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PHYSICO-CHEMICAL CHARACTERISTIC AND PERIPHYTIC ALGAL COMMUNITIES OF RIVER RORU-CHU, EAST SIKKIM, INDIA: A PRELIMINARY INVESTIGATION

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ABSTRACT
The present study deals with the study of physico-chemical characteristics and the periphytic algal community of the river Roruchu, in East Sikkim, India. During the investigation it was found that the periphytic algal community of Roruchu was represented by 54 taxa which belong to 3 major class namely Bacillariophyceae (27 sp.), Chlorophyceae (17 sp.) and Cyanophyceae (10 sp).The most common species include., *Cymbella* sp., *Fragillari*a sp., *Cosmarium* sp, *Gomphonema* Sp., *Syndera* sp, and *Navicula* sp. The physico-chemical analysis of water reveals the richness in Dissolve Oxygen & Total Dissolved Solids which might have favored the growth of periphytons. The stream was found to be devoid of any major industrial polluting sources. The primary conclusion based on the present study showed that the stream is having crystal clear water, and are free from pollution as Chlorophyceae are better represented. Further as a result of less anthropogenic pressure the quality of water is fairly good. Bacillariophyceae was the dominant group and include 27 sp. constituting 49% of the total periphytic populations.

KEYWORDS*:* Anthropogenic pressure, Periphytic Algae, Physico-Chemical analysis, Roruchu, Sikkim.

INTRODUCTION

The growth and type of algae in stream responds rapidly to both chemical pollutants (toxics, nutrient) and physical habitat distribution (loss of structural diversity, bank erosion, sedimentation, elevated temperature) providing a biological measures of changing environment quality. Besides being major contributor of carbon (energy) fixation the periphytic algae form a major source of food for the fish and water fowl (Peters *et al.*, 1968: Denny *et al.*, 1978) and are the life of environment of invertebrates and also the commercial fish (Pandit *et al.*, 1985). Algae are frequently found in polluted and unpolluted water and due to this behavior they are generally considered useful to determine the quality of water or as biological Indicator. Chemical analysis of water provide a good indication of chemical quality of the aquatic systems, but do not integrate ecological factors such as altered riparian vegetation or altered flow regime and therefore do not necessarily reflect the ecological state of the system. A very little literature on the study of the freshwater algae flora of the stream of the Sikkim Himalayas is available. As per the data available there are various reports on Freshwater algal flora of Gangtok, the capital of Sikkim (; Prasad & Mishra, 1987, Prasad, Srivastava & Khanna, 1988); Freshwater Algae of Sikkim (Bhakta *et al*., 2010*)*, cyanophyceae and Chlorophyceae flora of Sikkim Himalayas (Suseela & Toppo K, *2006*), Desmids from South Sikkim (Das and Keshri, 2012 a,b,c) and algal flora (Chlorophyceaes) of Namchi, Sikkim Himalayas (Kumar & Rai, 2005) were found. It was found that most of the algal studies of Sikkim Himalaya were done on the lakes and ponds only. Algae from Gurudongmar Lake, North Sikkim (Das and Keshri, 2013), Desmids from Memencho Lake (Das and Keshri, 2013), Sikkim. Algal communities can and have been used as biotic indicator of ecological condition and shows change in condition in response to human and natural disturbances, it is in this context of the relative importance of the algal community in stream ecology that the present study on periphytic algal community of a lesser known Himalayan river Roruchu was undertaken. Roruchu is a perennial freshwater stream and it is basically untouched by human interferences except the later course designated as site- 4 where during the sampling period extraction of stone and sand directly from the river bed were noted, excessive fishing activities using chemicals and fishing nets etc. were also observed.

Algal and water samples were collected from the 4 different sites of river Roruchu. Various species of bacillariophyceae, chlorophyceae, cyanophyceae etc. were recorded from these sites. The algal flora encountered shows the dominance of Diatoms throughout the investigation. Many green algae like *Spirogyra* sp. *Ulothrix* sp., *Cosmarium* sp. *Oedogonium* sp. *etc* were also encountered. It was noted that the freshwater algae of various streams of Sikkim have received little attention. Most of the streams in Sikkim are important as these are unexploited with very less human activities, which are characterized by very low temperature during the certain time of year (Das S.K. & B. Adhikary, 2012). Keeping in view of the mushrooming of mega and mini hydro projects within the state of Sikkim and the increase in the human interferences and dependence on the aquatic resources, a documentation of the available algal flora has become

necessary. Also, the phytoplankton encountered in the water body reflects the average ecological condition of the aquatic ecosystem and therefore they may be used as indicator of water quality (Bhatt *et al*., 1999: Saha *et al*., 2000).

