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Original Article

Fresh water Algal diversity of Central India

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ABSTRACT: Fresh water microalgae has drawn much attention due to their primary productivity in the water food chain of water ecosystem diversity, their biological assessment of water quality, pollution abatement capacity and as a source of structurally novel and biologically active metabolites with antimicrobial capacity etc. Distribution of fresh water microalgae of unexplored localities of some parts of central India has been investigated. A total of thirty fresh water algal samples were collected from different unexplored sites of central India. Thirty-four algal taxa comprising twenty-five genera in which eighteen unicellular, nine colonials and nine filamentous algae were identified based on microscopic observation and characters such as average filament length, colonial diameter, shape and cell dimensions. Results revealed that these microalgae belonging to three major classes Chlorophyceae (green algae), Bacillariophyceae (diatoms) and Cyanophyceae (blue green algae). Maximum algal taxa belonged to green algae followed by blue- green algae and diatoms. The occurrence of fresh water algae, their diversity and distribution was interpreted with water quality and its physico-chemical characteristics. The present study not only discusses the basic information of fresh water algal presence, distribution but also helps for future environmental monitoring studies.

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INTRODUCTION

Fresh water ecosystems vary in size and composition and contain a large variety of organism. Microalgae are vast group of prokaryotic and eukaryotic photosynthetic organisms found in many different forms viz. individual cells, colonies or extended filaments and exhibit vast diversity in the ecosystem [1]. They are cosmopolitan in nature found everywhere like oceans, lakes, rivers, ponds, puddles, moist surfaces and fresh water etc. [2].

These organism's potential can be utilized in various fields such as food, feed, fine chemicals, bio energy and bioremediation. They are also rich source of proteins and other nutrients, like higher plants [3, 4]. They play an important role as primary producers of water ecosystem for various consumers of aquatic fauna and rich source of protein, carbohydrates and especially essential fatty acids. They are one of the most helpful indicators of water quality due to their rapid response to environmental changes related to larger animals and plants [5, 6].

Thus, microalgae are used for biological assessment of water quality and bioindicators of eutrophication. The algal community both planktonic and benthic are important among other micro taxa which are found at different depths, where physicochemical properties of water influence the algal population and its occurrence [7-9].

The dominance of green algae and diatoms presence in relatively clean and oligotrophic water bodies, whereas blue-green algae bloom formation indicates that the water body is polluted or eutrophic [10-12].

There are few survey reports on the assessment of water quality based on physico-chemical and biological parameters in India [13, 14] but fresh water algal floristic identification and water quality monitoring in aquatic bodies of Bundelkhand region of central India is absolutely neglected [15-17]. Therefore, the present investigation has been carried out to assess fresh water algal diversity along with the physico-chemical parameters of the water to interpret water quality.

MATERIALS AND METHODS

Study area

Bundelkhand is in the geographic region of the state Uttar Pradesh (U.P.) in central India (Figure 1). It is located between 23°20' and 26°20' N latitude and 78°20' and 81°40' E longitude. Administratively the Bundelkhand region comprises of thirteen districts in which seven districts belong to Uttar Pradesh viz., Jhansi, Jalaun, Lalitpur, Hamirpur, Mahoba, Banda and Chitrakoot and six districts belongs to the state Madhya Pradesh (M.P.) namely Datia, Tikamgarh, Chattarpur, Damoh, Sagar and Panna. Bundelkhand region occupies almost 70,000 km² of the central plains in India. It consists of granite rock which occupies an area of 26,000 km² in southern Uttar Pradesh and north-eastern Madhya Pradesh in central India.

- i) **Jhansi district**- A total of 10 algal samples and water samples were collected from Atiyatal lake in Jhansi which is situated in 24°11' and 25°57' N latitude and 78°10' and 79° 25' E longitude. Lake is situated in the heart of Jhansi, having an area of about 15.41 hectares, with an average depth of 3.1m. Atiyatal is a typical urban lake.
- ii) **Banda district**- A total of 5 algal samples and water samples were collected from two localities in Banda district. 2 algal samples were collected from River Ken and another 3 algal samples were collected from pond

Chabbi. In which Ken River situated in 25°46' and 25.767°N latitude 80°31' and 80°80.517° E longitude whereas Chabbi pond situated in 25°28'27" N latitude 80°19'36" E longitude. Ken river arising from Vindhya hill ranges in the Central India reveals a significantly higher density in semi- natural compared with other two land use.

