ISSN: 0973-4929, Vol. 18, No. (3) 2023, Pg. 1003-1021

Current World Environment

www.cwejournal.org

Effect of Physico-Chemical Parameters and Inorganic Nutrient Ions in Relation with Seasonal Algal Diversity of River Ichhamati, West Bengal, India.

MONOJIT RAY[1] and SURAJ SK[2]*

[1]Department of Chemistry, Barrackpore Rastraguru Surendranath College, North 24 Parganas, India.
[2]Department of Botany, Barrackpore Rastraguru Surendranath College. North 24 Parganas, India.

Abstract

The present study reflects seasonal algal diversity as a source of food for fishes in the river Ichhamati during October 2021 to August 2022. To understand the seasonal algal pattern in the river Ichhamati, physico -chemical parameters of river water such as Hardness, Conductivity, pH, Total Dissolve Solids, Turbidity, Dissolve Oxygen, Salinity, Turbidity, Total Alkalinity, Salinity, Biological Oxygen Demand as well as biologically significant inorganic ion concentrations in river water namely sodium, potassium, calcium, carbonate, bicarbonate, nitrate, chloride were also evaluated during study period. It is found that physico-chemical parameters and inorganic ions in river water play an important and significant role in seasonal algal growth. Throughout the study period it was established that river Ichhamati is not very rich in floral diversity. During study time it was observed that dominant group of algae in this river are Chlophytes, Cyanophytes and Bacilariophyceae, including Species of *Oscillatoria Nostoc*, *Klebsormidium*, *Spirogyra, Lyngbya*, *Chlorococcum, Chlorella*, Diatoms in all seasons. During spring, summer and monsoon Conductivity, salinity, TDS and hardness of river water is high. Ichhamati contained adequate Na+, K+ and NO_3- in summer and monsoon season. High rate of bio-mineralisation during winter was found due to presence of high calcium ion concentration and also high TDS along with high salinity as well as high hardness of river water.

Article History
Received: 18 September 2023
Accepted: 02 December 2023

Keywords
Algae; Ichhamati; Physico-Chemical Parameters; Significant Inorganic Ions.

Introduction

River always plays a vital role sustaining life of any civilisation as it is a prime sector of economy. River is an important source to maintain ecosystem.[1] Ichhamati River make its way through India and Bangladesh and also acts as a border between India and Bangladesh.[2] Ichhamati travels a distance of nearly 216 km and finally meet with Kalindi river at Hasnabad, North

CONTACT Suraj Sk pu14bot@gmail.com Department of Botany, Barrackpore Rastraguru Surendranath College. North 24 Parganas, India.

Doi: https://dx.doi.org/10.12944/CWE.18.3.09

24 Parganas and finally ends in Bay of Bengal in Moore Island of West Bengal.[3] Ichhamati is a branch of Mathabhanga river bifurcates into two branches Ichhamati and Churni at Majdia of Nadia district in West Bengal. Range of algal diversity is wide from lentic to lotic ecosystem.[4] Seasonal variation in algal growth in aquatic environment is acquired due to change in nutritional, temperatur, light, grazing pressure level throughout a year.[5] Aquatic fauna such as fishes, snails, crabs and others finds a main source of their food from phytoplanktons such as algae. Phytoplanktons present at the base level in aquatic ecosystem forms major source of carbon.[6] Depending on water quality algae forms main connection between food chain and its productivity.[7] To asses water quality and its to understand its basic nature study of algal diversity play a major role.[8-,11] Physico-chemical parameters like pH, salinity, turbidity, Conductivity etc. plays an important role in living organism of free flowing aquatic ecosystem.[12-16] Inorganic nutrient ions are important factor for the growth and development of phytoplanktons such as algae.[17-19] Sodium, potassium and calcium ions are the bulk metal ions of living system. Presence of high calcium ion concentration leads to high rate of biomineralisation. In natural aquatic ecosystems, nitrogen, phosphorus etc. often occurs at low concentrations, which are limiting for the growth of algae.[21-22] This study is undertaken to evaluate seasonal algal composition of river Ichhamati water in different seasons such as autumn, winter, spring, summer and Rainy season in relation to some physicochemical parameters and biologically significant inorganic ions. The present study also evaluate presence of available algae act as a source of food for fishes in this river.

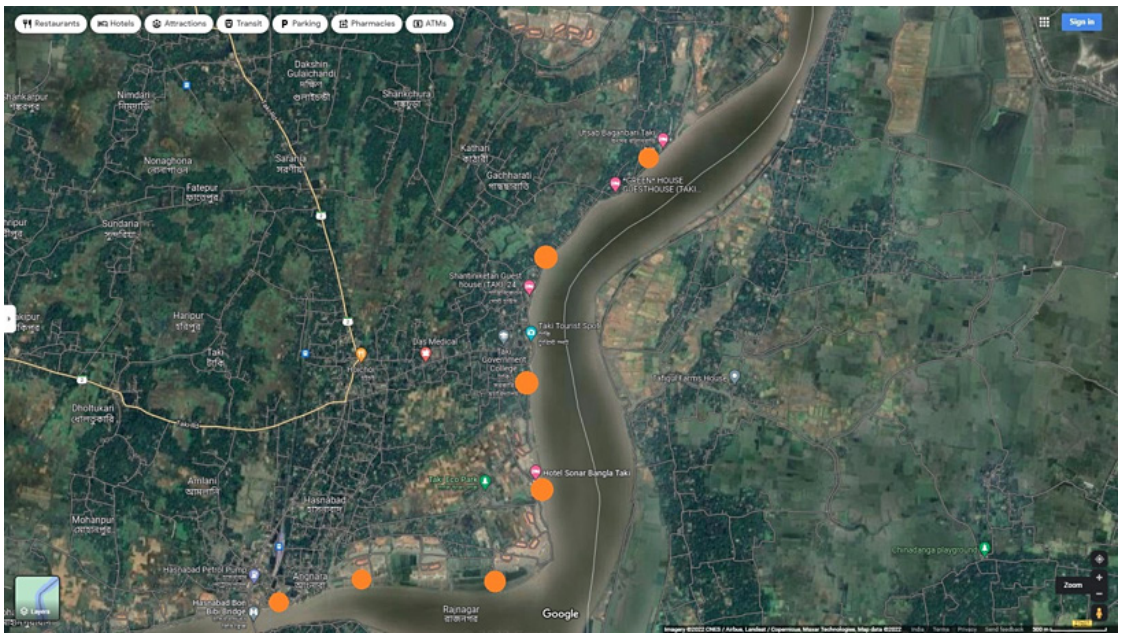
Methodology and Material

Study Location

Algae and water has been sampled from 7 sampling points (marked in orange circle) in Taki and Hasnabad namely Taki HWGP near BSF camp (22.576971, 88.936438) Taki Ecopark (22.576271, 88.938695), Taki HWQP (22.589497, 88.938607), Rajnagar (22.567804, 88.926102), Angnara (22.566387, 88.915240), Hasnabad (22.578140, 88.936522), Hasnabad Bon Bibi Bridge (22.565896, 88.912292) of North 24 Parganas, West Bengal, India. and circled them in orange in google map given below.

Sampling Site Abbreviation

L_1 = Taki HWGP near BSF camp, L_2= Taki Ecopark, L_3 = Taki HWQP, L_4 = Rajnagar, L_5 = Angnara, L_6 = Hasnabad, L_7 = Hasnabad Bon Bibi Bridge



Satellite image of all sampling sites in Google map

Water Sampling and Analysis

River water taken in the month of October - December 2021, January, February, March, May, July and August of 2022 frequently from Ichhamati. Water collected from river were analyzed through Titrimetry method, Flame photometry and spectrophotometric and other methods. On site analysis of pH, Conductivity, Temperature, Total Dissolve Solid, DO, Salinity were made by using proper scientific instruments. After collecting river water preserved in sterile Polyethylene sampling bottles and Turbidity, Total Alkalinity, Na^+ and K^+, Ca^+ and NO_3- ions analyzed by using proper scientific instruments and Titrimetric method. All instrumental and titrimetric methods were done at Laboratory.

Algal Sampling

Benthic algae grown on the hard surface of rock collected by using of spatula, scalpel, small knife by scraping algae from hard surface and kept in small jar of polyethylene. With the help of pipette algal specimen collected from soft muddy surface and kept in polyethylene bottle. Some floating algal specimen were collected from water surface by using fine meshed dip nets and with the help of hand and kept for preservation polyethylene sterile bottle. Plankton nets with 50µm mesh size are used for collection of phytoplankton from water. After collecting, specimens were preserved with 3% Formaldehyde solution. Standard microscopic methods were applied for observation of algal specimen. Identification of algal specimen made with proper literature.[23-26]

Result

Water from 7 study locations of Ichhamati River were taken in every season i.e., during autumn, winter, spring, summer and monsoon. Physico-chemical parameters and biologically significant nutrient ions are measured. 3 replicas of each parameter have taken. Replicas were taken from same place but from three different spots keeping distance at least 300 meters. IBM SPSS 20 Software and PAST Softare used in this study for statistical analysis and presented in tables below

