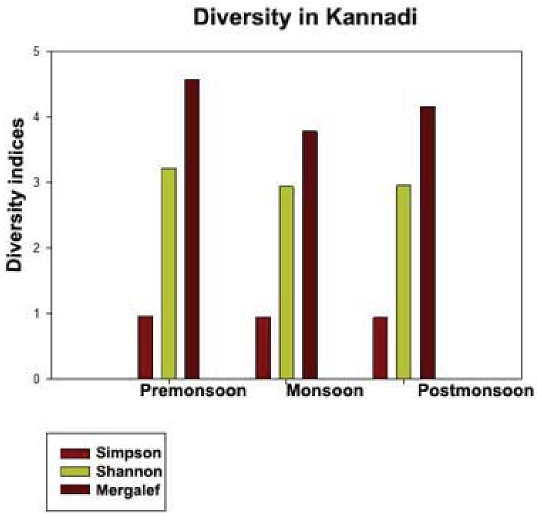


Fig. 6: Diversity profile in Kannadi river.

in pre-monsoon and station 1 (Figs. 3 and 4), then monsoon and station 2 (Figs. 3 and 6). But least value observed in post-monsoon and station 2 (Figs. 3 and 5). Comparing the total diversity profile in study area results high species richness in pre-monsoon but diversity in post-monsoon.

Conclusion

Contributions to knowledge arising from this study include the observations of

81 species of phytoplankton belonging to 6 divisions; Chlorophyceae, Bacillariophyceae, Cyanophyceae, Euglenophyceae, Xanthophyceae and Dinophyceae. Bacillariophyceae and Chlorophyceae were high compared to the observations in other algal groups. Information about the present study area is contaminated by the appearance of 12 pollution tolerant genera from the analysis of Palmer index. Marked changes in diversity and abundance of phytoplankton have been observed during post-monsoon season. TDS and Conductivity show marked increase in post-monsoon, diversity also high at post-monsoon. Studies on ecology and observation of the presence of 12 pollution tolerant algal genera from the study area reveal that the study area is organically polluted and eutrophic in nature.

Acknowledgement

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PHYTOPLANKTON DIVERSITY INDICES OF KALPATHY RIVER, PALAKKAD

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ABSTRACT

Rivers are the most important element of physical environment and valuable resource with numerous applications. Algae are small, unicellular or multicellular organisms, some of these form colonies and reach size visible to naked eye as minute green particles and also primary producers in both fresh water and marine systems. Kalpathy river, a major headstream of Bharatapuzha, the second longest river in kerala. The present study has been carried out to know the biodiversity of fresh water algae and its effects on physical properties of river. It is a well established fact that life in water depends upon the Physico-chemical factors in the water. In this investigation water samples were collected during September –December 2018. The samples were transferred into 1000ml capacity properly labeled plastic containers and immediately preserved with 4% formalin solution. Each samples concentrated to 10ml volume in the laboratory by centrifugation and this were used for slide mount for microscopic examination. Identification of phytoplankton organisms was done by reference to standard floras, texts and monographs. A total of 28 species of phytoplanktons were identified belonging to Chlorophyceae, Bacillariophyceae, Euglenophyceae and Cyanophyceae were recorded. In terms of abundance, Chlorophyceae had the highest distribution of phytoplankton, then Euglenophyceae, Bacillariophyceae and Cyanophyceae respectively. The physico-chemical parameters studied included temperature, Nitrate, Phosphate, Silicate, pH, Electrical Conductivity and Total dissolved solids from 6 different stations. Simpson index and Mergalefs species richness index were studied. The heterogeneity and abundance of phytoplankton observed in this study shows the river to be eutrophic. This is the first documented report on the phytoplankton community structure of Kalpathy River.