- iii) **Chitrakoot district**- A total of 6 algal samples and water samples were collected from river Mandakani in Chitrakoot district which is situated in 25°25'24" N latitude 81°8'55" E longitude. It is a holy river, at each new moon day a lot of people visit to Chitrakoot and take holy dip in the river and make worship offering to the river. It is called as mini Ganga.
- iv) **Jalaun district**- A total of 9 algal samples and water samples were collected from two localities in Jalaun district. Six algal samples were collected from Ramkund and another 3 algal samples were collected from Mahil pond in which Ramkund situated in 25°29'15" N latitude 79°33'28" E longitude whereas Mahil pond situated in 25°59'10" N latitude 79°26'58" E longitude. Ramkund is one of the important pond of this town due to its proximity to Thadeshwari temple, devotees flock to this place to take a holy dip after visiting temple. Mahil pond situated on the south-east part of the city Orai, U.P. Orai city is also known as city of king Mahil who was the ruler of this region during 18th century A D.

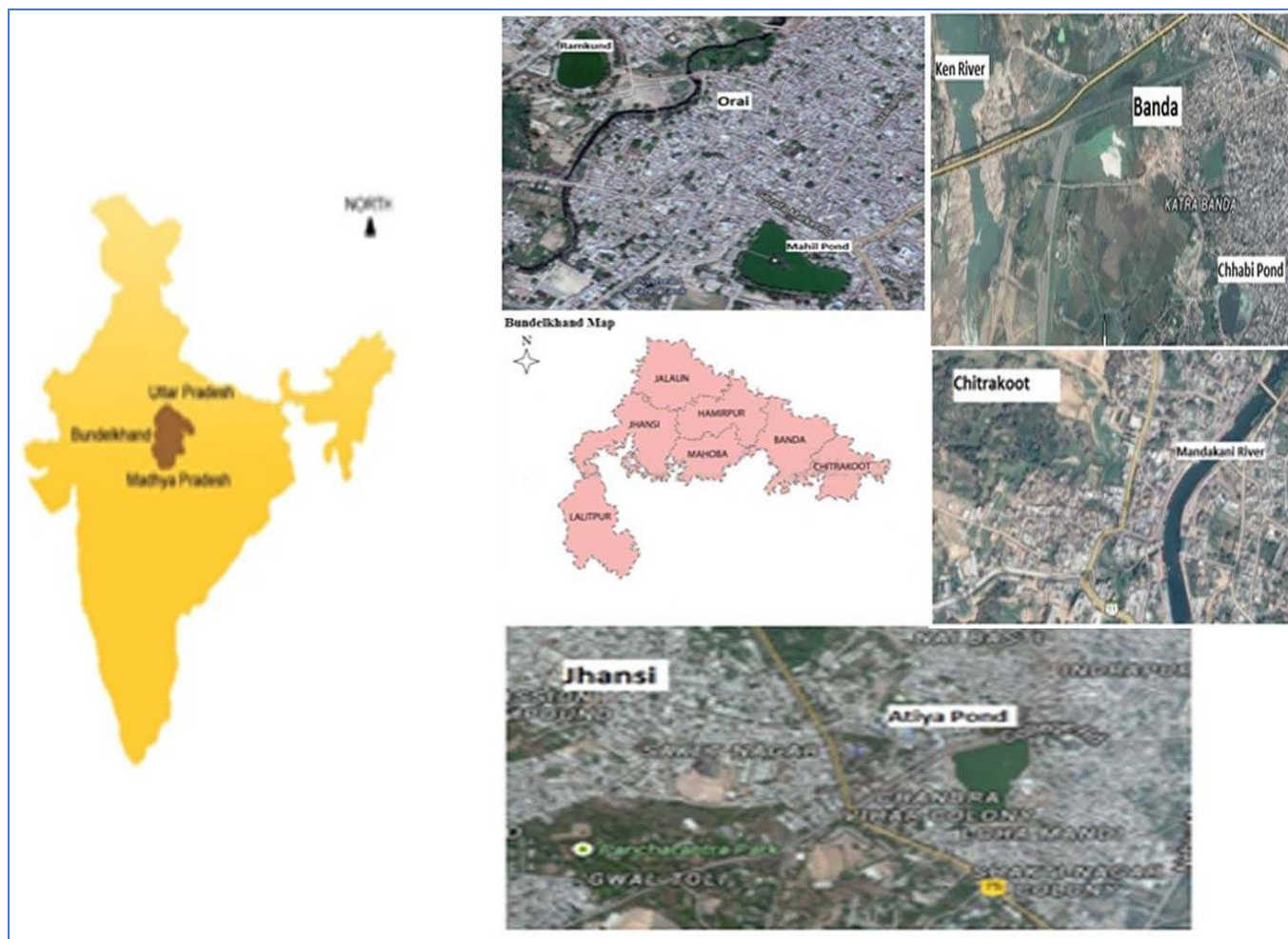


Figure 1: Map showing Bundelkhand region in the Central India

Physico-chemical analysis of water samples

Physico-chemical parameters of water samples were tested in the field itself. Parameters such as pH, conductivity, dissolved oxygen, temperature, nitrate, nitrite, phosphate, sulphate, iron and silica were measured by HACH instrument. Parameters such as pH, Conductivity, DO and Temperature were recorded on the spot by using different probes attached to the instrument whereas nitrate, nitrite, phosphate, sulphate, iron and silica were measured as per the standard protocol given in HACH manual of the laboratory. Collected algal samples were preserved in 4% formalin for further microscopic identification in the laboratory and voucher specimens deposited at the Phycology laboratory of National Botanical Research Institute Lucknow, Uttar Pradesh India.