Table 1: Data of Physico-chemical Parameters in River Ichhamati

Parameters	Sites	Autumn	Winter	Spring	Summer	Monsoon
Water Temperature (^{0}C)	L_1	29.45 ± 1.2	23.9 ± 3.25	25.35 ± 5.02	30.66 ± 0.4	30.06 ± 0.75
	L_2	29.40 ± 0.69	24.05 ± 3.6	25.75 ± 4.87	31 ± 0.5	30.13 ± 0.95
	L_3	29.50 ± 0.42	23.9 ± 3.25	25.45 ± 5.3	30.66 ± 0.4	29.86 ± 1.05
	L_4	28.80 ± 0.84	23.5 ± 3.95	25.5 ± 4.66	30.8 ± 0.45	29.73 ± 0.09
	L_5	29.8 ± 0.7	23.2 ± 4.24	25.55 ± 4.73	30.83 ± 0.7	30.16 ± 0.96
	L_6	30.1± 0.13	23.75 ± 3.74	25.45 ± 5.16	30.86 ± 0.3	30.06 ± 0.94
	L_7	29.45± 0.91	23.5 ± 3.67	25.3 ± 5.23	30.7 ± 0.36	29.93 ± 0.15
pH	L_1	7.79 ± 0.12	7.90 ± 0	7.97 ± 0.1	7.96 ± 0.07	7.95 ± 0.14
	L_2	7.93 ± 0.24	7.84 ± 0.05	8.01 ± 0.12	7.98 ± 0.1	8.05 ± 0.04
	L_3	8.0 ± 0.14	7.80 ± 0	7.92 ± 0.18	7.92 ± 0.15	8.03 ± 0.07
	L_4	7.65 ± 0.07	7.77 ± 0.03	7.82 ± 0.03	7.85 ± 0.05	7.81 ± 0.1
	L_5	7.76 ±	7.65 ±	7.85 ±	7.86 ±	7.84 ±

		0.05	0.11	0.07	0.09	0.05
	L_6	7.67 ± 0.03	7.70 ± 0	7.90 ± 0	7.92 ± 0.02	7.86 ± 0.06
	L_7	7.85 ± 0.07	7.82 ± 0.1	8.00 ± 0.07	7.95 ± 0.1	7.93 ± 0.02
Conductivity (µS/cm)	L_1	815 ± 7.07	855 ± 7.07	1625 ± 7.07	15673.33 ± 579.77	15720 ± 450.77
	L_2	808.5 ± 4.94	866 ± 8.48	1613 ± 4.24	15473.33 ± 231.15	15860 ± 246.37
	L_3	822.5 ± 3.53	862.5 ± 3.53	1652 ± 2.82	16026.67 ± 690.6	15750 ± 186.81
	L_4	823 ± 4.24	853 ± 4.24	1609 ± 1.41	15673.33 ± 219.39	15316.67 ± 116.76
	L_5	812.5 ± 3.53	847.5 ± 3.53	1597.5 ± 3.53	15633.33 ± 115.03	15240 ± 121.65
	L_6	815 ± 7.07	836.5 ± 2.12	1617.5 ± 3.53	15723.33 ± 142.24	15373.33 ± 230.28
	L_7	822.5 ± 3.53	844 ± 5.65	1607.5 ± 3.53	15776.67 ± 279.7	15450 ± 43.58
Salinity (ppm)	L_1	407.5 ± 3.53	415 ± 7.07	945 ± 7.07	10886.66 ± 80.82	9483.33 ± 47.25
	L_2	412.5± 3.53	408.5 ± 4.94	941 ± 5.65	14096.66 ± 25.16	9539 ± 24.75
	L_3	400.5 ± 6.36	409 ± 1.51	937.5 ± 3.53	10140 ± 52.91	9423.33 ± 25.16
	L_4	408.5 ± 4.95	406.5 ± 2.12	932.5 ± 3.53	11548.33 ± 12.58	9581.66 ± 14.43
	L_5	393 ± 4.24	398.5 ± 4.94	932.5 ± 3.53	10533.33 ± 30.55	9443.33 ± 11.54
	L_6	416 ± 5.65	424 ± 5.65	927.5 ± 3.53	10550 ± 30	9856.66 ± 25.16
	L_7	398.5 ± 4.94	418.5 ± 4.94	933.5 ± 2.12	10532.33 ± 9.29	9136.66 ± 37.85
TDS (ppm)	L_1	595 ± 7.07	611 ± 1.41	5720 ± 113.13	17533.33± 23.04	16417.66± 6.8
	L_2	581.5 ± 12.02	620.5 ± 7.77	5703 ± 117.37	16656± 36.67	16407.33± 75.63
	L_3	595 ± 7.07	615 ± 7.07	5886 ± 50.91	18457.33± 4.61	16338.33± 12.58
	L_4	577.5 ± 10.6	620 ± 7.07	5770 ± 70.71	17830.33± 4.5	16425.33± 5.03
	L_5	585± 7.07	617.5± 10.6	5696± 79.19	16958± 32.74	16236.66± 46.18
	L_6	577.5± 3.53	622.5± 3.53	5905.5± 43.13	18450.33± 42.92	15948.33± 37.52
	L_7	587.5± 10.6	617.5± 3.53	5696± 93.33	16460± 15.62	16330± 10
DO (ppm)	L_1	7.35± 0.21	6.85± 0.07	7.95± 0.07	7.03± 0.15	7.63± 0.15
	L_2	7.15±	6.85±	8.05±	7.06±	7.46±

		0.07	0.21	0.07	0.35	0.11
	L_3	7.2±	7.20±	8.05±	7.16±	7.56±
		0	0.28	0.07	0.05	0.11
	L_4	7.45±	7.20±	7.35±	7.20±	7.23±
		0.49	0.28	0.35	0.34	0.15
	L_5	7.45±	6.85±	7.95±	6.96±	7.4±
		0.21	0.07	0.07	0.11	0.1
	L_6	7.35±	6.80±	8.05±	7.00±	7.4±
		0.35	0.14	0.07	0.17	0.2
	L_7	7.45±	7.05±	8.05±	7.16±	7.36±
		0.35	0.07	0.07	0.3	0.37
BOD	L_1	2.5±	2.4±	1.35±	3.16±	2.60±
(ppm)		0.14	0	0.07	0.11	0.1
	L_2	2.4±	2.4±	1.5±	3.13±	2.6±
		0	0	0.28	0.2	0.1
	L_3	2.5±	2.50±	1.70±	3.00±	2.36±
		0.14	0.28	0	0.1	0.05
	L_4	2.3±	2.55±	1.75±	3.06±	2.53±
		0.28	0.07	0.21	0.05	0.37
	L_5	2.5±	2.25±	1.95±	3.03±	2.5±
		0.42	0.21	0.21	0.15	0.26
	L_6	2.3±	2.3±	1.45±	2.73±	2.43±
		0.14	0	0.21	0.15	0.15
	L_7	2.35±	2.3±	1.50±	3.06±	2.46±
		0.07	0	0.28	0.15	0.05
Hardness	L_1	167.57 ±	234.61±	484.76±	1915.22±	1047.34±
(ppm)		3.57	8.05	14.15	92.35	56.49
	L_2	166.05±	234.58±	804.81±	2100.75±	1047.51±
		8.48	6.3	53.52	46.34	51.98
	L_3	167.7±	234.8±	761.5±	2017.78±	1048.14±
		9.12	7.02	3.11	2.48	60.1
	L_4	165.77±	235.35±	868.78±	1942.6±	1050.39±
		7.74	8.3	2.3	3.12	2.71
	L_5	167.32±	235.06±	862.86±	1997.78±	1044.80±
		7.45	6.93	9.4	8.97	9.51
	L_6	166.67±	234.43±	825.11±	2049.55±	1051.83±
		7.67	6.67	3.06	7.73	4.2
	L_7	167.37±	235.71±	847.12±	1943.95±	1043.19±
		10.07	7.64	3.46	4.39	5.64
Total Alkalinity (ppm)	L_1	137.5±	170±	107±	126.66±	144.33±
		10.6	14.14	1.41	7.63	9.29
	L_2	134.5±	173.50±	103.50±	130±	143.33±
		10.6	12.02	3.53	8	6.42
	L_3	136.5±	171±	103±	131.33±	143.33±
		6.26	8.41	1.41	9.45	7.02
	L_4	131±	172.50±	107.50±	133.33±	141.33±
		5.55	13.43	0.7	11.71	10.26
	L_5	137.5±	173±	105±	136±	145.33v
		10.6	12.72	0	10.58	9.86
	L_6	134.5±	170.50±	102±	135.33±	144±