Keywords:Phytoplanktons, physico-chemical parameters, species and diversity

INTRODUCTION

Phytoplanktons aresmallest and most plentiful organisms on planet earth, free-floating unicellular and colonial appearance that grow photoautotrophically in aquatic environments and play a key role in the global ecosystem (Wetzel, 1983). They are target for controlling carbon-dioxide levels in the earth's atmosphere, biological primary production and elemental cycles of the earth (Pandey, 1973).Rivers are an important part of earth's water cycle and are veins of global water with cultural, economic as well as ecological significance. Most of the world's huge cities have developed on the banks of rivers. So there is a chance of acute anthropogenic activities. Anthropogenic activities such as discharge of domestic, industrial and other activities has caused major pollution problems to these rivers. Disposal of wastes like agricultural, industrial, and domestic are reason for water contamination. This will make adverse effect on the entire life on that ecosystem. Biomonitoring of water bodies also helps to understand the composition of biota and its dynamics. Phytoplankton are important in water quality indication because of their short life cycles and ability to respond to environmental change. They are of great importance in bio-monitoring of aquatic pollution (Rishi, *et al*., 2012), as their distribution, abundance, species diversity, species composition are used to assess the biological integrity of the water body. The aim of this study is to assess the phytoplankton community structure of Kalpathy River and to give baseline ecological information on the phytoplankton status.

Study Area

Kerala is a land blessed with diverse, luxuriant habitat types, varying topography, high rainfall and large number of water bodies.Kalpathy river originates from Anamalai hills and flows through Palakkad District.It is one of the tributary of Bharathapuzha, the second longest river in kerala. This river formed from the confluence of four tributaries, namely the Malampuzha River, Walayar River, KorayarRiver and Varattar River.MalampuzhaDam is built across this river just before it enters Palakkad town. The river is named after the Kalpathi Siva temple in Palakkad town. One of the problems faced by the Kalpathypuzha, like most other rivers in Kerala, is illegal sand mining. This has left many pits in the river bed, which leads to phytoplanktons growth. During summer the river is covered by a green carpet of Water Hyacinth and other shrubs.

MATERIALS AND METHODS

Systematic random sampling methods were adopted for collecting the water samples from rivers. Water samples collected from different stations from Kalpathy river in all the four months from September to December 2018. Keep one litre fresh samples for the phytoplankton identification and physico-chemical parameter study like Temperature, P^H, Conductivity, Total Dissolved solids, nitrate, phosphate and silicate. Samples were collected with the help of Plankton net for smaller forms and direct collection for larger ones. Collections were made from different water levels and then preserved in 4% formalin for further study. Digital images taken by Digital camera attached to microscope for further identification. Identification with the help of monographs and standard publications (Desikachary, 1959; Philipose, 1967; Prescott, 1982). Slide mounts were examined and phytoplankton organisms recorded in each mount as described by using Haemocytometer. The average count was taken to get the relative number of organisms per ml of original water sample. The following diversity indices were used for the ecological data analysis (i) Margalef species richness index (ii) Simpson's Dominance index (iii) Simpson's Reciprocal index.

RESULTS

A total number of genera 22 and species 28 belonging to Chlorophyceae (Genus-8, Species-9), Bacillariophyceae (Genus-9, Species-9), Cyanophyceae (Genus-1, Species-2), Euglenophyceae (genus-4, Species-8). Phytoplankton abundance ranged between 108 orgs/ml (station 6) and 338 orgs/ml (station 1). Due to the monthly fluctuations, Chlorophyceae Bacillariophyceae and Euglenophyceae was the dominant group of algae during the current study.

SL.NO.	PARAMETERS	AVERAGE VALUE
1	Temperature °C	27.9
2	PH	4.8
3	Conductivity mho/cm	580
4	TDS (mg/L)	260
5	Nitrate (mg/L)	0.062
6	Phosphate (mg/L)	0.0021
7	Silicate (mg/L)	1.79
9	DO (mg/L)	0.8
11	Ca (mg/L)	7.5
12	Mg (mg/L)	3.203
13	Cu (mg/L)	ND
14	Fe (mg/L)	0.864
15	Zn (mg/L)	0.008
16	Mn (mg/L)	0.011