MATERIALS & METHODS

Four sampling sites (S1, S2, S3 & S4) were identified along the flow of river Roruchu in a stretch of 10- 12 km before it joins with Ranichu river. Both these rivers viz. Roruchu and Ranichu are the major tributaries of River Teesta. Roruchu is locally known as *Bhusuk khola* located on the North-eastern side of the Gangtok. Gathering momentum, the river runs towards Ranipool between Rizey, Syari, Nandok etc before it joins with Rongni-chu as a tributary of River Teesta. The river takes its form from the place called Bhusuk village, before that the stream formation takes place by joining of various other small tributaries arising from the various perennial spring water sources from the immediate catchment of the densely covered canopy. The sites were identified differing in various environmental variables like depth, vegetation, human interferences etc.

TABLE 1: Physiographic variables of all the sampling sites

Physiographic Variables	Site:1	Site:2	Site:3	Site:4
Elevation (m a.s.l)	4844 ft	4415 ft	3092 ft	2713 ft
Embankment	Good riparian vegetation	Good riparian vegetation	Good riparian vegetation	Devoid of riparian vegetation
Boulders (>256mm)	60%	60%	40%	50%
Cobbles (64-256 mm)	40%	40%	40%	30%
Pebbles (16-64 mm)	25%	30%	30%	15%
Gravel (2-16mm)	10%	10%	15%	5%
Sand(<2 mm)	2%	3%	3%	1%

Site 1: This site has been taken as reference site, it is located in the pristine untouched stretch along the Bhusuk area, where the immediate catchment of the stream is free from any human settlement or devoid of anthropogenic activity of any kind.

Site 2: Nearly 4-5 km downstream of the site 1 where small nullahs and Jhoras etc in the form of urban runoff water consisting basically of domestic waste water and other perennial spring water sources coming from the catchment area of Tathangchen, Chandmari and Dicheling area get mixed with the main river body.

Site 3: Nearly 2-4 Km downstream of site-2, this sampling site is selected because the small nullahs and water bodies which are basically of agricultural runoff from the nearby agricultural fields of Nandok, syari area get mixed with the main stream

Site 4: The site selected is nearly 10 -12 Km downstream of the reference site *i.e.* site 1. The site is observed to be the most disturbed site due to quarrying activities and collection of sand, stone chips and boulders form the river bed, various humans' settlement and buildings etc were observed along the river banks and due to non availability of any municipal garbage disposal site nearby, it was observed that residents usually throw their house hold garbage directly into the river. Also observed that the selected site is just below the Hindu cremation site. All the ashes and un-brunt woods and religious offerings etc were directly thrown in the river body thereby making it a bit polluted. The sampling for the entire site was done during the month of November 2015, December 2015 and January2016.