		3.43	7.77	0	11.71	5.29
	L_7	137±	171.50±	106±	133.66±	145±
		5.55	12.02	0	8.5	8.88
Carbonate	L_1	14±	12±	10±	11±	9.33±
Alkalinity		0.82	2.82	0	1.41	1.15
(ppm)	L_2	12.5±	13±	11±	11±	10±
		2.12	2.05	1.41	1.41	2
	L_3	14±	11±	11±	11±	9.33±
		2.65	1.41	1.41	1.41	3.05
	L_4	11±	12±	9±	11±	7.66±
		1.24	0	1.41	1.41	0.51
	L_5	14±	13±	10±	12±	9±
		1.41	1.41	2.82	0	3.6
	L_6	11±	13±	10±	11±	10±
		1.41	1.41	0	1.41	2
	L_7	13±	12.50±	8±	9±	8.66±
		1.41	0.7	0	1.41	1.05
Bicarbonate	L_1	123.5±	157±	97±	115.33±	135±
Alkalinity		7.77	15.55	1.41	7.5	10.44
(ppm)	L_2	122±	158.50±	93.50±	118±	133.33±
		8.48	13.43	3.53	10	7.02
	L_3	122.5±	159±	92±	120±	134±
		10.6	8.48	2.82	9.16	10
	L_4	121 ±	159.50 ±	96.50 ±	122.66 ±	133.66 ±
		12.72	12.02	0.7	11.47	11.5
	L_5	123.5 ±	160 ±	96 ±	122 ±	136.33 ±
		9.19	14.14	1.41	10.39	11.59
	L_6	123.5 ±	157.50 ±	93 ±	124 ±	133.33 ±
		12.02	9.1	1.41	12.16	8.32
	L_7	124 ±	159 ±	97 ±	124.33 ±	136.33 ±
		14.14	12.72	1.41	8.62	9.5
Turbidity	L_1	315 ±	188.33 ±	340.5 ±	944 ±	816.33 ±
(NTU)		9.49	7.09	7.28	9.39	29.5
	L_2	316 ±	185.33 ±	330 ±	872.5 ±	812 ±
		9.59	15.27	72.53	24.34	43.48
	L_3	312 ±	183.66 ±	356 ±	883 ±	820 ±
		9.59	3.31	6.47	9.89	44.68
	L_4	312 ±	186.66 ±	356 ±	883 ±	809 ±
		22.62	16.07	17.78	26.87	28.29
	L_5	304 ±	184.66 ±	348 ±	894.5 ±	817.33 ±
		28.28	14.57	20.81	28.99	25.08
	L_6	304 ±	182.33 ±	337 ±	887 ±	801 ±
		6.76	10.11	30.91	9.89	34.84
	L_7	310 ±	180 ±	353 ±	864 ±	803.66 ±
		11.31	5.62	62.23	31.11	41.51

Data presented here as Mean ± Standard Deviation

Table 2: Average concentration of inorganic nutrient ions of Ichhamati River Water

Parameters	Sites	Autumn	Winter	Spring	Summer	Monsoon
Sodium (ppm)	L_1	104.34 ± 2.8	94.78 ± 6.47	385.37 ± 7.11	1707.33 ± 15.5	1770 ± 10
	L_2	103.56 ± 0.97	93.53 ± 7.41	376.11 ± 2.28	1560.33 ± 6.7	1772 ± 13.85
	L_3	102.26 ± 1.44	96.41 ± 2.01	375.61 ± 6.49	1788.66 ± 8.5	1892.33 ± 2.51
	L_4	105.82 ± 2.02	95.76 ± 4.71	380.16 ± 6.39	1560.66 ± 9.01	1794.66 ± 4.14
	L_5	101.43 ± 1.68	98.05 ± 0.57	370.22 ± 0.03	1670 ± 11.13	1875.66 ± 12.02
	L_6	102.74 ± 3.87	97.48 ± 1.92	375.24 ± 0.85	1569.33 ± 9.01	1743.33 ± 6.11
	L_7	102.24 ± 1.41	98.15 ± 2.68	375.14 ± 3.98	1566.66 ± 15.27	1788.33 ± 7.63
Potasium (ppm)	L_1	14.33 ± 0.44	7.35 ± 0.48	23.51 ± 0.7	944.85 ± 20.13	976.43 ± 12.3
	L_2	11.30 ± 0.33	7.28 ± 0.3	23.46 ± 0.51	940.18 ± 18.32	973.10 ± 11.38
	L_3	12.51 ± 0.12	7.22 ± 0.02	23.65 ± 0.07	940.95 ± 17.81	972.1 ± 7.66
	L_4	10.57 ± 0.45	7.67 ± 0.38	23.16 ± 1.15	938.39 ± 25.59	973.9 ± 5.77
	L_5	13.70 ± 0.07	7.40 ± 0.42	23.22 ± 0.24	937.36 ± 19.99	978.73 ± 7.97
	L_6	11.36 ± 0.22	7.07 ± 0.03	23.93 ± 0.16	942 ± 21.76	976.23 ± 9.74
	L_7	12.59 ± 0.06	7.30 ± 0.14	23.81 ± 0.09	942.69 ± 20.05	974.46 ± 5.27
Calcium (ppm)	L_1	432.50± 10.6	57.50 ± 3.53	63 ± 4.26	106.66 ± 3.05	428.33 ± 6.07
	L_2	429 ± 1.41	50.50 ± 6.36	62.50 ± 0.7	106.66 ± 4.16	421.66 ± 9.07
	L_3	421.50 ± 6.36	51 ± 5.61	60.50 ± 3.53	105.33 ± 4.5	424.66 ± 3.31
	L_4	426.50 ± 10.6	58 ± 4.24	57.50 ± 4.94	106 ± 3.6	423 ± 7.21
	L_5	420.50 ± 0.7	46.50 ± 7.77	64.50 ± 4.94	106.66 ± 3.05	426.66 ± 10.21
	L_6	430 ± 7.07	50.50 ± 6.36	64 ± 2.82	107.66 ± 3.08	432.33 ± 12.42
	L_7	422.50 ± 9.19	53.50 ± 3.53	63 ± 4.24	106.66 ± 4.16	427.33 ± 11.01
Nitrate (ppm)	L_1	1350 ± 14.14	385 ± 7.07	3546.50 ± 30.4	1362.66 ± 75.79	1632 ± 26.96
	L_2	1320 ± 7.07	387.50 ± 10.6	3591 ± 72.83	1477.66 ± 18.82	1646.66 ± 6.35

	L_3	1280 ± 14.14	338.50 ± 2.12	3675 ± 21.21	1489.66 ± 20.5	1646 ± 4
	L_4	1287.50 ± 10.6	360 ± 14.14	3631 ± 12.72	1425.33 ± 27.02	1637 ± 4.35
	L_5	1304 ± 8.48	355.50 ± 9.19	3702 ± 10.6	1480 ± 13.13	1656.66 ± 5.77
	L_6	1329 ± 15.55	360 ± 7.07	3586 ± 5.65	1413.33 ± 9.86	1672.33 ± 21.54
	L_7	1321 ± 12.72	344 ± 5.65	3538 ± 11.31	1469.33 ± 16.77	1652 ± 37.24
Carbonate (ppm)	L_1	7.15 ± 0.07	6.73 ± 0.64	6.6 ± 0.56	6.46 ± 0.46	4.36 ± 0.25
	L_2	6.45 ± 0.63	6.93 ± 0.3	6.5 ± 0	6.30 ± 0.26	4.46 ± 0.15
	L_3	6.7 ± 0.28	7.2 ± 0.36	6.3 ± 0.28	6.50 ± 0.1	4.70 ± 0.36
	L_4	6.6 ± 0.4	6.93 ± 0.45	6.5 ± 0.42	6.53 ± 0.25	4.56 ± 0.5
	L_5	6.8 ± 0	7.16 ± 0.2	6.4 ± 0.14	6.20 ± 0.36	4.53 ± 0.37
	L_6	6.35 ± 0.21	7.06 ± 0.2	6.55 ± 0.49	6.46 ± 0.4	4.50 ± 0.36
	L_7	6.9 ± 0.14	7.06 ± 0.47	6.55 ± 0.21	6.36 ± 0.41	4.46 ± 0.32
Bicarbonate (ppm)	L_1	159.40 ± 1.55	202.45 ± 11.24	189.17 ± 10.8	155.31 ± 13.29	172.03 ± 7.55
	L_2	160 ± 2.54	198.75 ± 3.6	185.76 ± 6.7	155.60 ± 9.54	170.26 ± 2.95
	L_3	159.70 ± 7.35	200.80 ± 1.97	185.30 ± 5.37	163.50 ± 5.59	170.25 ± 6.78
	L_4	158.55 ± 4.17	199.95 ± 2.33	186.63 ± 6.73	162.98 ± 7.2	170.42 ± 5.21
	L_5	157.35 ± 9.68	203.10 ± 7.77	188.82 ± 9.58	161.56 ± 3.61	171.30 ± 4.81
	L_6	158.50 ± 5.93	204.80 ± 7.91	190.25 ± 11.38	159.05 ± 4.13	170.76 ± 7.05
	L_7	158.85 ± 5.58	205.75 ± 9.68	190.62 ± 13.96S	159.91 ± 3.99	170.58 ± 5.13

Data presented here as Mean ± Standard Deviation

Table 3: Algal species of River Ichhamati

Algae	Autumn	Winter	Spring	Summer	Monsoon
Volvox sp (V)	+	+	-	+	+
Klebsormidium sp (Kl)	++	+	++	+	++
Spirogyra sp (Sp)	++	++	++	++	+++
Zygnema sp (Zy)	+	++	++	+	+
Chlorococcum sp (Ch)	+	++	+	+	++

Stigeoclonium sp (St)	+	+	-	-	+
Chlorella vulgaris (Cv)	+	+	++	++	++
Ulothrix sp (Ul)	+	++	++	+	+
Pithophora sp (Pi)	++	+	+	+	++
Cladophora sp (Cl)	+	++	++	+	++
Oedogonium sp (Oe)	++	++	++	+	+
Monoraphidium sp (Mo)	+	+	-	-	+
Microspora sp (Mi)	++	++	+	-	++
Rhizoclonium sp (Rh)	+	+	+	+	+
Nostoc sp (No)	+	+	++	++	++
Microcoleus paludosus (Mp)	++	++	+	++	++
Oscillatoria sp (Os)	+	+	++	++	++
Microcystis sp (Mic)	+	+	++	++	+
Anabaena cylindrica (An)	++	++	++	++	++
Lyngbya sp (Ly)	++	+	++	++	++
Anabaena azollae (Aa)	++	+	++	++	++
Nitzschia sp (Ni)	++	++	++	+	+
Navicula sp (Na)	++	++	++	+	+
Fragilaria sp (Fr)	+	+	+	+	++
Pinnularia viridis (Fr)	++	++	++	+	++
Aulacosiera sp (Pv)	+	+	+	+	+
Ulnaria ulna (Ul)	+	+	+	-	+
Coscinodiscus sp (Co)	++	++	++	+++	++
Surirella elegans (Su)	++	+	+	-	+
Cymbella sp (Cy)	++	++	-	-	+