Table 1: Results of Physico-chemical parameter analysis

Phytoplankton	Phytoplankton Abundance (counts/ml)	Percentage Abundance (%)	No. of Species	Station	Phytoplankton Abundance (counts/ml)
Bacillariophyceae	288	24.36%	9	1	338
Chlorophyceae	432	36.54%	9	2	188
Euglenophyceae	302	25.54%	8	3	244
Cyanophyceae	160	13.54%	2	4	188
				5	116
				6	108
Total	1182		28	6	1182

Table 2: Relative Phytoplankton Abundance in Kalpathy River

No.	Name of the species	S1	S2	S3	S4	S5	S6	Total
Chlorophyceae								
1	Coelastrum sphaericum	16		32	12			60
2	Ankistrodesmus falcatus		8	4	16			28
3	Closterium gracile	48	20	4			16	88
4	Cosmarium sp.	20	16	4		8		48
5	Cosmarium quadrum		4	12	4			20
6	Pediastrum tetras		4	8	4		8	24
7	Euastrum muosum	16	32	12		4		64
8	Gonatozygon aculeatum	36			20	4		60
9	Pandorina cylindricum	4		36				40
Bacillariophyceae								

10	Achnanthes sp.			8			4	12
11	Surirella sp.	8	32			8		48
12	Melosira granulata				4			4
13	Pleurosigma angulatum	20	16		12			48
14	Stauroneis anceps		8				4	12
15	Gyrosigma acuminatum	40		36		16	12	104
16	Cymbella tumida	16	4		16		4	40
17	Pinnularia species	8						8
18	Nitzschia scalpelliformis			12				12
Cyanophyceae								
19	Chroococcus turgidus		16			32		48
20	Chroococcus tenax	32			56		24	112
Euglenophyceae								
21	Trachelomonas scabra	20			12			32
22	Phacus acuminatus	4		36	4	8		52
23	Trachelomonas superba	24		4				28
24	Strombomonas sp.				24	8	28	60
25	Phacus monilatus	18	12	4		24		58
26	Trachelomonas armata	8		20	4		8	40
27	Euglena gracilis			12				12
28	Euglena proxima		16			4		20

Table 3: Phytoplankton indices in study stations

Phyoplankton	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Taxa	17	13	16	13	10	9

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Species	338	188	244	188	116	108
Simpson's index of diversity:	0.0					
Simpson's reciprocal index:	1					
Mergalef index	3.957					

Table 4: Ecological indices of Kalpathy River

DISCUSSION

The study revealed that the water quality parameters fluctuated with sites and seasons. The growth and reproduction of phytoplankton are influenced by physico-chemical characters of water. Phytoplankton distribution in the present study results Chlorophyceae contributed the highest number of phytoplankton 36.54% followed by Euglenophyceae 25.54 % and Bacillariophyceae 24.36%. The lowest was Cyanophyceae 13.54%. Species abundance low in station 6 and high in station1. This may have resulted in the higher abundance observed in station 1. The number of green algae ranged from 8 species (Station 3) to 3 in Station 6 respectively. Bacillariophyceae ranged from 5 in station 1 to 2 in station 5. Euglenophyceae range from 5 in station 1to 2 in station 6.

CONCLUSION

Contributions to knowledge arising from this study include the observations of 28 species of phytoplankton belonging to 4 divisions; Bacillariophyta, Chlorophyta, Euglenophyta and Cyanophyta, the river is now recognized as a water body having a wide array of phytoplankton that is floristically rich and diverse.

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REVIEW
MICROALGAE:-A POTENTIAL SOURCE

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Abstract:

This review presents an overview on the potentiality of microalgae on the global demand for renewable biofuels, biological sequestration of CO2, waste water treatment, production of bioactive compounds, food additives and biotechnology. As global population and consequent energy need increase the introduction of renewable energy sources becomes a serious matter. Many research reports and articles described many advantages of microalgae especially for the production of valuable compounds or for energetic use is widely recognized due to their more efficient utilization of sunlight energy as in comparison with other available feed stocks. The prospects of microalgae in development of biodiesl is not very recent and dates back to 1978, when the US Department of Energy started a program named "Aquatic species Program –Biodiesel from Algae". Microalgae present in all existing ecosystems, can live in wide range of environmental conditions and have much higher growth rates and productivity. In the current review we will highlight on the utility of microalgae has made a more attractive alternative source for the future.

