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Research Paper

Distribution pattern of freshwater algae in and around areas of Mangalore University Campus, Mangalagangothri, Dakshina Kannada District of Karnataka

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Abstract

In the present study, water samples from different sampling sites in an around areas of Mangalore University campus was collected on seasonal basis during the months from August, 2017 to March, 2018 and analyzed for physico-chemical characteristics. A detailed investigation on the species occurrence of algae, their distribution pattern in these different sampling stations was determined. A total of 60 species of algae were recorded in the eight sampling sites studied, among which 24 species of cyanobacteria,28 species of diatoms and 8 species of green algae were found out. When the species occurrence of algae was studied, it was revealed that, species of cyanobacteria like, *Merismopedia marssonii, Oscillatoria chlorina*, *Oscillatoria homogenea, Oscillatoria limnosa*, *Oscillatoria perornata* and diatom species namely, *Navicula clavata* were found to be dominant (with 100% frequency of occurrence). These species were also showed abundance occurrence in most of the sampling sites besides showing 100% frequency. The maximum number of algal count with dominant algae was noticed in a sewage drain site close to boy's hostel with three marker species of cyanobactaria viz., *Oscillatoria chlorina*, *Oscillatoria homogenea* and *Oscillatoria perornata.* The marker species further subjected for FTIR analysis and it revealed the presence of various classes of functional groups such as, hydrocarbons, oxygen compounds, nitrous oxide, carboxylic acid etc. in them.

Keywords: Freshwater, Cyanobacteria, Diatoms, Green algae, Indicator species, FTIR, Mangalore University

Introduction

Algae are morphologically simple, chlorophyll containing organisms that range from microscopic and unicellular (single celled) to multicellular. They are typically autotrophic, deriving their energy from their surroundings in the form of sunlight. They play an important role in food chains and in maintaining the oxygen supply on our planet. They are found in the sea, rivers, lakes, and ponds, on trees, soils and walls and as symbiotic partners with fungi (as lichens) and with animals (in corals, protozoans and cnidaria). Algae found just about everywhere where there is light with which to photosynthesize and where water is available for reproduction[1-3].

Algae comprise of photoautotrophic organisms of simple structure, which possess unicellular reproductive organs not enclosed within a cellular wall. Algal classes are usually distinguished on the basis of their pigmentation, nature of food reserves, fine structure of plastids, chemical nature of the cell wall and the number, position and fine structural details of flagella in the motile stages[4,5.] Algae occur in a variety of environment conditions and can be found in fresh as well as marine waters, many often occur in brackish water. A good number of algae are terrestrial, being found in moist soil as an important part of the soil flora essential in soil productivity and on bark of trees[5,6.]

Cyanobacteria are Gram negative, aquatic and photosynthetic prokaryotes that occur in water and can synthesize their own food. The species diversity, annual and seasonal variation of the cyanobacterial assemblage were investigated in different habitats namely, temple ponds, paddy field, estuaries, lakes, rivers and streams, ponds and sulfur spring[7]. During the recent past, studies on cyanobacteria have emphasized their important role in ecosystem. They grow at any place and in any environment where moisture and sunlight are available. The abundance and composition of cyanobacteria in surface waters of ponds and lakes have been discussed in many works and a conflicting general impression exists. Several reports are now available on the occurrence of algae in polluted waters[8,9].

Diatoms are microscopic unicellular algae characterized by large quantity of silica impregnated in the cell wall called frustules and are being extensively used as bio-indicators in water quality assessments as they have short generation time and many species have a specific sensitivity to ecological characteristics[10-12]. Diatoms tend to have significantly higher maximum uptake rates of nutrients than any other group and are considered as a euryhaline and eurythermal phytoplankton group, which grow quickly under estuarine conditions[13]. They prefer to inhabit and dominate the phytoplankton community in shallow, turbulent and upwelling region i.e. coastal region. Diatoms are generally known to be adapted to low light levels and are therefore capable of surviving in the turbid estuaries, while green algae are known to depend on relatively high light intensities[14]. Diatoms are preferred food for many grazers and organisms in the upper trophic levels and thus form the basis for many of the productive fisheries.

Alteration in physico-chemical factors in the habitats can lead to various ecological consequences like changes in species composition, blooms of phytoplankton and decrease of oxygen concentrations. Phytoplanktons are important in regulating the productivity of higher trophic level[15]. Meanwhile they served as bioindicators of water quality including pollution. Diatoms are a class of phytoplankton that are extensively being extensively being used as bioindicators for environmental monitoring these single celled organisms reproduce quickly and are sensitive to a number of environmental pressures including changes in salinity, pH, nutrients, turbidity, various pollutants, water depth, substrate availability etc. diatoms can provide valuable information for monitoring rivers, particularly on organic pollution[16,17]. The ecological importance and distinguishing features of algae, particularly as indicators of nutrient pollution, make them important in bioremediation. Algae of many kinds are really good indicators of water quality and many lakes are characterized based on their dominant phytoplankton groups. Many blue-green algae occur in nutrient-poor waters, while some grow well in organically polluted waters. Algae are good indicators of clean water since many species occur instantly and predominantly in the clean water zone of the streams. However it is more satisfactory to emphasize the presence or absence of several species of clean water algae then of any one species to define the clean water zone.

With reference to species occurrence and diversity of algae of the Mangalore University campus is lacking/less documented, since no such reports are available the present study was undertaken to study the occurrence, distribution pattern of freshwater algae (particularly cyanobacteria, diatoms and green algae) in relation to physico-chemical characteristics of their environment in and around areas of Mangalore University campus, Mangalagangothri, Dakshina Kannada District of Karnataka.