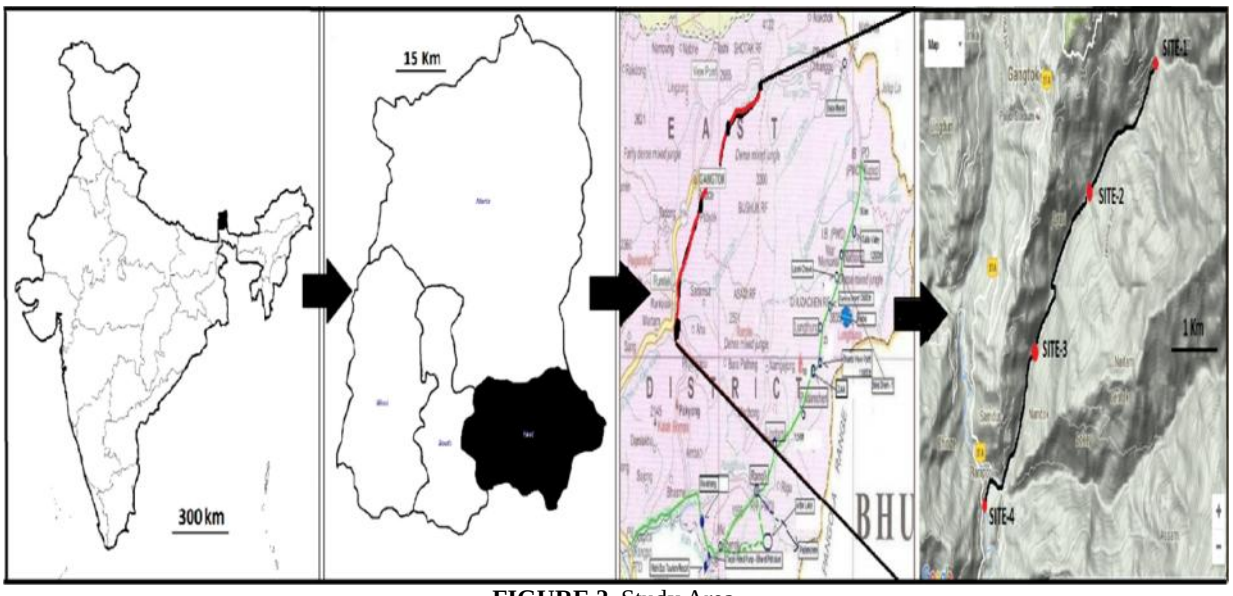

FIGURE 2. Study Area

METHODOLOGY

Stones of different sized were picked up from the bottom of stream and desirable area was marked on the stone. Theperiphytons from the marked area was scrapped with the help of scalpel and brushes and mixed with small amount of water and then labeled into the container. Periphytons sample were preserved in 5% formalin. After keeping it for 24 hr, the supernatant was discarded and 20ml concentrate was then obtained. Photo micrographic images of phytoplankton were analyzed with the help of Carl Zeiss (Priomostar) Trinocular Microscope with Tucsan camera attachment. The identification of the sample was carried with the help of taxonomical works of Prescott (1939 a,b), Tiffany & Britton (1952), Desikachary (1959) and Edmundson (1992). The physico- Chemical Analysis of 4 sites was done as per standard Method recommended by APHA (1998).

OBSERVATIONS

TABLE 2: Physico-Chemical characteristics of Roruchu

Parameters	Site-1	Site-2	Site-3	Site-4
Air Temperature (^oC)	7	7.5	10.4	11
Water Temperature (^oC)	5	5	7	7.5
Turbidity (N.T.U.)	4	3	5	7
Transparency (m)	0.54	0.46	0.48	0.30
Water velocity (m/sec)	2.35	1.96	0.95	0.99
pH	7.4	7.7	7.8	7.4
Total Dissolve solids(mg/l)	38	36	38	48
Conductivity ($\mu s/cm^2$)	0.15	0.19	0.21	0.21
Free CO_2 (mg/l)	1.076	1.076	1.32	2.42
Dissolve Oxygen (mg/l)	11.35	10.94	10.5	9.83
Phenolphthalein Alkalinity (mg/l)	50	50	48	52
Chloride (mg/l)	5.11	5.10	5.11	5.14
Total Hardness (mg/l)	58	61	60	74
Calcium Hardness (mg/l)	11.6	11.9	13.2	13.9
Phosphate (mg/l)	0.01	0.054	0.17	0.354