Key Words: **Microalgae; Biofuel; Biodisel; Forensic study; Lipid productivity; Waste water treatment;**

1.Introduction:

Microalgae are abundant microorganisms, which are found in freshwater and marine environments. They are critical to universe because they can produce the bulk of oxygen on Earth through photosynthesis; they produce approximately half of the atmospheric oxygen. Because they are Photoautotrophs, with minimal nutritional requirements, microalgae have more advantages compared to other cellular organisms. These microorganism-derived enzymes contain cellulases, proteases, lipases, amylases, antioxidant enzymes etc. Their growth and structural composition depends on different physical factors especially CO2, light intensity (17, 20), pH and also nutrients; mainly high lipid content (2,6,22,37). A significant positive correlation holds for chloride with PH, Mg, Na, Hardness and TDS; sodium with hardness, EC and sulphate. Negative correlation between potassium and turbidity (10, 111). Microalgal species can synthesize high value chemical products, such as carotenoids, antioxidants, fatty acids, and sterols. Green microalgae used as nutritional suppliment due to rich source of essential nutrients (63). It can use sunlight very efficiently and produce oils like plants (109). Microlagae possess high biomass productivity, oil content, growing in variety of environmental conditions, high growth rate, utilizing sunlight and other nutrients (106,68,60). They utilize huge fraction of solar energy and converted it to chemical energy (72, 34). Most recently, microalgae have become an attractive raw material of biofuel, in the form of biodiesel (28,65). They appear to be the only renewable source of biodiesel and also capable of meeting the global demand for transport fuels (119). Release of organic and inorganic substances to water; mainly from anthropogenic activities leads to organic and inorganic pollution (79,56). Microalgae have the ability to utilize inorganic nitrogen and phosphorus for their growth, so they are capable to remove heavy metals and toxic compounds (90,76) accumulate huge amount in their body and form microalgae biomass (46). Green house gases mainly from anthropogenic activities adversely affect not only global warming but also to environment and human life. Removal of CO2 from oceans mostly by algae bio-fixation, thereby reducing green house gases (83). Numerous studies have extensively reviewed about the potentialities and advantages of microalgae as biofuel, biomass cultivation, food suppliment, lipid extraction, lipid productivity and reduced cost of production(129,118). Abiotic factors can directly or indirectly influence the phytoplanktons diversity (55).

2.Viability of microalgae for biofuel:

Global climatic change and increase in atmospheric CO2 is a direct result of combustion of Petroleum for different purposes, has motivated an urgent need to develop more eco-friendly and renewable alternative to displace the present status (64,115), algae based fuels can meet this criteria (40,74). Unicellular microorganisms commonly used as biofuel production is that they are more efficient in conversion of light and nutrients into valuable products. A supportive benefit of using microalgae for biofuel production is the potential value of the spent biomass used as animal feed, also has significant contribution to the value of algal biomass (108).

In 1998, the aquatic species Program recommended a list of 50 microbial strains selected from different pools, which held the most promise as biofuel production organisms. Microalgae have the potentiality to provide the renewable fuel feed stock through utilization of non-potable water and non-arable lands, techniques for cultivation with high nutrient demands (35). Oleaginous microalgae are well known candidates for renewable energy production because of high biomass (128,31,32). In the case of diatoms, nutrient deficient conditions show maximal growth rate, this will induce tremendous amount of Triacylglycerol (TAG), it translated to biofuel which are real characteristics for biofuel production (58,33). The prime species applicable to biofuel production are Chlorophyceae family (Ulva and Caulerpa), red green growth (Gigartinales, Halymeniales, Palmariales), green growth (Fucales, Laminariales). They can be developed on sewage, waste water etc. (66). Under stressful environments, algae may switch carbon allocation from reproduction to oil production (27). Diatoms as fourth-generation biofuels. The aim of the so called fourth-generation biofuel is to co-opt basic biochemical pathways to generate photoautotrophic algal strains with high lipid yield (38,26,116). Growing diatoms as feedstock for biofuel production could displace all petroleum consumption in USA (74). Algal biofuels obtained from the solvent extraction of algal lipids through High pressure homogenization (HPH), enzymatic, microwave, ultrasound, acid pretreatment can be compared in terms of energy recovery and consumption (31,50,135). The energy input for the acid pretreatment is lower compared with other cell disruption models (31).