+++ = Abundant, ++ = Dominant, + = Rare, - = Absent, (Algal species Abbreviation used for Canonical Correspondence Analysis)

Statistical Correlation (Canonical Correspondence Analysis) Between Algae and Essential Water Quality Factors

One most important statistical method is CCA for understanding relationship between essential water quality factors and species, has been applied in this study for determining relationships between Physico-chemical parameter and algae. The triplet length of the graph gives an indication regarding effect of parameters and showed positive or negative relationship with axis.[27-28]

Table 4: Different water quality factors and Canonical biplot scores of Ichhamati

Parameter	L1		L2		L3		L4		L5		L6		L7	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Temperature	0.535	0.462	0.491	-0.574	-0.303	0.804	-0.495	-0.408	0.224	0.901	-0.100	-0.793	-0.104	-0.843
pH	0.695	0.142	-0.033	-0.212	0.467	-0.395	-0.658	0.081	0.672	0.370	-0.857	-0.150	-0.744	0.058
Conductivity	0.884	0.480	0.732	-0.451	-0.585	0.779	-0.670	-0.589	0.559	0.771	-0.466	-0.814	-0.459	-0.840
Salinity	0.885	0.467	0.902	-0.418	-0.636	0.788	0.788	-0.613	0.592	0.770	-0.485	-0.818	-0.509	-0.843
TDS	0.830	0.545	0.760	-0.495	-0.923	0.375	-0.972	-0.193	0.677	0.651	-0.637	-0.685	-0.576	-0.710
DO	-0.319	0.066	-0.221	0.454	0.524	-0.030	0.804	0.649	0.015	-0.358	-0.128	0.589	-0.162	0.635
BOD	0.655	0.527	0.766	-0.602	-0.476	0.632	-0.729	-0.691	0.365	0.875	0.095	-0.921	-0.149	-0.920
Hardness	0.868	0.473	0.951	-0.364	-0.751	0.723	-0.877	0.554	0.913	0.478	-0.859	-0.574	-0.853	-0.572
Total Alkalinity	-0.545	0.206	-0.299	-0.058	0.437	-0.233	0.262	-0.283	-0.455	0.182	0.446	-0.394	0.479	-0.279

Carbonate Alkalinity	-0.629	-0.236	-0.477	0.487	0.382	-0.318	0.035	0.233	-0.389	0.002	0.259	0.026	0.734	0.069
Bicarbonate Alkalinitty	-0.507	0.234	-0.280	-0.089	0.405	-0.207	0.285	-0.319	-0.463	0.157	0.448	-0.398	0.438	-0.310
Turbidity	0.717	0.720	0.671	-0.741	-0.384	0.933	-0.544	-0.841	0.617	0.774	-0.529	-0.790	-0.509	-0.811
Sodium	0.789	0.599	0.752	-0.526	-0.528	0.834	-0.646	-0.678	0.544	0.725	-0.461	-0.742	-0.445	-0.774
Potassium	0.612	0.788	0.600	-0.732	-0.284	0.884	-0.433	-0.894	0.513	0.786	-0.423	-0.824	-0.418	-0.851
Calcium	0.811	0.035	-0.447	-0.828	0.718	0.575	0.590	-0.567	0.544	0.636	0.624	-0.420	0.651	-0.465
Nitrate	0.460	-0.146	0.332	0.087	0.245	0.798	-0.415	0.260	0.429	-0.378	-0.417	0.528	-0.443	0.447
Carbonate	-0.609	0.102	-0.021	0.724	-0.156	-0.678	0.187	0.818	-0.175	-0.546	-0.182	0.455	0.015	0.511
Bicarbonate	-0.407	0.310	-0.265	-0.175	0.389	-0.064	0.346	0.434	-0.093	-0.820	0.093	0.689	0.033	0.721

Table 5: Eigen value & % of variance of water quality factors at 7 sites of river Ichhamati

	L1		L2		L3		L4		L5		L6		L7	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Eigenvalue	0.10 263	0.05 1689	0.07 8596	0.05 7201	0.08 8289	0.04 4775	0.07 0942	0.03 7878	0.06 7044	0.04 1078	0.06 6145	0.02 8895	0.06 388	0.02 9398
% of variance	48.63	24.49	42.02	30.58	47.05	23.86	50.04	26.72	47.18	28.91	49.82	21.76	49.12	22.61

CCA of all the 7 sampling locations has been drawn between 18 water quality factors and 30 algae. Overall dominant algal species throughout all seasons are *Klebsormidium* sp, *Spirogyra* sp, *Chlorella vulgaris*, *Cladophora* sp, *Microcoleus paludosus*, *Anabaena cylindrica*, *Anabaena azollae*, *Nitzschia* sp, *Coscinodiscus sp*, *Pinnularia viridis*.

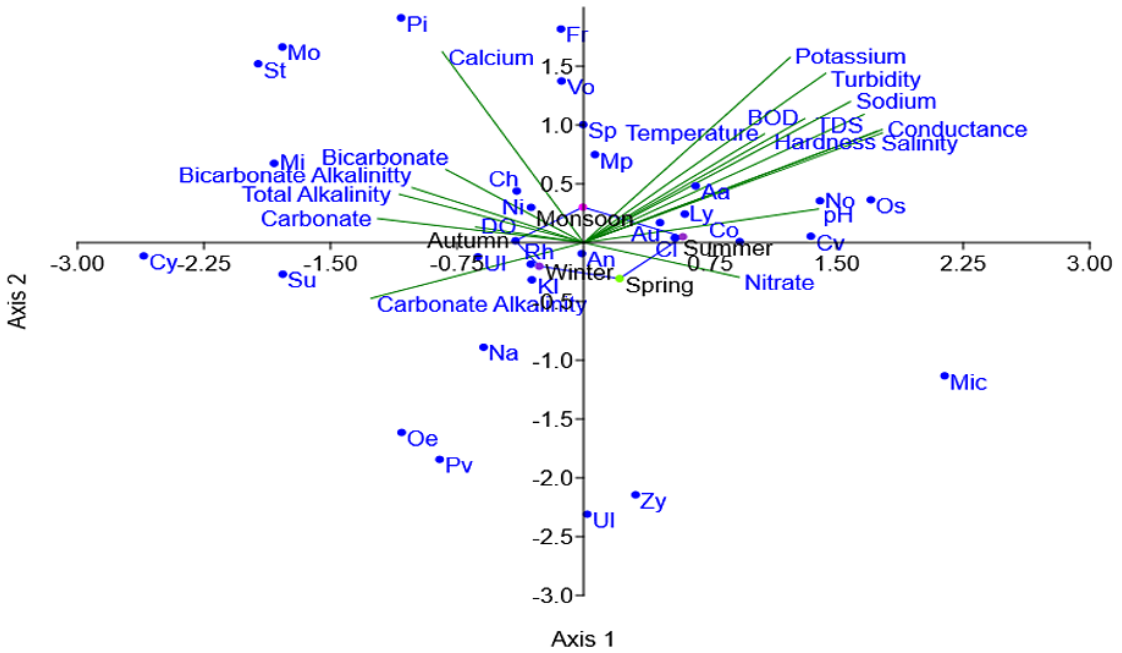


Fig 1: CCA score at L_1 between river algae and physico-chemical parameters

Eigen value of L_1, shown in fig-1 for axix 1 is 0.10263 explained 48.63% correlation and for axis 2 is 0.051689 showed 24.49% correlation between 18 parameters and dominant species of algae. *Volvox, Spirogyra*, *Fragilaria, Microcoleus paludosus* were positively correlated with axis 1. During monsoon and summer *Oscillatoria sp*, *Anabaena azollae*, *Lyngbya sp*, *Aulacosiera* sp, *Nostoc sp* showed positive correlation with Temperature, BOD, pH, TDS, Salinity, Conductivity, Hardness, K+ and Na+ ion concentration. Positive correlation observed during spring between *Microcystis* sp, *Zygnema sp*, and Nitrate ion concentration. *Anabaena cylindrica* is least affected by physico-chemical parameters.

Eigen value of L_2, shown in fig-1 for axix 1 (0.078596) showed 42.02% correlation and axis 2 (0.057201) showed 30.58% correlation between variables and dominant aalgl species. *Ulothrix*, *Zygnema*, *Cladophora* sp, were positively correlated with axis 1. During monsoon and summer *Oscillatoria sp*, *Micocystis* sp, *Anabaena azollae*, *Lyngbia* sp, *Aulacosiera* sp, *Nostoc sp* positively correlated with Temperature, BOD, Turbidity, TDS, Salinity, Conductivity, Hardness, K+ and Na+ ion concentration. During spring *Coscinodiscus sp*, *Zygnema sp*, *Cladophora* sp showed positive correlation with Nitrate ion concentration. physico-chemical parameters has least impact on growth of *Anabaena cylindrica* showed least affected by followed by *Spirogyra* sp.