TABLE 3: Periphyton compositions of Roruchu

Periphytons	Site-1	Site-2	Site-3	Site-4
Bacillariophyceae				
Achanthes undata	+	+	-	+
A.inflata	+	+	+	-
Amphora sp.	+	+	-	-
Cymbella aspera	+	-	+	-
C.affinis	+	-	+	+
C. tumida	+	+	+	+
Encyonema sp.	-	+	+	+
Epithema turgidula	+	+	+	-
Fragillaria virescens	+	+	+	+
Gomphomena abbreviatum	+	+	-	+
G. Elegans var. robusta	-	-	-	+
G. montanum var. geniumum	-	+	+	+
Hannaea arcus	-	-	+	+
Hantzchia sp.	-	-	-	+
Melosira varians	+	+	-	-
Navicula radiosa	+	+	-	-
N. viridula	+	+	+	-
N. sphaerophora	+	-	-	-
Nitzschia palea	+	-	+	-
Pinnularia major	-	-	+	+
P. viridis	+	+	-	+
Stauroneis anceps	+	+	+	+
Synedra ulna var. oxyrhynchus	+	+	-	-
S. ulna var. aequalis	+	+	+	+
S. tabulate	+	+	-	-
Surirella splendida	+	+	+	+
S. euglepta	+	-	-	-
Chlorophyceae				
Cosmarium awadhense	+	+	+	+
Closterium parvulum	+	-	-	-

Choroccocus sp.	+	+	-	-
Eudorina sp.	+	+	-	-
Microspora indica	+	+	+	+
Netrium digitus	+	-	+	-
Oedogonium globosum	+	+	+	+
Radiococcous bavaricus	+	-	-	-
Spirogyra grevilleana	+	-	+	-
S. maravillosa	+	-	-	+
S. notabilis	+	-	-	-
Stigeoclonium attenuatum	+	+	-	-
Scenedesmus quadricauda	+	-	-	-
Ulothrix zonata	-	+	-	-
U. tenuissima	+	+	-	-
Vaucheria synandra	+	-	-	-
Zygnema pseudopunctinatum	+	+	+	+
Cyanophyceae				
Anabaena cylindrica	+	-	+	+
Apanothece microscopica	+	-	-	-
Chaemisiphon confervicola	-	-	+	-
Clothrix sp.	-	+	+	-
Lyngbya truncicola	+	+	-	+
Nostoc muscorum	+	+	-	-
Oscillatoria princeps	+	-	+	+
O. cirviceps	-	-	+	+
Phormidium Atriculatum	+	-	+	+
Komvophoron constrictum	+	+	-	-

RESULT & DISCUSSIONS

Quality of an aquatic ecosystem is dependent on the physical and chemical quality of water and also biological diversity of the system. Ghavazan *et al*., 2006), *Tiwari and* Chauhan (2006): Tas and Gonulol (2007): Cairns and Dickson (1971) stated that the analysis of Biological materials along with Chemical characteristics of water form a valid method of water quality assessment. The various Physico-Chemical parameters are given in Table 2. It was observed that the fluctuation of these factors at various sites affect the biodiversity of periphytic algae in the stream.

Air and water Temperature

Air temperature ranged from 7°C (site-1) to 11 °C (site-4), where water temperature ranged from 5°C (site-1) to 7.5 °C (site-4). Lower water temperature was due to the cold low ambient temperature and shorter photoperiods. Jana (1973) & Chari (1980) stated that temperature is a critical factor for seasonal periodicity of phytoplankton..

Turbidity

In general turbidity ranged between 4 to 7 NTU, during sampling. It can be concluded that due to extensive quarry activities there is an increase in turbidity due to highly disturbed river bed and silt flow. Overall water is clear generally during this time of year and turbidity values recorded are basically low.

Transparency

The value ranged between 0.54m (site-1) to 0.30m (Site-4), transparency value was recorded high, due to winter season which can be related to lower rate of decomposition.

pH

pH of natural inland water is mainly controlled by carbonic system. The interaction among various carbon compound and ions i.e. CO_2, CO_3^{--}, HCO_3^- affects the value of pH (*Singh et. al* 1989) In general water maintained moderate pH on alkaline side and varied between 7.4 to 7.8 among different stations. This showed that during winter time pH was always on greater since the water level decreases and algal matter start decomposing at a very low rate resulted in conversion of carbonate ions into carbon dioxide as evidenced absence of free CO_2 and Alkalinity.

Total Dissolved solute (TDS)

Concentration of TDS varied from 38 mg/l (site-1) to 48 mg/l at (site-4), the value is slightly raised at Site-4, which may be due to the location of site in the Hindu cremation area where continuous flow of religious offering and ashes from burnt woods etc were disposed off directly into the river body and also may be due to the high anthropogenic activities.