3.Microalgae and Boidiesel:

Microalgae are of significant because of the presence of high yields of oil, mainly triacylglycerol (TAG), that can be converted to biodiesel through esterification (33,16). Microalgae forms sustainable renewable energy source for biodiesel (9,114,71,134) like other resource which need well agricultural land and sophisticated technologies for their commercial production (122,112,51,68). It obtained from vegetable oils and animal fats through trans esterification process (30,88). General equation for transesterification reaction is shown in figure 1.

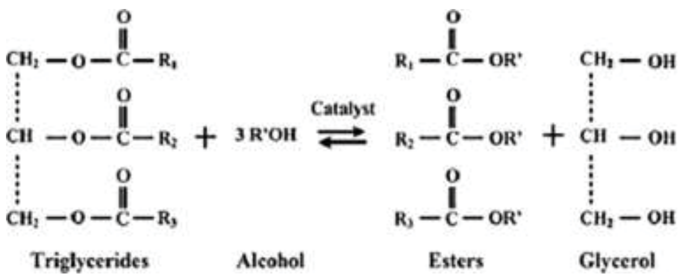

Figure 1: Shows General equation for Transesterification reaction

Yet this also can leads to food scarcity, deforestation because excess use of land, using fertilizers which harms environment (109). Biodiesel production is a well established one with soybeans, canola oil, palm oil, corn oil and waste cooking oil, most common commercial uses (11,40,118). Many research works reported that microalgae are more advantages than other available feedstocks for biodiesel production (75,117,60). Table1 shows comparison of different sources of biodiesel (126,46,7,4,109).

Biodiesel source	Oil yield (Liter oil/ha)	Land use (m2/GJ)	Energy (GJ/ha)	Water required (m3/GJ)
Soybean	446	689	15	383
Rapeseed	1190	258	39	383
Palm oil	5906	52	192	75
Sunflower	951	323	31	61
Jatropha	1896	162	62	396
Microalgae	**24355-136886**	**2-13**	**793-4457**	**<379**

Table 1. Comparison of different sources of biodiesel

4.Lipid Productivity:

Microalgae are unique photosynthetic organisms given that they accumulate lipids in substantial quantities at lower CO_2 concentrations (78) and thrive in high-salinity water. Microalgal biomass rich in lipid and nonlipid contents; lipids are potential source of biofuels and nonlipids are useful for the production of various chemicals (22, 99). Under nutrient-replete condition, accumulation of triacylglycerol (68) in cells leading to the formation of Lipid droplets (32,107). TAG accumulation also results from silicon starvation, deprivation of nutrients like nitrogen and phosphorus (24) and cell cycle arrest, that is under stress (127,2,65,120,117,33). Diatoms, as microalgae, can store lipids into oleosomes, the amount of which increases under stress conditions (32,43). This study has revealed the presence of one specific protein presenting a quinone protein-alcohol dehydrogenase. Using a fluorescent tag, the protein was found to be targeted to the endoplasmic reticulum where it could be involved in the formation of oleosomes. Transportation of oleosomes could occur by exocytosis as observed with the Chlorophyceae algae *Dunaliella salina*. (136,49). Marine microalgae are recognised as an important renewable source of bioactive lipids with a high proportion of polyunsaturated fatty acids (PUFA), which have been shown to be effective in preventing or treating several diseases. Depending on the fatty acid characteristics, oils can be utilised in the form of surfactants, biolubricants, omega-3 fattyacids, liquid fuels and gas. Microalgae based biofuel production depends on the balance between biomass growth and lipid accumulation, whereby conditions of stress, inhibit cell growth and thus lipid productivity low. So need a combinatorial framework reveals the relationship between microalgal growth and lipid accumulation which used to balance of biomass and oil productivity from algal strains ((11). Diatoms can accumulate between 25% to 45% lipids on dry weight basis, when grown in different environmental conditions.