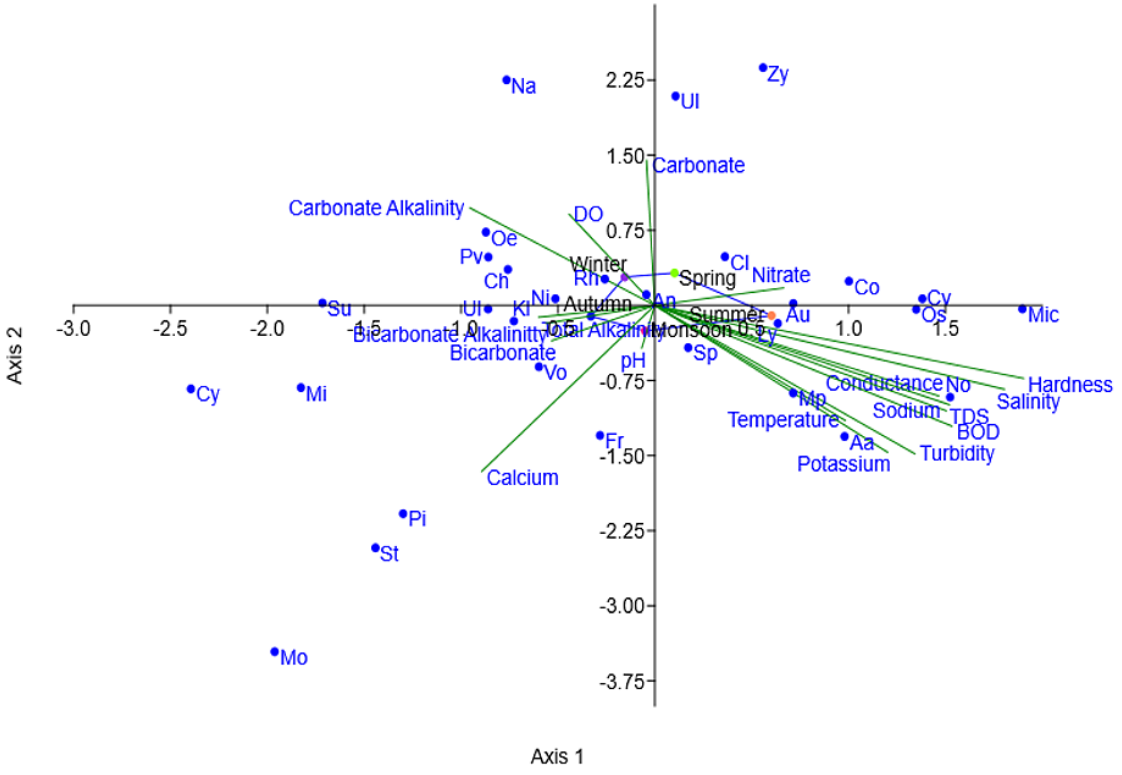


Fig 2: CCA score at L_2 between river algae and physico-chemical parameters

Eigen value of L_3, shown in fig-3 for axix 1 is 0.088289, made 47.05% correlation and axis 2 is 0.044775 showed 23.86% relationship between 18 variables and dominant species of algae. During monsoon and autumn *Volvox* sp, *Pithophora* sp, *Stigeoclonium* sp, *Monoraphidium* sp, *Fragilaria* sp, *Spirogyra* sp. showed positive correlation with calcium ion concentration. Close relation between pH and total

alkalinity indicates the river water is alkaline. *Zygnema*, *Ulothrix, Navicula* positively correlated with carbonate ion concentration during winter. During spring and summer *Oscillatoria sp*, *Micocystis* sp, *Coscinodiscus*, *Chlorella vulgaris Lyngbia* sp, *Aulacosiera* sp, *Nostoc sp* showed positive correlation with Temperature, BOD, Turbidity, TDS, Salinity, Conductivity, Hardness, K+, nitrate and Na+ ion concentration. Oedogonium sp, *Cymbella sp*, *Microspora sp*, Surirella elegans showed positive correlation with total alkalinity, carbonate and bicarbonate alkalinity. Physico-chemical parameters have least affect on diversity of *Anabaena cylindrica*l, *Klebsormidium*, *Chlorococcum*, *Microcoleus paludosus*.

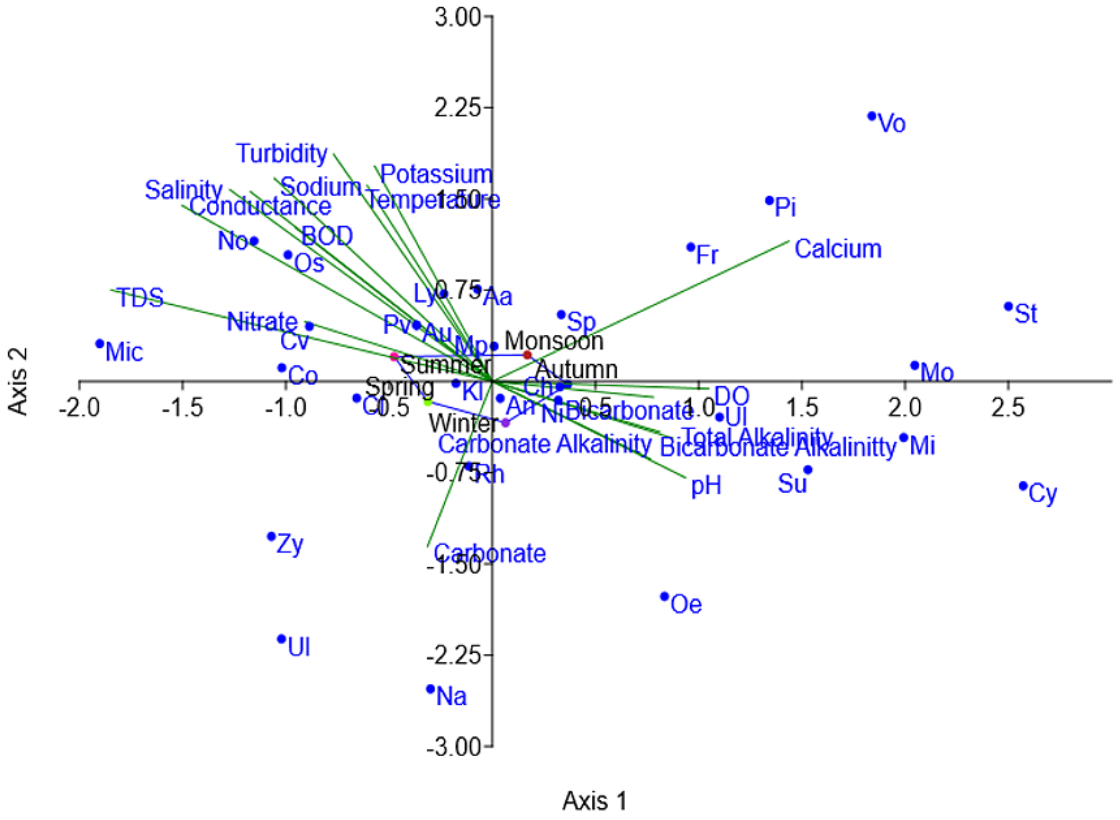


Fig 3: CCA score at L_3 between river algae and physico-chemical parameters

Eigen value of L_4, shown in fig-1 for axis 1 (0.070942) showed 50.04% relationship and axis 2 (0.037878) explained 26.72% relationship between 18 variables and dominant algae *Nitzschia*, *Navicula*, *Aulacosiera* sp, are in positive correlation with axis 1. During summer *Anabaena azollae*, *Oscillatoria sp*, *Micocystis* sp, *Chlorella vulgaris Lyngbia Nostoc* showed positive with Temperature, BOD, Turbidity, TDS, Salinity, Conductivity, Hardness, potassium, and sodium ion concentration. *Cladophora* sp, *Zygnema sp*, Ulnaria ulna showed positive correlation with nitrate ion concentration and pH. During monsoon spiceses of *Spirogyra*, *Stigeoclonium*, *Monoraphidium*, Rhizoclonium *Pithophora*, *Volvox, Fragilaria, Chlorococcum* has a close effect with Total alkalinity, Bicarbonate alkalinity, Calcium and bicarbonate ion concentration. *Nitzschia* sp, *Pinnularia viridis*, *Surirella elegans*, *Microspora sp*, *Oedogonium* sp, *Ulothrix*, *Klebsormidium* sp showed positive correlation with Dissolve oxygen, Carbonate alkalinity and carbonate ion concentration. Physico-chemical parameters has least impact on growth of *Anabaena cylindrica*