Conductivity

Concentration of conductivity varied from 0.15 ($\mu s/cm^2$) at Site-1 to 0.21 ($\mu s/cm^2$) at Site-4, which could be related to the lacking of nutrient flow during winter season. Site-III and Site-IV showed a clear increase in conductivity due to various human activities in the river bed which are clearly visible during sampling also.

Free CO_2

For CO_2 values fluctuated between 1.076 mg/l (site-1) to 2.42 mg/l at (site-4). The high value recorded at all the sites can be considered low because during this time of sampling free CO_2 are generally low since it was completely utilized for algal photosynthesis and it can be attributed to higher decomposition rate of the garbage disposed along the river banks and religious offering at cremation area and the disposal of ashes and un-burnt wood into the river. Presence of free CO_2 therefore indicates organic matter decomposition in these sampling stations.

Dissolved Oxygen

Dissolved oxygen (DO) plays a vital role in support of aquatic life, oxygen depletion often results during time of high community respiration and increased decomposition of organic matter (*Rochford, 1951 and Jameel, 1998*), with regard to DO variables, values fluctuated between 11.35 mg/l at Site-1 to 9.83mg/l at Site-4. The higher value at site-1 recorded can be attributed to lower rate of decomposition, low respiratory demand and the capacity of water to hold high Oxygen concentration at low temperature. The discharge of garbage and religious offerings from the cremation site might have attributed to reduced DO level at site-IV.

Phenolphthalein Alkalinity

Alkalinity is a measure of weak acid present in water and of the cations balanced against them (*Sverdrap et al*, 1942).It ranged between 47-52 mg/l, it didn't showed much fluctuation between the different stations, although maximum and minimum values were different from each other. In general sites receiving pollutants and disturbances etc. registered greater values as compared to Site-I. It appears from the data that Alkalinity value of 48 mg/l recorded at Site-III is slightly on decreased side, which may be attributed to dilution due to mixing of various nallas and small spring water sources from the immediate catchment which are devoid of any polluting sources. Alkalinity is one of the basic parameter to measure the productivity of fresh water. From the values recorded at different site the highly productive nature of Roruchu River is evident. This is supported further by the distribution of algae at the different station investigated.

Chloride

Chloride values as such didn't showed any major fluctuations between all the sites, the maximum of 5.14 mg/l was recorded at Site-IV. A faintly increased in concentration of chloride downstream is due to the reduced flow and polluting sources in the river.

Total & Calcium Hardness

Both total and calcium hardness showed a similar relationship in their fluctuation at different sampling sites. Comparing the different sites, Site-I recorded the lowest total and calcium hardness. Maximum total hardness of 74 mg/l was recorded at the Site-IV and maximum calcium hardness was highest (13.9 mg/l) at this site, which could be attributed to garbage disposal, household waste water disposal and religious offering and disposal of charcoal and ashes from the crematory.

Phosphate

The phosphate content ranged between 0.01 to 0.354 mg/l between stations as shown in table.2. It can be concluded that the high value of phosphate was due to mixing drainage of small agricultural runoff from near agricultural land etc.

Periphytic composition

Algae attached in the fast flowing water should be firmly anchored in they live of hard surfaces. Algal growth of natural substrate like pebbles, stones, leaves and sand etc. represent the natural flora. In the present study of river Roruchu, the submerged macrophyte were not recorded at all time and mostly they were absent at all the sites. Thus the Periphytons study was carried out only from submerged stones and pebbles. The distribution of lithophytic algae showed basically three major specoise groups Bacillariophyceae, Chlorophyceae and Cyanophyceae. A total of 54 periphytons species (table-3) belonging to 3 major group were documented in this study indicate diverse nature of phytoplankton of which 27 belongs to Bacillariophyceae, 17 belongs to Chlorophyceae and 10 belongs to Cyanophyceae.

The order of dominance was Bacillariophyceae> Chlorophyceae>Cyanophyceae. The presence and absence of phytoplankton at the selected site is given in table 3.