Study area: The study area Mangalore University campus is located at Mangalagangothri 21 km from Mangalore on the Southern side, confined between 74° 55' 15.99" east longitude and 12° 48' 34.02" north latitude. The selected study area includes different sampling stations (such as artificial tanks, natural ponds and sewage drain etc.) in and around areas of Mangalore University campus, Mangalagangothri, Konaje, Mangalore (Figure 1).

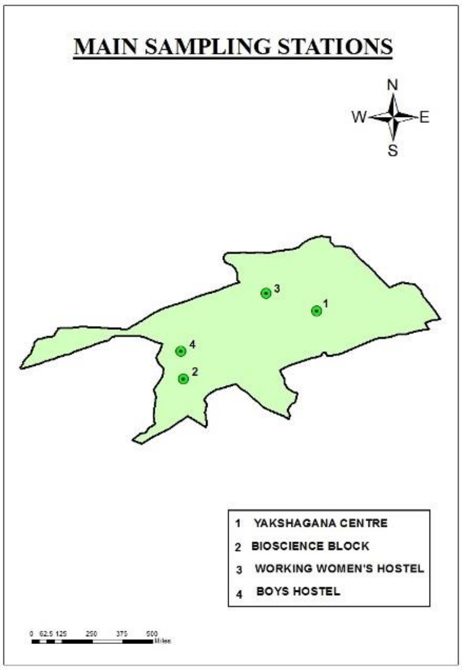

Figure 1: Map showing different sampling stations/locations in and around areas of Mangalore University campus, Mangalagangothri, Mangalore

Sample collection
Sampling was conducted in the forenoon between 9.00 A.M to 12.30 P.M. From each sampling site, the water was collected in plastic cans/vials for physico-chemical analysis in the laboratory. The sampling was also made by taking the scrapings from the surfaces of rock, pillars etc. from the ponds and tanks. They were collected in a sterile bottle and brought to the laboratory for identification. The other method employed was the direct examination of water. For this 10 ml of water was taken and was directly observed under the low and high power objective of the binocular microscope (Magnum-B, U. K.) for the presence of algae.

Physico-chemical characteristics of water samples
Water temperature of the samples collected from each sampling site was determined by mercury thermometer, while the pH, conductivity, salinity and total dissolved solids (TDS) were assessed using a water analysis kit (Water Analyzer 371, Systronics, Gujarat, India).Identification of algae (Cyanobacteria, diatoms and green algae). Morphological identification of the cyanobacterial species encountered in different sampling stations was done according to[18-20]. Diatoms and green algal species were identified by referring standard manuals[21-23].

Species frequency was calculated as follows

$$\text{Species Frequency (F\%)} = \frac{\text{Total number of samples in which species occurred}}{\text{Total number of samples studied}} \times 100$$

FTIR (Fourier-transform infrared spectroscopy) analysis

FTIR (Fourier-transform infrared spectroscopy) analysis was carried out for the three species of cyanobacteria which were found to be indicator species, since having more dominant frequency of occurrence among the sampling sites studied. Through FTIR analysis, the presence of various classes of active functional groups present in those species was determined.

Results
Physico-chemical characteristics of water samples
The physico-chemical parameters such as temperature, electrical conductivity, total dissolved solids, salinity and pH was analyzed for the water samples collected from different sampling stations from Mangalore University campus, Konaje which is shown in Table 1. The water temperature was

recorded at the time of sample collection while, other parameters such as pH, conductivity, salinity and total dissolved solids were analyzed in the laboratory with the help of a water analyzer kit.

Table 1: Physico-chemical characteristics of water samples collected from differentsampling stations of Mangalore University campus, Mangalagangothri (n = 3, Average values of three water samples taken on seasonal basis)

	Physico-chemical parameters				
Sampling stations	**Temperature (ºC)**	**Conductivity (µS)**	**TDS (ppm)**	**Salinity (ppt)**	**pH**
S1	30.9	58.6	31.5	0.02	7.42
S2	29.7	190	101	0.09	6.55
S3	30.1	112	59.9	0.04	7.25
S4	31.0	154	82.5	0.05	7.25
S5	30.6	111	59.3	0.04	7.43
S6	30.2	399	214	0.13	7.50
S7	31.1	172	91.8	0.06	7.78
S8	30.3	816	90.3	0.06	8.48

Sampling Stations*
S1-Bioscience quadrangle pond, **S2-**Working Women's hostel drainage, **S3-**Bioscience garden pond 1, **S4-**Bioscience garden pond 2, **S5-**Bioscience artificial tank 1, **S6-**Bioscience artificial tank 2 , **S7-**Stream near Yakshagana study center, **S8-**Boy's hostel sewage drain.

Temperature
The temperature plays an important role for controlling the physico-chemical and biological parameters of water and considered as one among the most important factors in the aquatic environment particularly for freshwater. The temperature of the samples ranged from 29.7-31.1ºC. The temperature was the highest in sample station 7 (S7) i.e., the one which was collected from stream nearer to Yakshagana study center. It can be due to high solar radiation, low water level, clear atmosphere and high atmospheric temperature. The lowest temperature was reported in sample station 2 (S2) i.e., the one which was collected from Working Women's hostel drainage.

Conductivity
Water capability to transmit electric current is known as electrical conductivity and served as a tool to assess the purity of water. The electrical conductivity of the samples ranged from 58.6-816 µS. The conductivity was the highest in the sample station 8 (S8) i.e., the one which was collected from Boy's Hostel sewage drain. The high level of conductivity in water indicates a high pollution status. The conductivity was the lowest in the sample station 1 (S1) i.e., the one which was collected from Bioscience quadrangle pond.