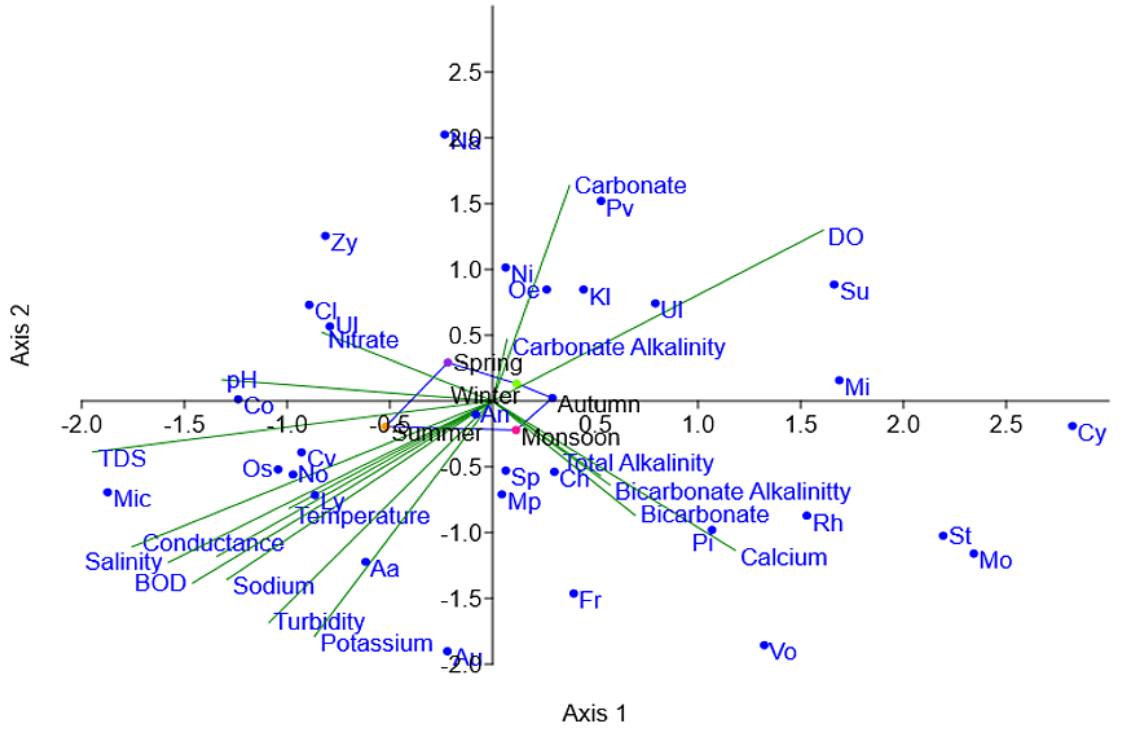


Fig 4: CCA score at L_4 between river algae and physico-chemical parameters

Eigen value of L_5, shown in fig-3 for axix 1 is (0.067044) made 47.18% correlation and axis 2 (0.041078) showed 28.91% relationship between 18 variables and dominant species of algae. *Fragilaria* sp are in positive correlation with axis 1. During summer *Nostoc sp*, *Aulocosira sp*, *Chlorella vulgaris*, *Anabaena azollae*, *Oscillatoria sp*, *Coscinodiscus sp*, *Lyngbya sp* positively correlaaated with Temperature, BOD, Turbidity, TDS, Salinity, Conductivity, Hardness, pH, potassium, calcium and sodium ion concentration. *Microcystis* sp, *Cladophora* showed positive correlation with nitrate ion concentration during spring. During monsoon *Monoraphidium* sp, *Pithophora* sp, *Stigeoclonium* sp, *Volvox* sp, *Microcoleus paludosus*, Ulnaria ulna has a positive effect with Total alkalinity, Bicarbonate alkalinity and calcium ion concentration. Surirella elegans, *Cymbella sp*, showed positive correlation with Carbonate alkalinity concentration during autumn. *Navicula sp Ulothrix* sp, *Nitzschia* sp and *Chlorococcum sp* positively correlated correlation with Carbonate and Bicarbonate ion concentrations. *Spirogyra* sp, *Anabaena cylindrica* showed least affected by 18 variables (Physico-chemical) followed by *Klebsormidium* sp.

Eigen value of L_6, shown in fig-1 for axix 1 (0.066145) showed 49.82% correlation and axis 2 (0.028895) made 21.76% relationship between 18 variables and dominant species of algae *Navicula*, *Nitzschia* sp, *Microcoleus paludosus* have positive relation with axis 1. During monsoon and summer *Nostoc sp*, *Aulocosirea sp, Chlorella vulgaris*, *Micrcystis sp*, *Coscinodiscus sp*, *Lyngbia* sp showed positive correlation with Temperature, BOD, Turbidity, TDS, Salinity, Conductivity, Hardness, pH, potassium, and sodium ion concentration. Ulnaria ulna, *Zygnema sp*, *Rhizoclonium sp*, *Cladophora Oscillatoria sp* showed positive correlation with nitrate ion concentration. During winter Surirella elegans, Ulnaria ulna, Oedogonium sp, Pinularia viridis showed a positive tendency with Dissolve oxygen and carbonate ion. During autumn and monsoon *Stigeoclonium* sp, *Volvox* sp, *Pithophora* sp, *Monoraphidium* sp, *Cymbella sp* showed positive correlation with Carbonate alkalinity, Total alkalinity, and Bicarbonate alkalinity, calcium and bicarbonate ion concentration. *Spirogyra* sp, *Anabaena cylindrica* have no relation with physic-chemical parameters followed by *Lyngbia* sp.

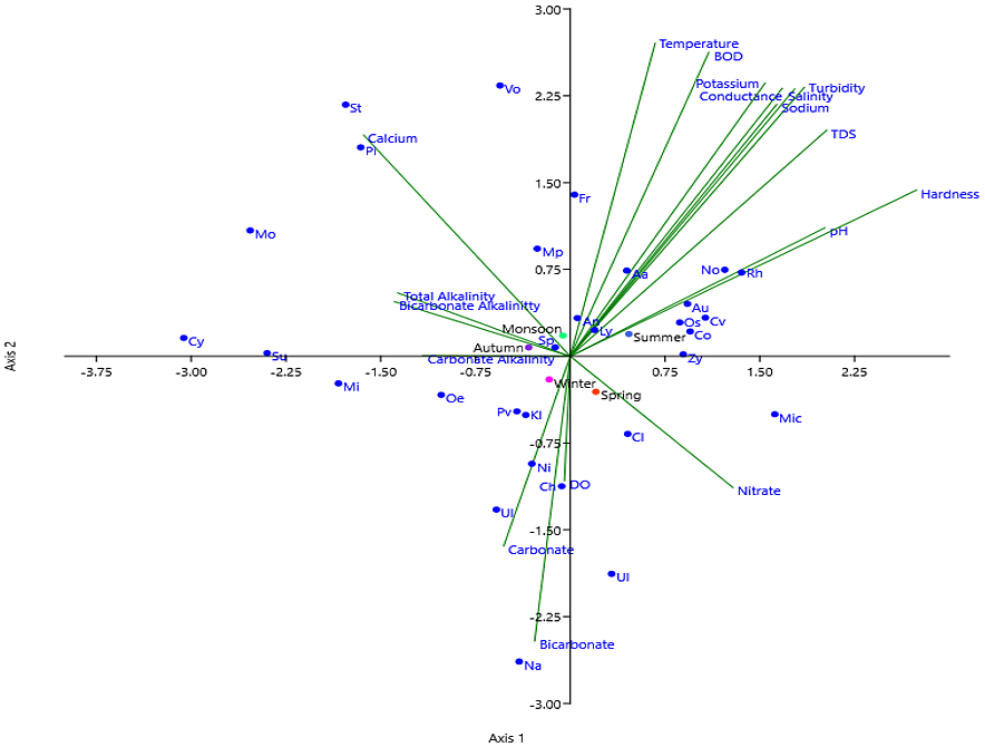


Fig 5: CCA score at L_5 between river algae and physico-chemical parameters

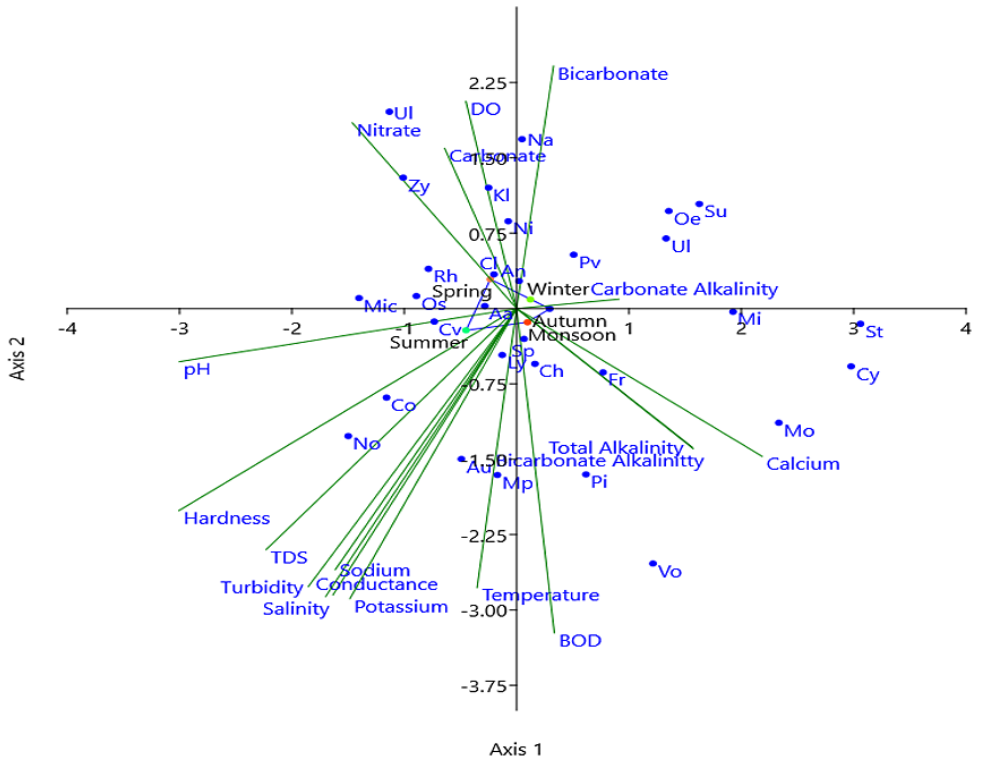


Fig 6: CCA score at L_6 between river algae and physico-chemical parameters

At L_7 (Fig 7) the eigen value for axis1 (0.06388) justified 49.12% relationship and axis 2 (0.029398) showed 22.61% relationship between 18 variables (physic-chemical) and dominant species of algae. *Navicula*, *Klebsormidium* sp, *Nitzschia* sp, *Anabaena azollae* were positively correlated with axis 1. During monsoon and summer *Nostoc sp*, *Aulocosirea sp, Chlorella vulgaris*, *Micrcystis sp*, *Coscinodiscus sp*, *Lyngbia* sp, Aulacosirea sp, *Oscillatoria sp* showed positive correlation with Temperature, BOD, Turbidity, TDS, Salinity, Conductivity, potassium, and sodium ion concentration. During spring *Nitzschia* sp, *Cladophora* sp, *Zygnema sp* made positive effect with nitrate ion concentration and pH. Surirella elegans, *Microspora sp*, Ulnaria ulna, Oedogonium sp, Pinularia viridis showed a positive relation with Carbonate alkalinity and carbonate, Bicarbonate ion concentration during winter. During autumn and monsoon *Stigeoclonium* sp, *Volvox* sp, *Rhizoclonium sp*, *Pithophora* sp, *Monoraphidium* sp, *Cymbella sp* showed positive correlation with Carbonate alkalinity, Total alkalinity, Bicarbonate alkalinity and calcium ion concentration.