Morphological analysis

Microscopic observation of algal samples was done by Lieca DM. 500 research microscope and microphotography was done with attached camera EC-3 [18-19]. Morphological observation for green algae presence of chloroplast, shape and size of cells and filaments, for diatoms presence of striae, raphe, presence and absence of centriole, presence of silica, and for blue green algae presence and absence of sheath, heterocysts, shape and size of cells were taken into consideration. The identification of taxa was done by referring standard taxonomic manuals of (2), (12), (13), (19).

RESULTS AND DISCUSSION

A total of 34 algal taxa belonging to 25 genera were identified (Figure 2 and 3) from 30 samples of 6 water bodies. These microalgae belonging to three major classes Chlorophyceae (green algae), Bacillariophyceae (diatoms) and Cyanophyceae (blue green algae). Maximum algal taxa belong to green algae followed by blue green algae and diatoms. Among the green algae dominant forms were *Scenedesmus* at Mandakani river, *Chlamydomonas* and *Chlorella* at Chabi pond and *Spirogyra* in Atiyatal, where ascommonly found green algae were *Chaetophora*, *Ulothrix*, *Nannochloropsis* and *Oedogonium* in Atiyatal. Rarely found green algae were *Caracium* at Mandakani river, *Cosmarium*, *Geminella* and *Pediastrum* at Atiyatal. Among the blue green algae *Microcystis* was dominant and only alga at Mahil pond whereas *Oscillatoria*, *Phormidium* were dominant and *Spirulina* was very common in Ramkund and in Atiyatal *Merismopedia* was a very rare form. Among the diatoms *Fragillaria* was dominant form found in Ramkund, whereas *Navicula*, *Gamphonema*, *Synedra* were common in Chabi pond, Ramkund and Mandakani river respectively and *Cymbella*, was found rarely in Ramkund.

Systematic enumeration and Taxonomic description of identified algae**Chlorophyceae (Green algae)**

Class – Chlorophyceae

Order – Chlorococcales

Family – Scenedesmaceae

Genus - *Scenedesmus****Scenedesmusabundans* (Kirchner) Chodat**

Colonies usually 2-4 celled, rarely eight-celled, and arranged in a linear series. Cells ovoid to oblong-ovoid. External cells with one or more median lateral spines from the outer face in addition to spines from the four corners of the colony. Internal cells with 1-2 spines from their poles, or rarely without spines.

Cells 3.89-4.80 μm broad, 6.56-7.40 μm long. Spines 3.7-8 μm long

Collection Site: Mandakani river (Chitrakoot)

***Scenedesmuscarinatus* (Lemm.) Chodat**

Colonies usually four- or eight-celled. Cells arranged in a linear series with only a third of their length in the median region in lateral contact. Cells fusiform to naviculoid with beaked ends. Inner cells with 2-3 teeth from their poles. Terminal cells with a long-recurved spine from each pole in addition to denticulations. All cells with a distinct longitudinal ridge on each side, the ridge extending from pole to pole or distinct only at either end of the cell.

Cells 2.8-3.23 μm broad, 8.9-12.11 μm long. Spines of terminal cells 7.81-13 μm long

Collection Site: Mandakani river (Chitrakoot)

***Scenedesmusquadricauda* (Turpin) Brebisson**

Colonies usually four-celled, sometimes 2- or 8-celled. Cells oblong-cylindrical with rounded ends and arranged in a linear series. Poles of terminal cells with a long, straight or curved spine. Cell wall smooth and without ridges.

Cells 3-4.14 μm broad, 6.36-6.95 μm long. Spines 6.5-12 μm long

Collection Site: Mandakani river (Chitrakoot)

***Scenedesmusarmatus* (Chodat) G. M. Smith**

Colonies usually four-celled, rarely two- or eight-celled. Cells oblong-ellipsoid with acute spines and arranged in a linear series. Terminal cells with a single long spine from each pole. All cells with a median lateral longitudinal rib which is sometimes indistinct or distinct only at either end of the cell.

Cells 5-6 μm broad, 15-15.24 μm long. Eight-celled colony Spines 7.8-9.21

Collection Site: Mandakani river (Chitrakoot)

***Scenedesmus caudate-aculeolatus* Chodat**

Colony four-celled, cells loosely connected in a linear series. Cells oblong with rounded poles. Terminal cells slightly curved and with a long-recurved spine from each pole. Two to three short spines also present on the poles of terminal as well as internal cells.