Total dissolved solids (TDS)
Total dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates and some small amounts of organic matter that are dissolved in water. The Total dissolved solids (TDS) ranged from 31.5-214 ppm. The highest TDS was observed in the sampling station 6 (S6) i.e., the one which was collected from the Bioscience artificial tank 2. This indicates that the water is polluted. The contamination can be due to garbage and other related wastes in the surface of the water. The lowest TDS was observed in the sampling station 1 (S1) i.e., the one which was collected from the Bioscience quadrangle pond.

Salinity
Salinity is the measure of all the salts dissolved in water. In fresh water the concentration of salts or salinity, is nearly zero. Salinization refers to an increase in the concentration of total dissolved solids in water. The salinity of the samples ranged from 0.02-0.13 ppt. the highest salinity was reported from the sampling station 6 (S6) i.e., the one which was collected from the Bioscience artificial tank 2. The lowest salinity was reported in the sampling station 1 (S1) i.e., the one which was collected from the Bioscience quadrangle pond.

pH

Freshwater lakes, ponds and streams usually have a pH of 6-8 depending on the surrounding soil and bedrock. In deeper lakes where stratification occurs, the pH of water is generally higher (7.5-8.5) near the surface and lower (6.5-7.5) at greater depths. The p H of the samples ranged from 6.55-8.48. The highest pH was observed in the sampling station 8 (S8) i.e., the one which was collected from the Boy's hostel sewage drain. The lowest pH was recorded in the sampling station 2 (S2) i.e., the one which was collected from Working Women's hostel drainage.

Distribution pattern of algae (Cyanobacteria, Diatoms and Green algae)in different sampling stations

Occurrence of the algae in and around the campus of Mangalore University campus, Mangalagangothri, Mangalore is recorded in the Table 2 given below. In the present study, a total of 60 species of algae were recorded including 24 species were cyanobacteria, 28 species of diatoms and 8 species of green algae were identified and recorded.

Table 2: Distribution pattern of algae (Cyanobacteria, Diatoms and Green algae) in different sampling stations in and around areas of Mangalore University campus, Mangalagangothri of Dakshina Kannada District

S. No.	Algal Group/Species	Sampling Stations*								Frequency (%)
I.	**Cyanobacteria**	S1	S2	S3	S4	S5	S6	S7	S8	
1.	*Anabaena fertilissima* C. B. Rao	+	-	-	+	-	+	+	-	50.0
2.	*Chroococcus minor* Nageli	+	+	+	+	+	-	+	+	87.5
3.	*Dactylococcopsis fascicularis* Lemm.	+	+	-	+	-	+	-	+	62.5
4.	*Dactylococcopsis raphidioides* Hansg.	+	+	+	+	-	-	+	+	75.0
5.	*Lyngbya polysiphoniae* anagnostidis	-	+	-	-	+	-	+	+	80.0
6.	*Merismopedia marssonii* Lemm.	++	+	++	+	+	+	+	++	100
7.	*Myxosarcina spectabilis* Geitler	-	-	-	-	-	+	-	+	25.0
8.	*Oscillatoria amphibia* Ag.	+	+ +	+	-	-	+	++	+	75.0
9.	*Oscillatoria chlorina* Kutz.	+	+ +	+	+ +	+	+	+	++	100
10.	*Oscillatoria curviceps* Ag.	-	-	+	+	-	-	+	+	50.0
11.	*Oscillatoria homogenea* Fremy	+	++	+	+	+	++	+	++	100
12.	*Oscillatoria limnosa* Ag.	+	+	+	++	+	+	++	+	100
13.	*Oscillatoria perornata* Skuja	+	++	+	++	+	+	+	++	100
14.	*Oscillatoria princeps* Vaucher	++	+	+	+	-	-	++	++	75.0
15.	*Oscillatoria pseudogeminata* Schmid	-	-	-	+	-	+	-	+	37.5
16.	*Oscillatoria sancta* Gomont.	+	-	-	+	-	+	-	+	50.0
17.	*Oscillatoriasub brevis* Schmidle	+	-	-	-	+	-	+	-	37.5
18.	*Oscillatoria boryana* Bory	-	-	-	-	-	+	-	+	25.0
19.	*Oscillatoria acuta* Bruhl & Biswas	+	-	-	-	-	+	-	-	25.0
20.	*Phomidium tenue* Gom.	-	-	-	+	+	+	-	+	50.0
21.	*Phormidium anomala* Rao	+	-	-	-	+	-	+	+	50.0
22.	*Phormidium corium*Gomont	+	-	+	-	-	-	-	+	37.5
23.	*Phormidium fragile* Gomont	-	+	+	-	+	-	-	+	50.0
24.	*Phormidium valderianrum* Gom.	-	-	+	-	+	-	+	+	50.0
	TOTAL (24)	**16**	**12**	**13**	**14**	**12**	**14**	**15**	**21**	
II.	**Diatoms**									
1.	*Achnanthidium minutissimum* Joseph	+	-	+	-	+	-	+	+	50.0
2.	*Actinoptychus senarius* Ehrenb	-	+	-	+	-	-	-	-	25.0
3.	*Bacteriastrum comosum* Pavill	+	-	+	+	-	-	-	-	37.5
4.	*Caloneis crassa* Greg	+	-	-	-	+	-	+	+	50.0