5.Microalgae and waste water treatment:

Water pollution is one of the most critical environmental problem. To solve this various conventional methods are used in india, but that are very costly and not economical. During last 50 years, biotreatment of waste water using Microalgae have gained more importance (86,95), it is also most effective than conventional methods. Waste water treatment using commercial use of algal cultures history spans about 75 years by the production of different strains such as Chlorella and Dunaliella (90,89,104). The intensive production and harvesting of microalgae for the removal waste water was first studied by (14), further investigations by (94). They have the ability to remove nutrients (Nitrogen, Phosphorus), heavy metals, toxic substances, BOD,COD and other impurities using sunlight, CO2 and also have the ability to fix excess CO2 present in atmosphere, release O2, thereby reducing global warming (111,45,41,93,29,105). Marine diatoms studies in India were initiated by Desikachary, studies from Arabic and Indian oceans, inlcudes fossil studies. Diatoms can reconstruct productivity and silicon cycling (59), and also exporter of organic carbon to the sea (131, 4, 134). Influence of environmental and spatial gradients on freshwater diatom community and examine its acts on freshwater bodies (53). Algal culture can treat human waste (119,86,62). Livestock wastes (77) and agricultural wastes (79). Water quality assessment using diatoms has got ecological preferences, but there also lack of proper information about taxonomic identification of diatoms (48,80), this can be reduced with quality assurance (QA), as identification exercises (70,32). Phycoremediation is an eco-friendly approach and also low cost way to remove nutrients in aqutic system, its biomass utilised for the production of fuels, fertilizers, fine chemicals and feed in agriculture (91,131,25). Presence of water treatment plants (WTPs) can efficiently reduce or remove microcystins, some hepatotoxins that are produced by Cyanobacteria. Ability of microalgae to utilise organic and inorganic substances mainmly N and P in waste water for their growth leads to decrease the concentration of these substances in water bodies and also used to the generation of energy and other products through processing (38,123,53,67). Not only chemical concentrations, but also human impacts also alter the constitution of aquatic environments, so the term biomonitoring is essential one because it provides a diagnosis of aquatic ecosystems based on the characteristic of their biota (81). Accumulation of Cd by *Scenedesmus bijugus*, nitrate and phosphate consumption by *Botroyococcus braunii* (136). Cu, Pb and chlorinated hydrocarbons by Dunaliella species. One of the dominant algal community that is diatoms can significantly provides the nutrient removal and dissolved oxygen levels in water, as major carbon carrier in deep oceans to be the main contributors to Biological carbon pump (88,39,13). The combinatorial use of diatom algae- bacteria symbiosis has been proved to provide good quality of water treating by uptaking organic matters, nutrients, contaminants and pathogens (88,81). Pollutant removal efficiency also enhanced by symbiosis between algae and bacteria (8,132). To assess metrics based on diatom ecological guilds and life forms could be used to assess the impact of chemical and physical water parameter changes in the river monitoring network (69,3,28,21). Increasing nutrient and organic matter contamination can modify the relative abundances of ecological guilds and life forms (82).

6. Biological Composition of Microalgae:

Table 2. shows microalgal composition. Micoalgae contain numerous essential vitamins such as Vitamin A, B_1, B_2, B_6, B_{12}, C, E, nicotinate, biotin, folic acid and patothenic acid. Also rich source of Carotenoids, which make microalgae a great source of essential compounds for maintaining health, pharmaceutics, cosmetics, nutraceuticals and medical industries (24,116,110).