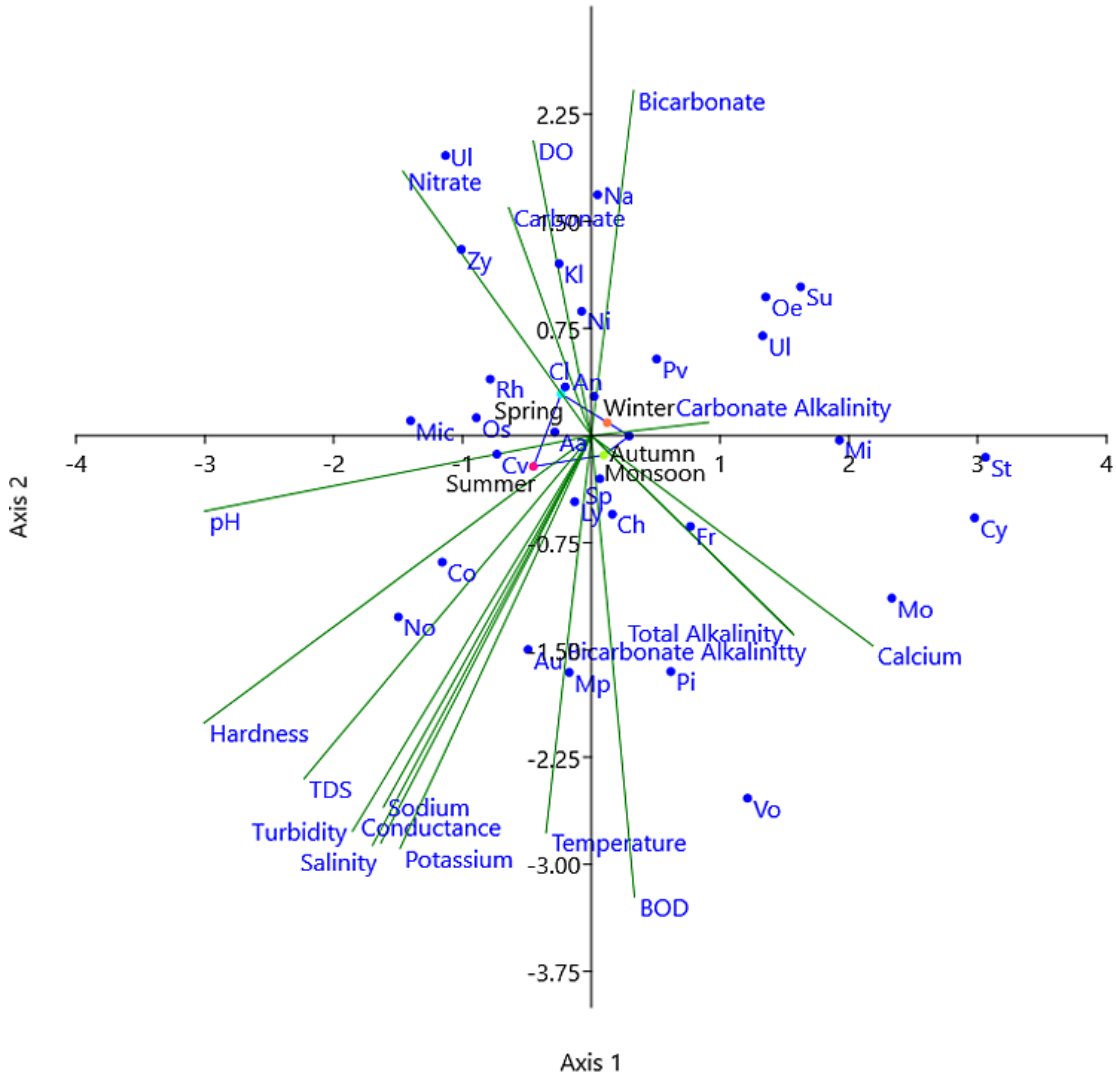


Fig 7: CCA score at L_7 between river algae and physico-chemical parameters

Discussion

The mean temperature of river water of Ichhamati ranges between 23.2ºC to 31ºC throughout study period. It is reported that 25-30ºC temperature range is ideal for algal growth.[29] The present study also suggests these findings. pH value of River Ichhamati ranged between 7.65 to 8.05 and make this slightly alkaline. It was reported that pH range 5.0 to 6.6 increased algal abundance.[30] The present study report that slightly alkaline river water is suitable for some algal growth (Table 3). The mean value of Conductivity ranged between 808.5- 16026.67 µS/cm. For periphyton algae increased Conductivity can stimulate attached algal biomass and productivity.[31] This study also found abundance growth of periphytonic algae during study time. Mean salinity value of river water was 393 to 14096.66 ppm during study time. Ichhanmati water TDS value found between 577.5 – 18457.33 ppm. TDS effectively related with salinity to create toxicity and change in ionic composition of fresh water creating limited biodiversity, shifting of aquatic populations and exclusion of weakly tolerable species.[32] The present study also found presence of less aquatic flora during high salinity and TDS level but some micro algae may be tolerant of high salinity and TDS as shown in table 3. Dissolve Oxygen (DO) have great impact on aquatic ecosystem and helpful for assessment of water quality. This study finds mean DO of Ichhamati River between 6.80 to 8.05 ppm and suggest Ichhamati river ecosystem is ideal for growth of Cyanophytes, Chlorophytes, Diatoms.[33] Another important parameter BOD indicate level of organic pollution of water. Ichhamati river showed mean value of BOD between 1.35 – 3.16 ppm giving indication of suitable aquatic environment. Mean hardness of river Ichhamati water ranged between 166.05 – 2100.75 ppm. Turbidity lied between 180 and 944 NTU. Total alkalinity lied between 102 to 173.50 ppm. Cyanophycean algae like *Anabaena cylindrica* needs adequate Na+ ion concentration in water for their growth.[34] Mean sodium content ranged between 93.53 to 1892.33 ppm. Sodium ion concentration is high during summer and monsoon and growth of some diatoms and green algae stunted during this period rather than blue green algae. Mean potassium ion concentrations ranged between 7.07 to 978.73 ppm which suggesting the river is good for algal habitant.[35] Calcium ion concentrations range between 46.50 to 432.50 ppm. Nitrate ion concentration is important factor for promoting algal growth 36. Mean nitrate concentration ranged between 344 to 3702ppm. The present study observed high nitrate concentration during March, May and August month of 2022 and probable reason may be addition of chemical manure with rain water used by farmers for agricultural purpose besides river bank. Bicrbonate ion concentration is key for algal photosynthesis.[37] Bicarbonate ion of this river ranged between 155.31 and 205.75 ppm making this good photosynthetic condition throughout the year. This study finds the river water is suitable for growth of Chlorophyceae and Diatoms.. Monsoon has rich variety of vegetation. This study had identified 7 cyanophycian algae, 14 chlorophycian algae and 9 diatoms (Table 3) belonging to the family Cyanophyceae, Chlorophyceae, Charophyceae and Bacillariophyceae. Monsoon season present some abundant growth of algal species such as *Klebsormidium*, *Spirogyra*, Lymgbya, *Nitzschia*, *Pinnularia*. Temperature change during winter may be probable reason for diatoms as dominant species. Fishes preferred diatoms as food. It is reported that dominancy of diatoms in aquatic body improve the growth of fish and shrimp to meet their nutritional demandL.3[8] Ichhamati a number of variety of fishes. We examined gut sample of Mystes tengara and found *Spirogyra*, *Ulothrix*, *Pinnularia*, *Chlorella*, *Pithophora* and *Chlorococcum* from gut sample. So it is clear that algae provide a large part of food for fishes in river Ichhamati. Present study identified 7 cyanophycean algae reportedly having biological nitrogen fixing ability[39] and resulting river bank soil fertility and cessation of submerged weeds growth. Green algae *Chlorella vulgaris* conain good quantity of protein[40] and important source of fish food and their growth, immunity.[41]

Conclusions

It may be concluded that ecosystem of river Ichhamati is suitable for algal growth and diversity. Data of present observation in the sense of dominance showed by different group of algae and present observation reported accordingly 47% belongs to Chlorophyta, 23% are Cyanophyta and 30% are Diatoms form food reserve for aquatic animal. According to their dominancy various algal division were Chlorophyta > Cyanophyta > Bacillariophyta in the autumn, spring and monsoon. In winter it was observed that the dominancy is Bacillariophyta > Chlorophyta > Cyanophyta and in summer Cyanophycea >

Chlorophyceae > Bacillariophyceae. It may also reported that Ichhamati is good for fishery mainly for *Hilsha* fish. But in spring, summer and rainy season salinity, TDS is very high and this may be mixing of sea water during high tide. Presence of sufficient concentration of nitrate and potassium ions justified that river bank is fertile for agricultural purpose.