5.	*Caloneis westii* Hendey	-	+	+	+	-	+	-	+	62.5
6.	*Campylodiscuscrebrecostatus* Grev	+	-	+	+	-	-	-	+	50.0
7.	*Cymbella austriaca* Grunow	+	+	-	-	-	-	+	+	50.0
8.	*Cymbella* sp.	+	+	-	+	-	+	-	+	62.5
9.	*Delphine issurirelloides* Hendey	+	-	+	-	-	-	+	-	37.5
10.	*Diploneis petersenii* Andrews	-	+	-	+	+	+	+	+	75.0
11.	*Gomphonema*cf. *Hebridense* Grunow	+	-	-	-	+	+	-	+	50.0
12.	*Gomphonema productum* Metzeltin	-	+	-	+	+	-	-	+	62.5
13.	*Mastogloia paradoxa* Grunow	+	+	+	-	+	+	-	+	75.0
14.	*Navicula clavata* Greg.	++	+	+	+	++	+	+	++	100
15.	*Navicula cryptotenella* Lange.	-	-	-	-	+	-	+	+	37.5
16.	*Navicula tenella* Var.	+	+	-	-	+	-	-	+	50.0
17.	*Nitzchia maxima* Grun.	-	+	+	+	-	-	-	-	37.5
18.	*Nitzschia thermalis* Grun.	-	-	-	+	-	-	-	+	25.0
19.	*Pinnulariaa coricola* Hustedt	-	-	+	+	-	+	-	+	50.0
20.	*Pinnularia alpine* Wm. Smith	++	-	-	-	+	-	+	++	50.0
21.	*Pinnularia subcapitata* Krammer	+	-	-	-	+	-	++	+	50.0
22.	*Pleurosigmanicobaricum* Grun.	-	+	-	+	-	+	-	-	37.5
23.	*Stenopterobia delicatissima* Kusber	-	-	-	+	+	-	-	+	37.5
24.	*Stenopterobia* sp.	+	-	-	-	+	-	-	+	37.5
25.	*Synedra* sp.	-	+	+	+	-	-	+	+	62.5
26.	*Tabellaria* sp.	+	-	+	-	+	-	+	+	62.5
27.	*Trachyneisaspera* Cleve	+	-	-	+	-	+	-	-	37.5
28.	*Trigonium* sp.	-	+	+	-	+	-	+	-	50.0
	TOTAL(28)	**16**	**13**	**12**	**15**	**15**	**9**	**12**	**21**	
III.	**Green algae**									
1.	*Chlorella vulgaris* Beyerink	+	+	+	+	+	+	-	+	87.5
2.	*Closteriumpritchardianum* W. Archer	+	+	+	+	-	+	+	++	87.5
3.	*Hydrodictyon reticulatum* Bory	+	-	+	-	+	+	-	+	62.5
4.	*Oedogonium nodulosum* Wittrock	++	+	-	+	-	-	-	-	60.0
5.	*Scenedesmus* sp.	-	+	+	+	+	+	+	-	75.0
6.	*Ulothrix* sp.	+	-	-	-	-	+	-	+	37.5
7.	*Vaucheria geminata* De Candolle	-	+	-	+	-	-	-	-	25.0
8.	*Volvox aureus* Ehrenberg	+	-	+	-	-	+	+	-	50.0
	TOTAL (8)	**6**	**5**	**5**	**5**	**3**	**6**	**3**	**4**	

+: Present, - : Absent, ++: Dominant

Sampling Stations*

S1-Bioscience quadrangle pond, **S2-**Working Women's hostel drainage, **S3-**Bioscience garden pond 1, **S4-**Bioscience garden pond 2, **S5-**Bioscience artificial tank 1, **S6-**Bioscience artificial tank 2 , **S7-**Stream near Yakshagana study center, **S8-**Boy's hostel sewage drain.

Cyanobacteria

The name 'cyanobacteria' comes from the color of the bacteria. They obtain their energy through photosynthesis. The ability of cyanobacteria to perform oxygenic photosynthesis is thought to have converted the early reducing atmosphere into an oxidizing one, which dramatically changed the composition of life forms on earth by stimulating biodiversity and leading to the near extinction of oxygen-intolerant organisms.

In the present observed data i.e., Table 2, which indicated the presence of about 24 species of cyanobacteria among the sampling stations studied. Among which five species exhibited 100% frequency of occurrence. The species such as, *Merismopedia marssonii, Oscillatoria chlorina*, *Oscillatoria homogenea, Oscillatoria limnosa* and *Oscillatoria peronata* are found to be dominant among the 24 species observed (100% frequency of occurrence) followed by *Chroococcus minor* with a moderate frequency of 87.5%, *Lyngbya polysiphoniae* showed a frequency of 80%, *Oscillatoria princeps* and *Dactylococcops israphidioides* showed a frequency of 75% , *Dactylococcopsis fascicularis* showed a frequency of 62.5%,species like, *Phormidium* sp., *Oscillatoriacurviceps*, *Oscillatoria sancta*, *Phomidium tenue*, *Phormidiumanomala* and *Phormidium fragile* showed 50% frequency of occurrence. According to the data *Oscillatoria pseudogeminata*,*Oscillatoriasub brevis* and *Phormidium corium*showed frequency of 37.5%, while, *Oscillatoria boryana* showed 25% frequency. Considering the sampling stations studied, it was Boy's hostel sewage drain (S8) that exhibited maximum number of cyanobacteria in which 21 species were recorded. A total of 16 species was found in the sampling stations S1 and S7 (15 species), followed by S4 having a total of 14 species and S3 and S6 having a total of 13 species and S2 and S5 having a total of 12 species of cyanobacteria.

Diatoms

Diatoms are a major group of algae and are of the most common types of phytoplankton. Most diatoms are unicellular, although they can exist as colonies in the shape of filaments or ribbons, fans, zigzags (e.g. *Tabellaria*). Diatoms are producers within the food chain. A characteristic feature of diatom cell is that they are encased within a unique cell wall made of silica (hydrated silicon dioxide) called a frustules. These frustules show a wide diversity in form, but usually consist of two asymmetrical sides with a split between them, hence the group name.