Bacillariophyceae

In general the distribution of lithophytic algae showed Bacillariophyceae as the most dominant group at all the stations consisting of 27 taxa which constitute the most dominant speciose group of phytoplankton. The diatoms were mainly represented by the species of *Gomphonema, Navicula, Nitzchia , Fragillaria, Cymbella, Synedra, Acanthes, Diatimella, Caloneis etc. Navicula sp* was recorded to be the most dominant species amongst Bacillariophyceae. The abundant occurrence of pollution tolerance species like *Gomphonema sp, Nitzchia sp* (Venkateswalu, 1981) in site-4 indicated that it is comparatively more polluted as compared to other sites studied. With respect to the phytoplankton communities Bacillariophyceae or Diatoms group remained dominant in the river Roruchu during the sampling, which could be attributed to the fact that they are able to grow under the condition of weak light and low temperature which are less suitable for other algae.

Chlorophyceae

Chlorophyceae was mainly represented by Desmids, Zygnematales and Chlorococcales with 17 nos. taxa found to be the second most speciose group at all the sites. The most abundant species in terms of abundance were *Spirogyra sp, Cosmarium sp and Ulothrix sp*. Among Chlorophyceae *Spirogyra sp*. was found to be the most dominant species at the selected sites. Site-1 showed greater composition of green algae with declined at site-IV, due to various polluting sources. Species of *Spirogyra, Cosmarium, Ulothrix and Oedogonium etc.* were quite common. The distribution of these genera showed remarkable difference among different stations.

Cyanophyceae

Blue greens were the least dominant group with 10. taxa found to be the third most species group of phytoplankton at all the selected sites. Species of *Oscillatoria, Nostoc* and *Anabeana* was recorded in good number. The most dominant species in terms of population were *Oscillatoria* sp.

CONCLUSION

Periphyton communities do not respond only to natural change in the stream, but may also present variations as consequences of human intervention affecting water body, either directly or through activities carried out in the immediate catchment on whole. It can be ascertain that various physico-chemical factor like high pH, dissolved oxygen, phosphate, calcium and low water temperature are favorable for growth of diatoms. The high dissolved oxygen and other parameter in considerable quantity are important factors in the growth of green algae. Present investigation indicated that among all the sites, Site-IV is

highly polluted which is evident from individual indicator species presence of such as *Gomphonema* sp. *Nitzschia* sp.

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REFERENCES

A. P. H. A. (1998) Standard Methods for Examination of water and wastewater. 20th Ed. American Public Health Association, Washington, D.C.

Bhakta, S., Das, S.K., Adhikary, S.P. (2010) Freshwater Algae of Sikkim, *J. Indian Bot. Soc.* Vol.89 (1& 2): 169-184.

Baba A. I., Sofi, A.H., Bhat, S.U., Pandit, A.K. (2011) Periphytic Algae of River Sindh in the Sonamarg Area of Kashmir Valley. *Journal of Phytology*, 3(6): 01-12, ISSN: 2075-6240.

Cairas, S. and Dickson, K.L. (1971) A simple method for Biological Assessment of effect of waste discharge on the aquatic bottom dwelling organism: *J. wat. Poll*. Central Fed., 775.

Chari, M.S. (1980) Environmental variation in the Physico-Chemical characteristic of freshwater pond. M.Phil Thesis. Aligarh Muslim University, Aligarh.

Denny P., Bowker, D., Bailey, R. (1978) The Importance of the littoral epiphyton and food for commercial fish in the recent African manmade lake, Nyuba Yamungu Reservior, Tanzania-Bio. J. limn. Soc, 10(1): 139-150

Desikachary, T.V. (1959) Cyanophyta. ICAR. New Delhi, pp. 686

Das, D. & Keshri, J.P. (2012) Desmids from Manmecho (Mamencho)Lake, Eastern Himalaya I. *NeBio* 3 (2):37-44.

Das, D. & Keshri J.P. (2012) Algae from Gurudongmar Lake (north Sikkim, Eastern Himalaya*), NeBio* Vol. 4, No. (6), 61-69

Das, D. and Keshri, J.P. (2012) Desmids from South Sikkim, India, *Nelumbo* 55:172-180.

Edmonson W.T. (1992) Ward and Whipple Fresh water Biology. 2nd ed. Intern. Books and Periodicals Supply Service New Delhi.

Ghavazan, N.J. Gunale & R.K. Trivedy (2006) Limnological evaluation of an urban freshwater river with special reference to phytoplankton. *Pollu. Res*. 25. 250-268.