Cells 3-3.88 μm broad, 10-11.85 μm long, Four – celled colony

Collection Site: Mandakani river (Chitrakoot) and Atiya Tal (Jhansi)

***Scenedesmus arcuatus* (Lemmermann) Lemmermann**

Colonies usually eight-celled, rarely four-or 16 celled, curved and with small intercellular spaces. Cells in eight-celled colonies in two series, oblong-ovoid, sometimes slightly angular at the base due to mutual pressure. Cell wall smooth, without teeth or spines.

Cells 3.5-4.55 μm broad, 8.4-12.08 μm long, Four-celled colony

Collection Site: Mandakani river (Chitrakoot)

Order – Chlorococcales

Family – Oocystaceae

Genus - *Chlorella*

***Chlorella vulgaris* Beijerinck**

Cells usually solitary or in small colonies, spherical and with a thin cell membrane. Chloroplast parietal, cup-shaped and with a pyrenoid which is sometimes indistinct.

Cells usually 3.66-6.57 μm in diameter

Collection Site: Chabbi pond (Banda) and Ramkund (Jalaun)

Order – Eustigmatales

Family – Monodopsidaceae

Genus – *Nannochloropsis*

***Nannochloropsis oculata* (Anita & Cheng, 1982) Algae base**

Cells usually unicellular round free-floating, subspherical, yellow-green parietal chloroplast; pigment typically eustigmatophycean.

Cells usually 2.68-4.53 μm in diameter

Collection Site: Chabbi pond (Banda) and Ramkund (Jalaun)

Order – Chlamydonadales

Family – Chlamydomonadaceae

Genus – *Chlamydomonas*

***Chlamydomonas angulosa* Dill 1895, P.337**

Cells broadly ovoid to cylindrical, often truncated anteriorly and with a prominent papilla. Contractile vacuoles 2, below the flagella, which are as long as or slightly longer than the cell body. Chloroplast a massive, parietal cup with a large angular pyrenoid in the base; pigment-spot anterior and lateral.

Cells 5.72-6.25 μm in diameter, 11.78-12.36 μm long

Collection Site: Chabbi pond (Banda) and Ramkund (Jalaun)

Order – Chaetophorales

Family – Chaetophorales

Genus – *Chaetophora*

***Chaetophora attenuata* Hazen 1902, p.213 Pl.13**

Forming attached, firm, gelatinous globules, 2-5 mm in diameter, having radiating, nearly parallel, erect branches from numerous basal, rhizoidal processes. Filaments usually dichotomously (some-times trichotomously) branched, ending in sharply pointed, setiferous cells; branches not fasciculate, but loose and evenly developed from the main axis and much elongated.

Cells 5-6.61 μm in diameter, 10.12-11.73 μm long

Collection Site: Atiya Tal (Jhansi)

Order – Ulotrichales

Family – Ulotrichaceae

Genus – *Ulothrix*

***Ulothrix tenuissima* Kuetzing 1833, p.518 Pl. 67**

Filaments long, composed of cylindrical cells that are shorter than wide, 16-20 μm in diameter, thin-walled and not constricted at the cross walls. Chloroplast a broad encircling about 2/3 of the circumference of the cell, with 2 or several pyrenoids.

Cells 8.7-9.06 μm in diameter, 11-12.63 μm long

Collection Site: Atiya Tal (Jhansi)

Order – Desmidiales

Family – Desmidiaceae

Genus – *Cosmarium*

***Cosmarium angulosum* Breb. Var. *concinnum* (Rab.) West et West P1. 19**

Cells very small, a little longer than broad, deeply constricted, sinus narrow and linear, semi-cells hexagonal with sharp angles and parallel sides, apex narrow and slightly retuse; cell wall smooth.

Cells 9.5-15.42 μm diameter, Cells 11.5-16.81 μm long, isthmus 5.6-5.7 μm .

Collection Site: Atiya Tal (Jhansi)

Order – Sphaeropleales

Family – Characiaceae

Genus – *Characium*

***Characium angustum* A. Braun**

Cells straight and lanceolate with a short hyaline apical beak. Stalk short and thick with a colorless disc-shaped basal thickening.

Cells 3-4.75 µm broad and 25-29.54 µm long

Collection Site: Mandakani river (Chitrakoot)

Order –Oedogoniales

Family –Oedogoniaceae

Genus –*Oedogonium*

***Oedogonium* sp. 1820, p.5**

Cells cylindrical or enlarged toward the anterior end, where one or more ring like scars resulting from cell division are usually apparent. Chloroplast a parietal reticulum with many pyrenoids. Nucleus at the periphery of the proplast.