In this study, a total of 28 species of diatoms were recorded. Among which *Navicula clavata* showed highest frequency of occurrence (100%) followed by *Mastogloia paradoxa* and *Diploneis petersenii* (75%). The species such as, *Caloneiswestii*, *Cymbella*sp., *Synedra* sp. and *Tabellaria* sp. and *Gomphonema productum* showed a frequency of 62.5%, followed by species viz., *Caloneis crassa*, *Campylodiscuscrebreco status*, *Trigonium* sp., *Pinnularia subcapitata*, *Pinnulariaa coricola*, *Navicula tenella*, *Gomphonema*cf. *hebridense, Cymbella austriaca*, *Achnanthidium minutissimum* and *Pinnularia alpine* with 50% frequency of occurrence. A frequency of 37.5% was exhibited by *Bacteriastrum comosum*, *Navicula cryptotenella*, *Stenopterobia* sp., *Stenopterobia delicatissima*, *Delphine issurirelloides, Nitzchia maxima*, *Pleurosigmanicobaricum* and *Trachyneisaspera.* A least frequency of 25% was observed in *Actinoptychus senarius* and *Nitzschia thermalis*. Considering the sampling stations, it was in S8 that had a maximum number of diatoms i.e., a total of 21 species. A total of 16 species occurred in S1 and 15 species in S4 and S5. A total of 13 species was recorded in the sampling station S2 followed by the sampling stations S3 and S7 having 12 species each and S6 having 9 species.

Green algae

The green algae are distinguished mainly on the basis of ultra-structural morphology, especially by the arrangement of their flagella. They are usually green due to the dominance of pigments chlorophyll-a and chlorophyll-b. The chloroplast may be discoid, plate-like, reticulate, cup-shaped, spiral or ribbon shaped in different species. Most of the members have one or more storage bodies called "pyrenoids" located in the chloroplast. Pyrenoids contain protein besides starch. Some algae may store food in the form of oil droplets. Green algae usually have a rigid cell wall made up of an inner layer of cellulose and outer layer of pectose.

There were 8 species of green algae found in different sampling stations. The maximum frequency of 87.5% was shown by *Chlorella vulgaris* and *Closteriumpritchardianum*. A frequency of 75% was shown by *Scenedesmus* sp. followed by a frequency of 62.5% and 60% by *Hydrodictyon reticulatum* and *Oedogonium nodulosum* respectively. 50% frequency was shown only by *Volvox aureus*, A frequency of 37.5 % was observed in *Ulothrix* sp. and the least frequency of occurrence was noticed in *Vaucheria geminata*(i.e., 25%). A maximum of 6 species were found in the sampling stations S1 and S6 followed by S2, S3 and S4 having a total of 5 species each. The sampling station S8 showed a total of 4 species and least number of green algae was recorded in the sampling station S7 where, only 3 species were observed.

FTIR (Fourier-transform infrared spectroscopy) analysis

FTIR (Fourier-transform infrared spectroscopy) analysis was carried out for three algal samples (cyanobacteria) which were found to be very high dominant species in the sampling stations studied particularly S8. The presence of active sharp absorption bands indicating the presence of various classes of functional groups in those three species of cyanobacteria namely, *Oscillatoria chlorina*, *Oscillatoria homogenea* and *Oscillatoria peronata* is given in Table 3, 4 and 5 respectively. In the study, the FTIR spectra showed the presence of certain sharp absorption bands indicating the presence of various classes of functional groups such as, hydrocarbons, oxygen compounds, nitrous oxide, carboxylic acid, etc. in them.

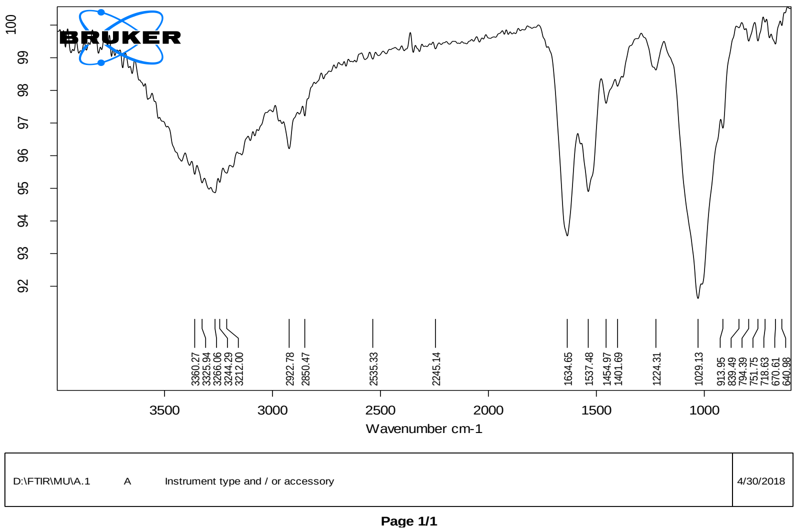

Figure 2: FTIR spectra showing the presence of sharp absorption bands in *Oscillatoria chlorina*

Table 3: showing various classes of functional groups present in *Oscillatoria chlorina*

FTIR Wave number (cm^{-1})	Functional group present	Class
3360.27	O-H	Alcohol
2922.78	C-H	Alkane
2850.47	C-H	Alkane
2535.33	O-H	Carboxilic acids
2245.14	-N=C=O, -N=C=S, -N=C=N-, $-N_3$, C=C=O	Isocyanates, Isothiocyanates, Diimides, Azides, Ketenes
1634.65	C=O	Amides
1537.48	N-H	Amides
1454.97	C=C	Aromatic
1401.69	S=O	Sulfate
1224.31	C-O, C-N	Ester, Carboxilic acids, Amines
1029.13	C-O, C-N	Ester, Carboxilic acids, Amines