Acknowledgement

The authors are extremely grateful to Governing Body and Research monitoring committee of Barrackpore Rastraguru Surendranath College for financial assistance and funding research project.

Funding

Barrackpore Rastraguru Surendranath College. Fund No. – College/Science/2018-19/RP

Conflict of Interest

Both the author declares that they have no conflict of interest.

References

1. Bunn, S. E., and Arthington, A. H.. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492-507. 2002
2. SayedAM. *Banglapedia: National Encyclopedia of Bangladesh* (Second ed.). Asiatic Society of Bangladesh. 1943.
3. Mondal I and Bandyopadhyay J.. Physicochemical Analysis of Ichamati River and Estimation of Soil Parameters using Geospatial Technology. *Journal of The Institution of Engineers* (India) Series E 97. 10.1007.2016.
4. Patil S.V., Karande V.C. and Karande C.T.. Limnological study of Venna Lake, Mahabaleshwar, Maharashtra, India. *International Research Journal of Environment Sciences.*, 4(8), 45-49. 2015.
5. Agrawal, S.C.. Limnology. APH Publishing Corporation. 1999.
6. Gaikwad, SR, Tarot, SR, Chavan, TP. Diversity of Phytoplankton and zooplankton with respect to pollution status of river Tapi in North Maharastra region, *J. Curr. Sci.*; 5 : 749-754. 2004.
7. Meshram, C.B. and Dhande, R.R. Algal diversity with respect to pollution status of Wadali lake, Amaravati, Maharashtra, India. *J. Aqua. Biol.* 15:1-5. 2000.
8. Palmer, C.M. A composite rating of algae tolerating organic pollution.J.Phycol.5:78-82. 1969.
9. Cascallar, L., Mastranduono, P., Mosto, P., Rheinfeld, M., Santiago, J., Tsoukalis, C. and Wallace, S. Periphytic algae as bioindicators of nitrogen inputs in lakes. *J. Phycol.* 39:7-8. 2003.
10. Siangbood, H. and Ramanujam, P. 4 Effect of anthropogenic activities on algal assemblages in Umiew river, Meghalaya. Phykos. 44(1):415-51.2014.
11. Gopinath P. and Kumar A. K. G. Micro algal diversity of the fresh water lake in Thiruvananthapuram district, Kerala. International journal of plants, animals and environment science. 5 (1): 288-291.2015.
12. Ray M. Seasonal Variation of Physico-chemical parameters of Jalangi River water: Relation with Water Uses and Water Pollution.MS-Academic. 5 (1).82-87.2015.
13. Ray M. Pal S. Study of aquatic biodiversity and correlation with physical parameters of Jalangi river, *European Journal of Biological Research,* 11(2), 212-216. 2021. DOI: http://dx.doi.org/10.5281/zenodo.4516528
14. Ray M. Seasonal Variation of Physico-chemical Parameters of River Churni. Nadia During 2019-2020. *Journal of Science and Technological Researches,* , 3(1), 1-5. 2021. DOI: https://dx.doi.org/10.51514/JSTR.3.1.2021.1-5
15. Ray M. Comparison of Physico-chemical Parameters of River Bhagirathi, Jalangi and Churni within Nadia, WB During 2020-2021. *Journal of Science and Technological Researches,* 3(3), 1-8.2021. DOI: https://dx.doi.org/10.51514/JSTR.3.3.2021.1-8
16. Negi S, Ray M, Pant H, and Joshi H C. Comparison of water quality of eight rivers around Dehradun district of Uttarakhand during november and December 2021.

Journal of Science and Technological Researches, 4(3), 32-35. 2022. DOI: https://doi.org/10.51514/JSTR.4.3.2022.32-35

17. Ray M. Seasonal Variation of Different Biologically Significant ion Concentrations of the Jalangi River water. *Indian Journal of Biology*,. 2(2),179-183. 2015. DOI: https://dx.doi.org/10.21088/ijb.2394.1391.2215.12
18. Ray M, Sengupta K . Soil composition and nutrient dynamics of some phytoplankton's of River Jalangi, Nadia WB. *Indian Journal of Biology*, 2(2),167-170. 2015. DOI: 19.https://dx.doi.org/10.21088/ijb.2394.1391.2215.10
19. Ray M, Comparison of Biological Significant Ions of River Bhagirathi, Jalangi and Churni within Nadia, WB During 2020-2021 *Journal of Science and Technological Researches,* 4(1), 1-8. 2022. DOI: https://dx.doi.org/10.51514/JSTR.4.1.2022.1-8.
20. Tank JL, Dodds WK.. Nutrient limitation of epilithic and epixylic biofilms in 10 North American streams. Freshwater Biol 48: 1031–1049.2003.
21. Elser JJ, Bracken MES, Cleland EE, Gurner DS, Harpole WS, Hillebrand H, Ngai JT, Seabloom EW, Shurin JB, Smith JE.. Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems. Ecol Lett 10: 1135–1142. 2007.
22. Steven N., Steven F. Rier T and Whorley S. Methods for Sampling and Analyzing Wetland Algae. Wetland Technique.Springer, 1-58. 2013.
23. Desikachary, T.V. Cyanophyta. – Indian Council of Agricultural Research, New Delhi, 24.1959.
24. Cox, E. R., Hightower, J.. Some corticolous algae of McMinn County, Tennessee, U.S.A. *Journal of Phycology* 8:203–205, 1972.
25. Sarode P. T. And Kamat N.D.. Fresh water diatoms of Maharashtra, Pub. Saikrupa Prakashan Aurangabad, 1-338, 1984.
26. Sharma O.P. Algae. McGraw Hill Education (India), 2011.
27. Abrantes, N. Antunes, S.C. Pereira, M.J. and Gonalves, F. Seasonal succession of cladocerans and phytoplankton and their interactions in a shallow eutrophic lake (Lake Vela, Portugal). Acta Oecologica. 29 (1), 54-64. 2006.
28. Liua C , Liub L, Shen H C. Seasonal variations of phytoplankton community structure in relation to physico-chemical factors in Lake Baiyangdian, China. *Procedia Environmental Sciences.* 2, 1622–1631. 2010.
29. Singh S.P. and Singh P. Effect of temperature and Light on the growth of algae species: a review. Renewable and Sustainable Energy Reviews. 50: 431-444. 2015
30. Leavitt P R,. Findlay D L,. Hall R I and. Smol J P.. Algal responses to dissolved organic carbon loss and pH decline during whole-lake acidification: Evidence from paleo limnology. The American Society of Limnology and Oceanography. 44(3): 757–773.1999.
31. Drerup, S A. Vadeboncoeur, Y. Elevated specific Conductivity enhances productivity and biomass of periphytic cyanobacteria from Lake Tahoe and Lake Tanganyika. Phycologia. 55(3): 295-298.2016.
32. Bierhuizen J.F.H. and. Prepas E E, Relationship between nutrients, dominant ions and phytoplankton standing crop in prairie saline lakes. Can. *J. Fish. Aquat. Sci.,* 42: 1588-1594.1985.
33. Sk S, and Ray M.. Studies of Seasonal Algal composition during Monsoon and winter seasons of the river Rupnarayan, West Bengal, India in correlation with some physic-chemical parameters. *Applied Ecology and Environmental Sciences.* 10(3), 126-130.2022.
34. Amelia. K. Ward R. and Wetzel G.. Sodium: Some effects on blue-green algal growth. *Journal of Phycology.* 11(4), 357- 363. 2008.
35. Gupte Y.. Uptake of potassium by algae and potential use as biofertilizer. *Indian Journal of Plant Physiology.* 1-4.2015.
36. Harrison P J and. Hurd C L. Nutrient physiology of seaweeds: application of concepts to aquaculture. Cahiers de Biologie Marine, 41; 71-82, 2001.
37. Shevela D, Julain J. and Eaton R. Photosystem II and the unique role of bicarbonate: Ahistorical perspective. *Biochemica et Biophysica Acta(BBA)- Bioenergetics.* 1817(8), 1134-1151, 2018.
38. Nesara KM and Bedi CS. Diatomix : a diatom enhancer. *Journal of fisheries sciences.com.* 13(2), 12-15, 2018.

39. Ahmed. A. Issa, Mohamed H A A and Ohyama T. Advances in Biology and Ecology of Nitrogen Fixation. Intech Open. Tokyo. 2014.
40. Uchechukwu D. E. *Chlorella vulgaris* as Protein Source in the Diets of African Catfish Clarias gariepinus. Fishes.2(4), 17, 2017.
41. Azza A.A. Galal R,. Reda M and , Amany A R M. Influences of *Chlorella vulgaris* dietary supplementation on growth performance, hematology, immune response and disease resistance in Oreochromis niloticus exposed to sub-lethal concentrations of penoxsulam herbicide. Fish & Shellfish Immunology. 77, 445-456, 2018