Cells 21-24.31 µm diameter, Cells 30-40.23 µm long

Collection Site: Atiya Tal (Jhansi)

Order –Zygnematales

Family –Zygnemataceae

Genus –*Spirogyra*

***Spirogyra* sp. 1820, p.5**

Filaments long and unbranched, usually without basal-distal differentiation but sometimes with rhizoidal branches developing laterally where the filament comes in contact with substrate. Cells cylindrical, short, to very long in some species, with plane (even and smooth), replicate, or colligate (exterior H-shaped piece) end walls. Chloroplast a parietal band or ribbon which may be spirally twisted ½ to 3 (rarely 8) turns, or may be nearly straight (as in genus *Sirogonium*, not separated here); 1-16 chloroplast in a cell.

Cells 20-24.15 µm diameter, Cells 140-160.87 µm long

Collection Site: Atiya Tal (Jhansi)

Order –Chlorellales

Family –Chlorellaceae

Genus –*Geminella*

***Geminellamutabilis* (de Breb.) Wille 1911, p.72 Pl. 6**

Uniseriate filaments of broadly ovate, spheroidal, or cylindrical cells, almost equally separated from one another, but with daughter cells remaining in approximation. Chloroplast completely covering the cell wall.

Cells 5-6.62 µm in diameter and 11-12.65 µm long

Collection Site: Atiya Tal (Jhansi)

Order –Chlorococcales

Family –Hydrodictyaceae

Genus –*Pediastrum*

***Pediastrum simplex* Meyen 1829, p 772, p1 43**

Colonies circular to oval, of 4-8-16-32 or more cells. Inner side of marginal cells nearly straight, outer side produced into a gradually tapering process, sides concave. Inner cells polygonal. Cells in contact with adjacent ones and usually without intercellular spaces. When present, intercellular spaces very small and few in number. Cell wall smooth or punctate to granulate.

Cells 4-5.82 broad, 14-18.5 µ long

Collection Site: Atiya Tal (Jhansi)

Bacillariophyceae (Diatoms)

Class –Bacillariophyceae

Order –Cymbellales

Family –Cymbellaceae

Genus –*Cymbella*

***Cymbella affinis* Kuetz. P1. 34**

Valves asymmetrical, semi-elliptical having dorsal margin concave, ventral margin slightly convex with constricted, very slightly produced rostrate ends; raphe thick, eccentric, curved with distinct central nodules, terminal fissures dorsally bent; axial area narrow, linear gradually widening towards central area elliptical with distinct puncta on the ventral side, striae coarse, lineate, radiate throughout the valve.

Length, 39.53 µm; breadth 10.71 µm; striae, 9-13 in 9.5 µm.

Collection Site: Ramkund (Jalaun)

***Cymbellalanceolata* (Ehrenberg) Van Heurck**

valves quite asymmetric, naviculoid, dorsally convex, ventrally concave with a median expansion; raphe eccentric, narrow, and medianly curved; axial area narrow, with slight median expansion, no isolated dots; transverse striations perpendicular to median line, except near the poles, 9-16 in 10 µm, with punctae 15-18 in 10 µm Pl. 74.

Cells 24-34 µm in diameter and 70-210 µm long

Collection Site: Ramkund (Jalaun)

Family –Gomphonemataceae

Genus –*Gomphonema*

***Gomphoneisherculeana* (Ehrenberg) Cleve.**

Valves clavate, with broad apex and somewhat acute base; axial area very narrow; central area rounded with a single dot; transverse striations, alternating with a double row of punctae,

9-12 in 10 µm, radial; longitudinal lines indistinct; a short septum at the apex.

Cells 10-10.08 µm in diameter, 32-37.22 µm long, Pl. 73

Collection Site: Atiya Tal (Jhansi) and Ramkund (Jalaun)

Order –Fragilariales

Family –Fragilariaceae

Genus –*Fragilaria*

Fragilaria Lyngbye

Cells rectangular in girdle view, with one or two (sometimes none) intercalary bands, without septa and costae, united into free-floating or sessile colonies: mostly zigzag chains, sometimes flat, stellate colonies; valves linear to fusiform, bilaterally symmetric, usually attenuated at the poles, sometimes capitate, often medially inflated (rarely constricted); transverse striae usually fine, sometimes coarse; pseudoraphe narrow and indistinct or broad and prominent.

Cells 18-18.38 in diameter and one cell 3-4.34 long

Collection Site: Atiya Tal (Jhansi)

Fragilariacapucina Desmazieres.

Valves linear with pseudoraphe and rectangular to elliptical central area; transverse striation fine, about 15 in 10 µm.

Cells 2-5 in diameter and 25-100 µm long. Pl. 62, fig. 698

Collection Site: Atiya Tal (Jhansi) and Ramkund (Jalaun)

Genus –*Synedra*

Synedra ulna (Nitzsch) her. P1.24

Valves solitary, linear much elongated, gradually attenuated to the rostrate ends; pseudo-raphe distinct, narrow, widening towards center; central area quadrangular having small lineate striae on both margin; striae coarse, lineate, transverse, parallel throughout the valve.