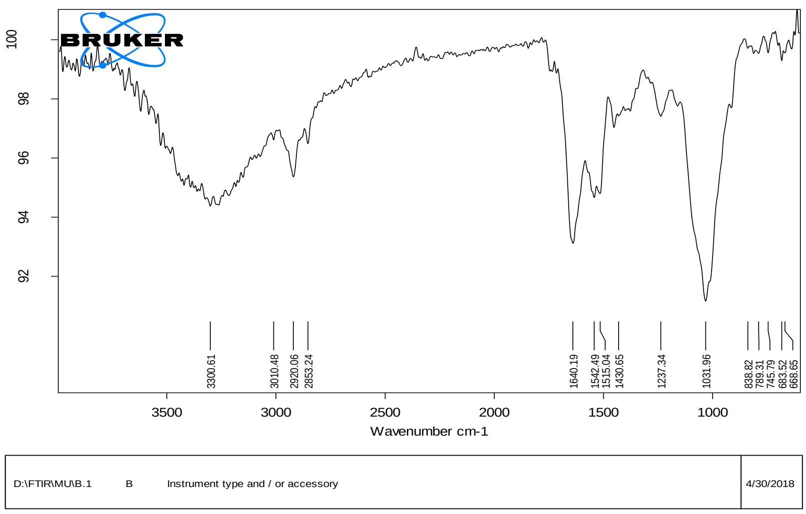

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Figure 3: FTIR analysis of *Oscillatoria homogenea*

Table 4: Showing various functional groups in *Oscillatoria homogenea*

FTIR Wave number (cm^{-1})	Functional group present	Class
3300.61	N-H O-H	Amines Alcohol
3010.48	C-H	Aromatic
2920.06	C-H	Alkane
2853.24	C-H	Alkane
1640.19	C=C	Alkene
1542.49	C=C	Aromatic
1430.65	S=O	Sulfate
1237.34	P=O	Phosphonate
1031.96	S=O	Sulfoxide
838.82	S-OR, NH_2 & N-H	Esters , Amines
683.52	NH_2 & N-H	Amines

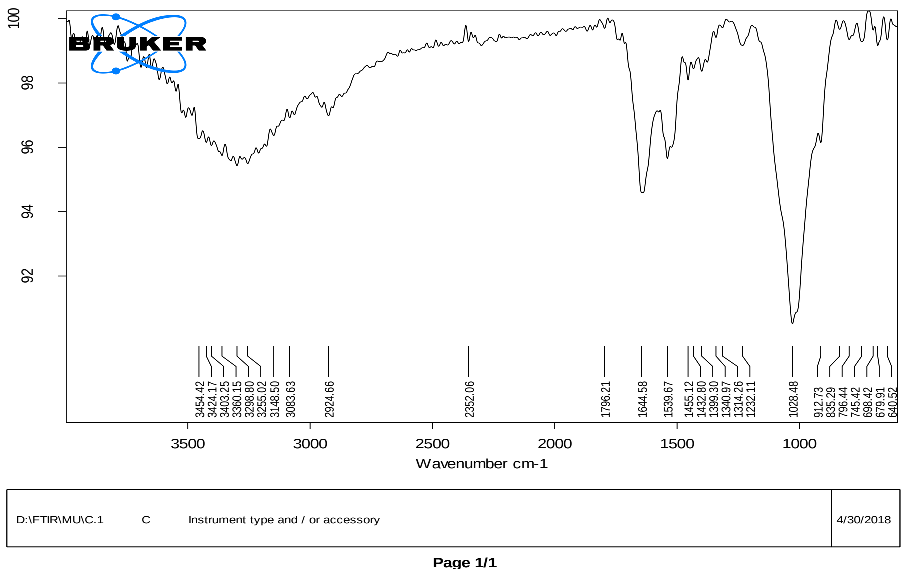


Figure 4: FTIR spectra of *Oscillatoria peronnata*

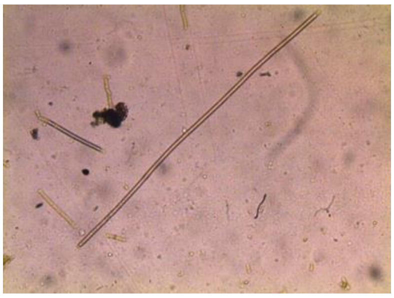
Table 5: showing the presence of various functional groups in *Oscillatoria peronnata*

FTIR Wave number (cm^{-1})	Functional group present	Class
3454.42	O-H,	Alcohol
	N-H	Amines
3148.50	O-H	Carboxylic acids
3083.63	O-H	Carboxylic acids
2924.66	O-H	Carboxylic acids
	C-H	Alkane
2352.06	P-H	Phosphine
1796.21	C=O	Acyl halides
1644.58	C=C	Alkene
1539.67	C=C	Aromatic
1455.12	C=C	Aromatic
1028.48	P-OR	Esters

Microphotographs of some of the selected algal species in the observed samples from various sampling stations

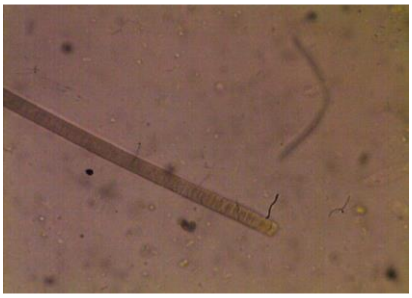
1. Cyanobacteria

*Phormidium valderianrum*Gom.