Table 2. Shows the constituents in Microalgae:

Proteins	8-71%
Carbohydrates	4-64%
Lipids	20-50%

Nucleic acids	1-6%
Vitamins	0.4 to 554 mg kg^{-1}

7.Microalgae and high value molecules:

Microalgae can be used to produce a wide range of metabolites such as proteins, lipids, carbohydrates, carotenoids or vitamins for health, food, feed additives and cosmetics. During stress conditions, microalgae synthesize considerable amount of secondary metabolites, among these Astaxanthin- xanthophyll family of carotenoids, is one of the valuable algal compound used in food, feed, cosmetics, pharmaceuticals, powerful antioxidant, used for anti-tumour therapies (15,19,71), age related muscular degeneration, Alzheimers and Parkinson diseases (97,87). Fucoidan is a sulphated polysaccharide found in some algae, commonly used as anticoagulant, anti-thrombotic, anti-cancer and anti-proliferative (42,122,62,55). Diatom-Derived Carbohydrates have significant influence on the bacterial community. Estuaries, dominated by epipelic diatoms, they exude large amount of extracellular polymeric substances (EPS) comprising polysaccharides and glycoproteins, which provides a substantial pool of organic carbon available to heterotrophs in sediments (57).

In diatom, *Nitzschia panduriformis* frustules used for protein and viral nanoparticle adsorption, so for this frustules developed into a material useful in viral nanoparticle purification systems or as a biosensor for the detection of viruses. This was one of the first approach in which cell wall (frustule) of diatoms has been attempted to be developed as an IMAC system for the purification of recombinant proteins and viral particles through chemical modification by using IPS and IDA to immobilize Cu2+ ions, the modification being confirmed by using FE-SEM, EDS and FT-IR. adsorption of VP2-441 SVPs to the Cu2+- coupled biosilica have potential to be developed into a material useful in protein and nanoparticle purification systems (84). The chemical modification of the living diatom *Thalassiosira weissflogii* using a titania precursor, titanium (IV) bis-(ammonium lactato)-dihydroxide (TiBALDH). Its incorporation of Ti into the diatom is achieved via repeated treatment of cultures with non-toxic concentrations for enhanced metabolic insertions that prolong the exponential growth phase of the culture (78,71). A first report of apoptosis induction by galactolipids using marine diatom isolated from *Phaeodactylum tricornutum,* using the patented ApopScreen cell-based screen for apoptosis-inducing, potential anticancer compounds, its structure can be determined by using NMR, mass spectrometry and chemical degradation (11).

8.Microalgae in Forensic study:

Diatoms constitutes valuable tool in forensic studies, especially in drowning cases. These are deposited in various body parts, so can predict whether a person dead or alive at the time of drowning (27,33,68,98).Same species of diatoms seen inside the body of drowned victim as that of putative drowning medium may serve as corroborative or conclusive evidence to support the diagnosis of death.

9.Microalgae and Biotechnology:

Microalgal biotechnology really began to develop in the middle of the last century. Study on the Biotechnology in algal biomass culture (18,105,124,26), it compressed to form algal biomass is the prominent product in microalgal biotechnology used for the manufacture of powders, tablets and capsules, the major source used for this purpose is chlorella and spirulina (101,102). Phototropic microalgae are used to incorporate stable isotopes from inorganic C-sources, H-sources, N-sources, it can be used for the scientific purposes like elucidation of molecular structures (101). Applications in industrial fields such as biofuel production (96,103,74), waste water treatment (95,121), fertilizers and animal feeds (85,12,9), human food (10,73), medical compounds (56).

10.Conclusion:

Global warming and the exhaustion of fossil fuels are major world-wide problems. In the present review emphasis was placed on applications of microalgae with regard to green approaches. The productivity of microalgal lipid with respect to dry weight of biomass can be 15 to 300 times greater than that derived from plants, its photosynthetic efficiency also greater than plants range from 3 to 8%. Beside its advantages, there are still many challenges in the development of algae derived fuels including algal strain selection, cultivation and processing. Microalgal biodiesel is not yet economically viable enough to replace petroleum based fuels or other conventional energy sources. Now it was totally changed, maximum efforts on algal biofuel production, maximize lipid productivity as well as energy requirements. Microalgal cultures offer an elegant solution to waste water treatment due to its ability to use inorganic nitrogen and phosphorus for their growth and also capacity to remove heavy metals as well as toxic organic compounds, that is phycoremediation is cost effective as it saves power and many chemicals and potential for CO_2 sequestration-a solution for the threat of Global warming.

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