Length, 170-218 µm; breadth, 6.84-10.62 µm; striae, 12-13 in 10 µm.

Collection Site: Mandakani River (Chitrakoot)

Order –Naviculales

Family –Naviculaceae

Genus –*Navicula*

Naviculacryptocephala Kuetz.

Valves lanceolate with slender, somewhat capitate ends, central area elongated transversely; striations, medially radial and polarly convergent, 16-18 in 10 µm, lines fine Pl. 67

Cells 5-8.68 µm in diameter, 20-36.39 µm long

Collection Site: Chabbi pond (Banda)

Cyanophyceae (Blue green algae)

Class –Cyanophyceae

Order –Oscillatoriales

Family –Oscillatoriaceae

Genus –*Oscillatoria*

Oscillatoria Vaucher ex Gomont

Trichome single or forming a flat or spongy free-swimming thallus, sheath absent, rarely with a very delicate sheath, motile, mostly by a creeping movement causing rotation on the longitudinal axis; end of trichome distinctly marked, pointed, bent like a sickle or coiled more or coiled like a screw. Hormogones formed by the division of the trichome.

Cells 3-4.55 µm in diameter and 3.2-4.20 µm long

Collection Site: Ramkund (Jalaun)

Genus - *Phormidium*

Phormidiumretzii (Ag.) Gomont Pl. 44

Thallus bright blue-green, compact, filaments straight, mostly unconstructed at the cross-walls, not attenuated at the ends, not capitate, straight, 4.5-12 µm broad, dull blue-green; sheath thin, firm or mostly diffuent, not coloured violet by chlor-zinc-iodide; cells shorter or longer than broad, 4-9 µm long, septa not granulated; end cells truncated, with a thickened outer membrane, calyptras absent.

Cells 4-4.69 µm in diameter and 13-14.03 µm long

Collection Site: Ramkund (Jalaun)

Phormidiumambigum Gomont Pl.44

Thallus expanded, bright blue- green, dark or yellowish green; filaments flexuous, variously entangled; trichomes slightly constricted at the cross-walls, at the ends not attenuated, not capitate, 4-6 µm broad, blue-green; sheath thin, firm or diffuent sometime thick and more or less lamellated, colored violet by chlor-zinc-iodide; cells shorter than broad, 1.5-2.7 µm long, rarely granulated at the cross-walls, sometimes with gas-vacuoles; end cell rounded, calyptras absent.

Cells 2-2.81 µm in diameter and 3-3.90 µm long

Collection Site: Kane River (Banda) and Ramkund (Jalaun)

Order –Spirulinales

Family –Spirulinaceae

Genus –*Spirulina*

***Spirulina major* Kuetz. ex Gomont**

Cells regularly spirally coiled, blue-green, spirals.
 Cells 2.3-3.86 μm in diameter and 2.1-2.67 μm long
 Collection Site: Ramkund (Jalaun)
 Order –Synechococcales
 Family –Merismopediaceae
 Genus –*Merismopedia*

***Merismopediaglauca* (Ehrenb.) Nag. Pl. 29**

Colonies mostly small with 16-64 cells, cells oval or spherical, closely arranged, pale blue-green.

Cells 45-150 μm in diameter, 3-4.89, μm broad
 Collection Site: Atiya Tal (Jhansi)
 Order –Chroococcales
 Family –Microcystaceae
 Genus –*Microcystis*

***Microcystisaeruginosa* Kuetz.**

Colonies when young round or slightly longer than broad, solid, when old becoming clathrate, with distinct hyaline colonial mucilage; cells 2-2.62 μm in diameter, spherical, generally with gas-vacuoles

Collection Site: Mahil pond (Jalaun)