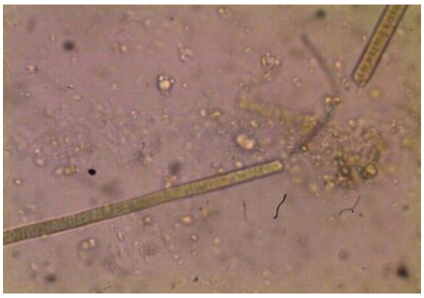


Phormidium corium Gomont

Oscillatoria sp.



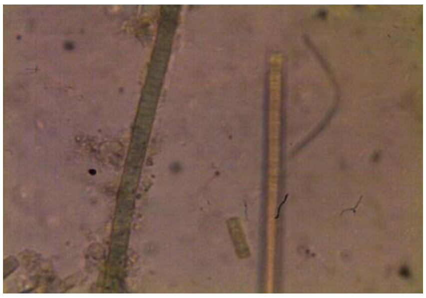
Oscillatoria homogenea Fremy



Oscillatoria acuta Bruhl & Biswas

Oscillatoria limosa Ag.

Oscillatoria subbrevis Schmidle

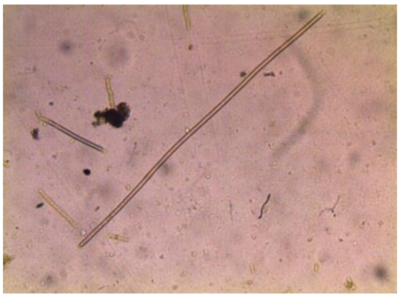


Oscillatoria sancta Gomont.

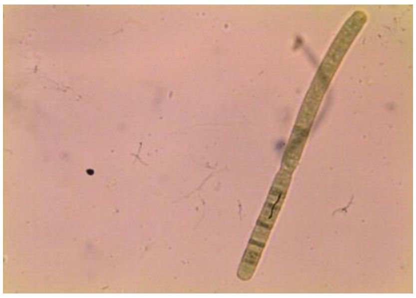
Myxosarcina spectabilis Geitler

Phormidium fragile Gomont

Oscillatoria pseudogeminata Schmid



Phormidium anomala Rao


Oscillatoria curviceps Ag.


Oscillatoria boryana Bory


Oscillatoria chlorinaKutz

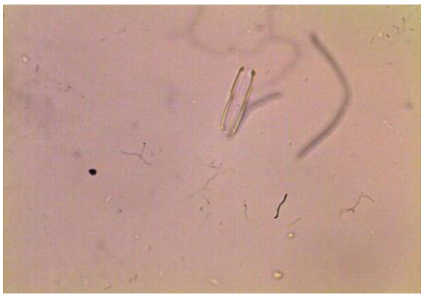

Phomidium tenue Gom.

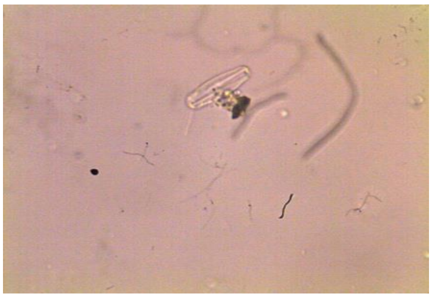

Oscillatoria amphibia Ag.


Oscillatoria princeps Vaucher

2. Diatoms


Navicula cryptotenella Lange.

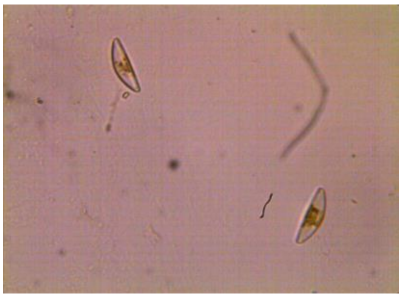

Nitzschia thermalis Grun.


Pinnulariaa coricola Hustedt


Achnanthidium minutissimum Joseph

Gomphonema productum Metzeltin

Pinnularia subcapitata Krammer

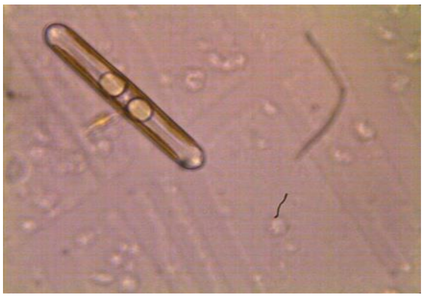


*Gomphonema*cf. *hebridense* Grunow

Cymbellaaustriaca Grunow

Stenopterobia sp.

Naviculatenella Var.



Diploneis petersenii Andrews

Stenopterobia delicatissima Kusber

Discussion

When the physico-chemical parameters of different sampling stations from Mangalore University campus, Mangalagangothri were compared, it was noticed that there was no much variations in the temperature. It was ranged from 29.7°C to 31.1°C. In this study more number of cyanobacterial species was recorded in the sampling station S7 and S8. Moderate temperature is required for the growth of cyanobacteria which can be one of the reasons behind the abundance and dominance of cyanobacteria among the others such as diatoms and green algae. This agrees with the findings of Hariprasad and Ramakrishnan (2003), Waleron et al. (2007)[24,25] who are of the opinion that the temperature being a major factor limits the geographic distribution of cyanobacteria into temperate and tropical species. The temperature was positively correlated to number of species. Most of the workers noted that optimum temperature and warm weather favors the growth of cyanobacteria[25,26]. The abundance of cyanobacteria is attributed to favorable contents of nutrients.

pH is one of the important factor as it plays an important role in the acid-base neutralization and water softening. The pH of water samples recorded in eight different sampling stations varied between 6.55 and 8.48. In general, cyanobacteria prefer neutral or slightly alkaline environments for their optimum growth[27,28]. Prasad and Singh (1982)[29] reported that cyanobacteria grew well in the pH range of 7.5-8.5. The maximum pH value of 8.48 was observed in the sampling station 8 (S8) and the minimum pH value of 6.55 was observed in the sampling station 2 (S2). Generally pH of water promotes the growth of algae[30]. In the present study also we found the abundance and maximum growth of algae occurred in the sampling station with the highest pH value. Verma et al. (1992)[31] have reported a direct relationship between pH and phytoplankton. Robert et al. (1974)[32] suggested that pH 5 to 8.5 is ideal for phytoplankton growth and this was found to be true in the present investigation.