Hassan Khalida, Yousuf A.R., Balkhi M.H., Jamila Ifran & Dar Sabzar Ahmad (2012) Seasonal Assessment of Physico-Chemical Characteristics of water in River Jhelum of Kashmir, *J. Himalayan Ecol. Sustain. Dev*. Vol. 7, ISSN 0973-7502

Irshad Ahmad Ahangar, Saksena, D.N., Mohammad Farooq Mir & Mohammad Afzal Ahangar (2012) Seasonal variations in physico- chemical characteristics of anchar lake, kashmir, *I.J.A.B.R*., VOL. 3(2) 2012: 352-357.

Jana, B.B. (1973) Seasonal periodicity of plankton in freshwater pond in West Bengal, India. *Hydrobiologia*, 58, 127-143.

Jameel, A.A. (1998) Physicochemical studies in Vyyakandan channel water of river Cauvery.*Poll. Res*. 17: 111-114.

Jyoti, M.K., Gupta, K and Sharma, A. (2003) Effects of pilgrimage on the quality of biota of stream Ban-Ganga (katra), Jammu. *Oriental Sci*., 8:41-53.

Kumar, S. and Rai, S.K. (2005) Contribution to the Algal Flora (Chlorophyceae) of Namchi, Sikkim Himalayas. *Our nature* 3:50-55.

Peters J.C., Ball, R.C., Kayen, N.R. (1968) An evaluation of artificial substrate for measuring Periphyton. Tech Rep. No.1. red Cedef. River Ser., Institute for water resources, Michigan state University, 71p.

Prescott, G.W. (1939a) How to know the fresh water Algae. Brown Co. publishers. 450pp

Prescott G.W.(1939b) Some relationship of phytoplankton to limnology and aquatic biology. - *Publ. Amer. Asso. Adv. Sci*., 10: 65-78.

Prescott, G.W. (1951) Algae of the Western Great Lakes Area Michigan, 932 pp.

Pandit A.K., Pandit, S.N., Kaul, V. (1985) Ecological relations between invertebrates and submerged macrophytes in to Himalayan lakes- *Poll res*., 4(2): 53-58.

Prasad, B.N. and Mishra, R. (1987) Desmids Flora of Sikkim *I. Geography* 17(2):163-173.

Prasad, B.N., Srivastava, M.N. & Khanna, P. (1988) Diatoms of Kalimpong, West Bengal (India), *Geophytology* 18(1): 78-86.

Rochford, D.J. (1951) Studies in Australian estuarine hydrology. Introductory andcomparative features. *Aust. J. Mar. Fresh. Res.* 2(1): 116.

Sverdrap, H.H., Johnson, M.W. and Fleming R.H. (1942) The Oceans: *Their physics,chemistry and general biology*. Prentice Hall, New York.

Santra, S.C. 1984. Algal Flora of Sikkim.

Himalaya-I: A contribution to our knowledge of the Blue-green Algae of North-East Sikkim (India). *Journal of Economic and Taxonomic Botany* 5 (5):1209-1219.

Suseela, M.R. and Toppo, K. (2006) Enumeration of Freshwater Algal Flora of Gangtok, Sikkim, India. *Geobios* 33(4): 225-232.

Suseela, M.R. and Toppo, K. (2007) Contribution to the Desmids flora of Sikkim Himalayas, India. *Bull. Natt. Mus. Nat. Sci*. Ser B. 33(3-4):105-114.

Tiffany, L.H. and Britton, M.E. (1952) The algae of Illinois. Hafner publishing Co., New York, pp. 1-407.

Tiwari, A. and S.V.S. Chauhan (2006) Seasonal phytoplankton diversity of Kithan Lake, Agra. J. Environ. Boi;., 27, 35-38.

Tas. B and Gonulol, A. (2007) An ecological and Taxonomic study on Phytoplankton of a shallow lake: Turkey *J. Environ, Biol*. 28, 439-445.

Venkateswarlu, V. (1981) Algae as indicator of river water quality and pollution. WHO workshop on Biological indicators and indices of Environment Pollution, Osmania University, Hyderabad pp 93-100.