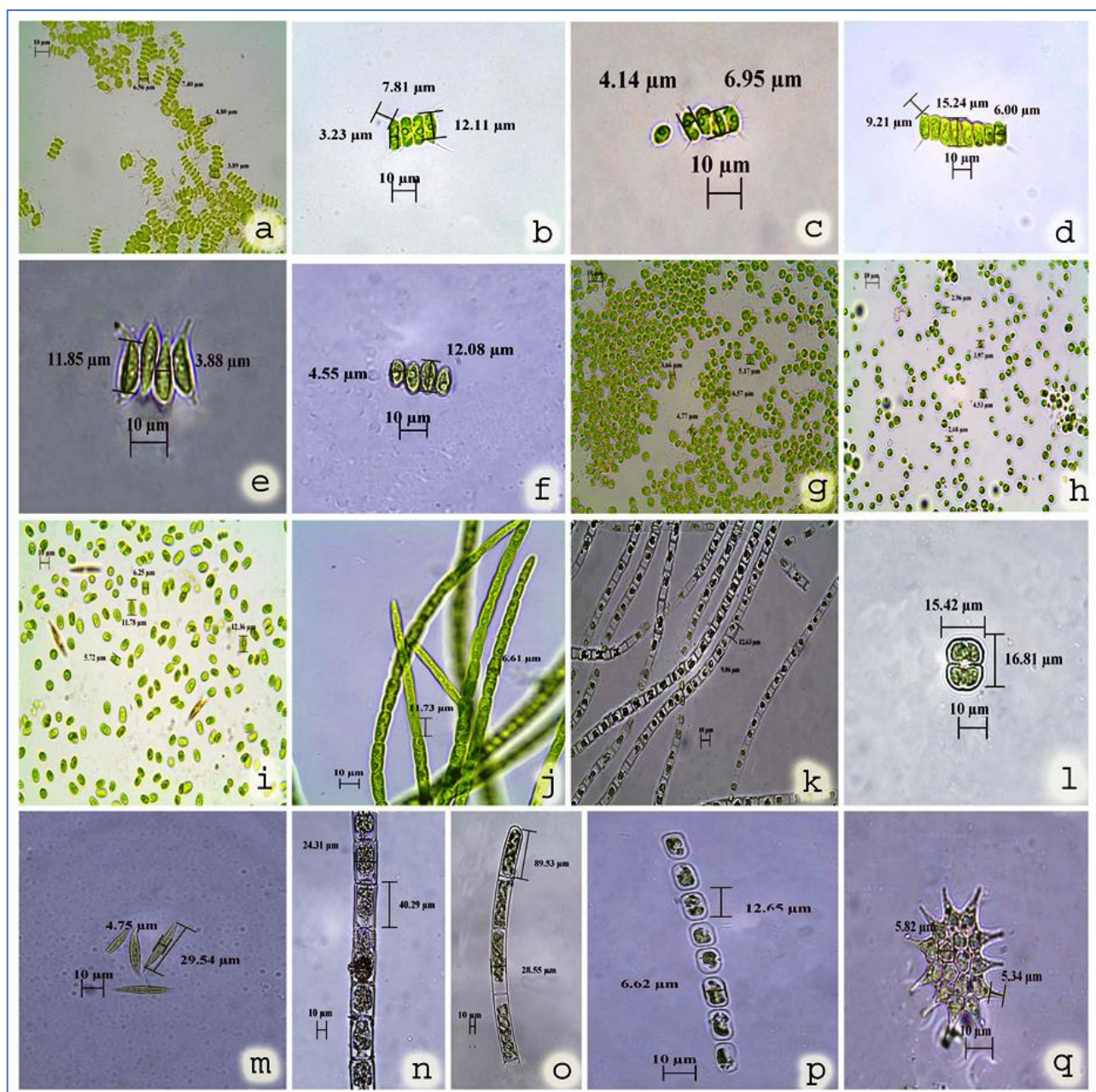


Figure 2: photographs of Chlorophyceae

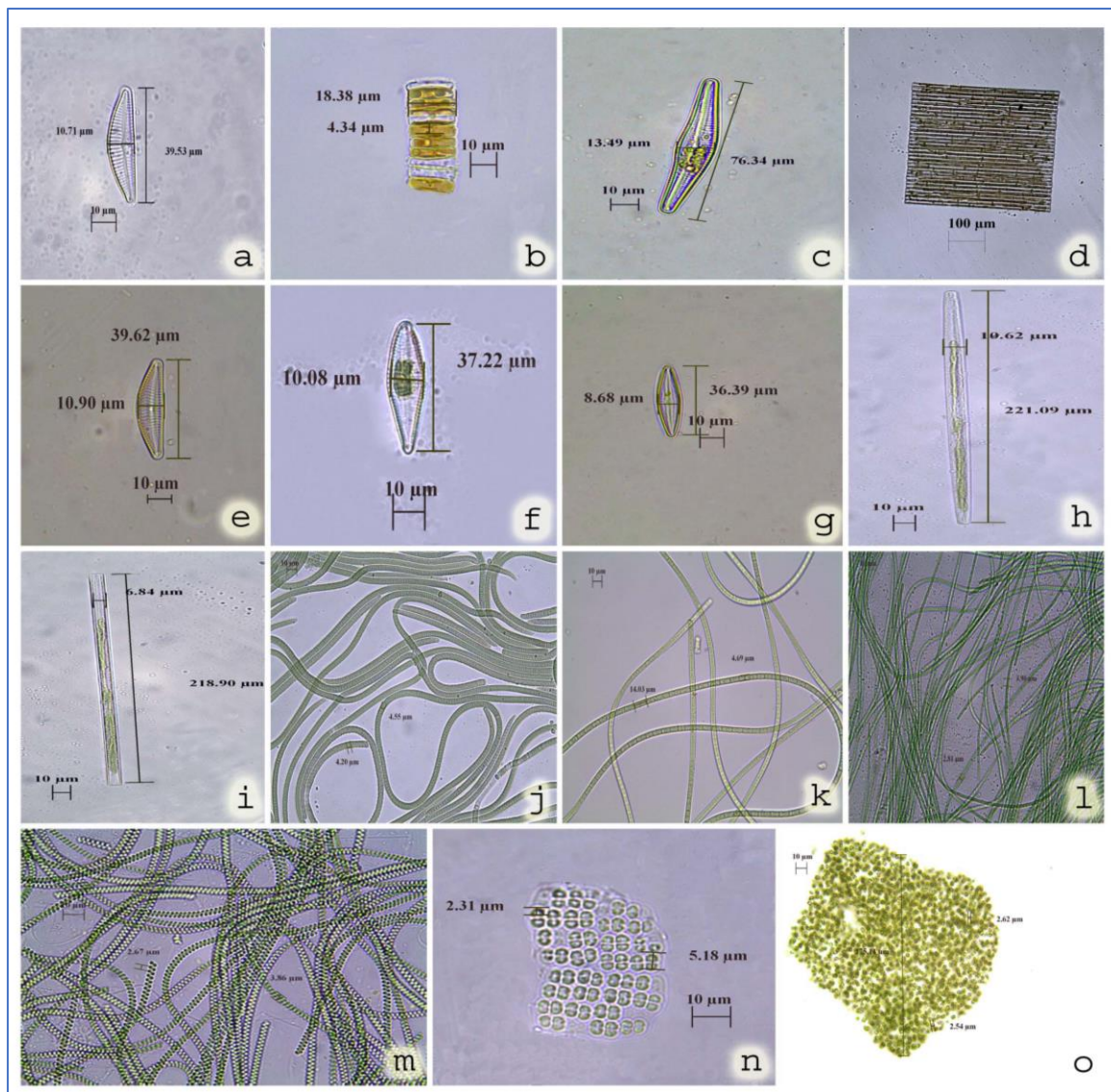


Figure 3: Photographs of Bacillariophyceae and Cyanophyceae

Figure 2:

- a. *Scenedesmus abundans* (Kirchen) Chodat
- b. *Scenedesmus carinatus* (Leemm) Chodat
- c. *Scenedesmus quadricauda* (Turp) Breb
- d. *Scenedesmus armatus* (Chodat) G.M. Smith
- e. *Scenedesmus caudato –coleolatas* Chodat
- f. *Scenedesmus arcuatus* (Lemm)
- g. *Chlorella vulgaris* Beijerinck
- h. *Nannochloropsis oculata* (Anita & Cheng, 1982) Algae base
- i. *Chlamydomonas angulosa* Dill
- j. *Chaetophora attenuata* Hazen

- k. *Ulothrix tenuissima* Kuetzing
- l. *Cosmarium angulosum* Breb
- m. *Caracium angustum* A. Braun
- n. *Oedogonium* sp.
- o. *Spirogyra* sp.
- p. *Geminella mutabilis* (de Breb) Wille
- q. *Pediastrum simplex* Meyen
Cymbella affinis kuitz

Figure 3:

- a. *Cymbella affinis* Kuetz.