The solids remaining in the water after filtration are called Total Dissolved Solids. Dissolved solids may be organic or inorganic in nature. Precisely, the dissolved solids are composed mainly of carbonates, bicarbonates, chloride, sulfate, calcium, magnesium, phosphate, nitrate, sodium, potassium and iron[33]. The present study indicated that the total dissolved solids contents vary between 31.5 and 214 ppm. The maximum concentrations of total dissolved solids contents were recorded at the sampling station 6 (S6) and the minimum concentrations of total dissolved solids contents were recorded at the sampling station 1 (S1).

Langenegger (1990)[34] and Edet et al. (1994)[35] have described the importance of Electrical Conductivity. Values of electrical conductivity obtained during the study ranges from 58.6 to 816 µS. The maximum value of electrical conductivity was observed in the sampling station 1 (S1) and the minimum value of electrical conductivity was observed in the sampling station 8 (S8).

A total of 28 species of diatoms were recorded in the present study. Among which Navicula clavata showed dominance in the sampling stations S1, S5 and S8, which also showed maximum frequency of occurrence (100%) compared with all other observed diatoms. Prasad and Singh (1982) are of the opinion that water temperature ranging from 30^{o} to 35^{o} C enhances the multiplication of diatoms. However in the present study temperature ranged from $29.7^{o}C$ to $31.1^{o}C$. This observation clearly indicates that the temperature less than $31.1^{o}C$ but, above $29.7^{o}C$ is highly congenial for diatoms growth and multiplication. This observation however, differs from that of Singh and Swarup (1979)[36] and Venkateswarlu (1986)[37]. Diatoms play a very important role ecologically as they comprise of major components of producers in wetland ecosystem[38, 39]. Diatoms are ubiquitous, unicellular microorganisms from the basic bulk of planktonic population in freshwaters characterized by siliceous cell wall[40].

Planktons are cosmopolitan in nature and are found in all water bodies, irrespective of their altitude, attitude and physicochemical condition. Their food value for the aquatic organisms has been acknowledged by all the workers in this field. Considering its great importance as food for aquatic animals including fishes and prawns, their presence ensures productivity. Freshwater ecosystems are subject to temporal changes that cause uncertainty in phytoplankton composition and assemblage[41,43]. Subramanian et al. (1994)[44] have reported freshwater micro-algae of Sathamangalam area temple tank, pond, lake and roadside puddles of Virudhachalam Taluk of Tamil Nadu. The growth and abundance of phytoplankton varies with season, depth, metrology and water properties, which in turn reflect on diversity of organisms within the ecosystem[45-48]. Rajkumar (2001)[49] has studied the biodiversity and quantitative distribution of phytoplankton of a polluted freshwater pond. He reported phytoplanktonic components and their seasonal distribution in the polluted freshwater pond located at Pollachi. It has been reported that the flora of four freshwater habitats (all of them located Pollachi and Udumalpet, Coimbatore District, Tamil Nadu), such as Krishnan Anaikattikulam pond, Alampalayam pond, Aliyar River at Anaimalai section and Amaravathi River at Udumalpet section a total of 61 species of diatoms have been recorded in these water bodies[15]. It has been reported that the basic process of phytoplankton production was dependent upon temperature, turbidity and nutrients[50-52].

Seaweeds are highly sensitive to the changes in the physico-chemical characteristics of the coastal ecosystem. Sahoo et al. (2003)[53] reported that large-scale aqua cultural activities in Chilika Lake, Orissa have resulted in eutrophication which has changed its floristic composition. Satheesh et al. (2012)[54] noted that anthropogenic activities have affected the diversity of seaweeds in developing countries. Gradual disappearance of marine algae along Visakhapatnam coast by disturbances created by the discharge of effluents, environmental factors, tidal waves and the cyclones[5].

Conclusion

The present study concludes in spite of the fact that, algal dynamics are often influenced by the availability of nutrients and the physico-chemical conditions of the ecosystem. These particular environmental conditions may favour the dominance of cyanobacteria. It was found that, the sampling station 8 (S8) which showed the maximum number of abundant species and some of these species can be served as the “Marker/indicator species” of the study area. Since the “Marker species” was found in the water sample having high pH and conductivity, it can be concluded that such species may be indicators of pollution. These species were also found to have various functional groups in it. Biotic and abiotic factors influence the distribution of cyanobacteria in a freshwater environment. Bearing this in mind, freshwater algae were studied from different water bodies in and around areas of Mangalore University campus. The present basic information on the distribution pattern and abundance of algal species would be a useful tool for further ecological assessment and monitoring of these freshwater bodies in the Mangalagangothri, Konaje region.

The differences in species occurrence of algae between the sampling sites might be due to the tolerance capacity of species to higher temperature, pH, conductivity and TDS or due to variations in the mineral composition of these habitats. In addition, the common species of algae found in between the sampling stations showed a better adaptability towards their flexible environment. In the aquatic ecosystem, the growth of the organisms is linked to the availability of adequate amounts of nutrients. The physico-chemical changes in the water may affect particular species and induce the growth and abundance of other species, which leads to the succession of several species in a course of time. The ability of cyanobacteria and other algae to tolerate various stress factors suggest that, they are likely to benefit from environmental changes associated with global warming.

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