- b. *Fragillaria* sp.
- c. *Cymbella lanceolata* (Ehr.) V.H., Consp. Crit. Diat.
- d. *Fragillaria capucina* Desmazieres

- f. *Gomphoneis herculeana*(Ehrenberg) Cleve
 g. *Navicula cryptocephala*Kuetzing
 h. *Syndra ulna* (Nitzsch) Ehrrenberg
 i. *Oscillatoria* sp. Hist. conf., 165, 1803; Gomont, Monoger. Oscillariees, 198, 1892.
 j. *Phormidium retzii* (Agardh) Gomant
 l. *Phormidium ambigum* Gomont
 m. *Spirulina major* kutz. Ex Gomont
 n. *Merismopedia glauca* (Ehrenb.) Nag
 o. *Microcystis aeruginosa* kutz

Table 1: Relative dominance and floristic diversity of Chlorophyceae

S. no.	Name of organism	Abundance		
		Dominant	Common	Rare
1.	<i>Scenedesmus abundans</i> (Kirchen) Chodat (Mandakani River)	+++	-	-
2.	<i>Scenedesmus carinatus</i> (Leemm) Chodat (Mandakani River)	+++	-	-
3.	<i>Scenedesmus quadricauda</i> (Turp) Breb (Mandakani River)	+++	-	-
4.	<i>Scenedesmus armatus</i> (Chodat) G.M. Smith (Mandakani River)	+++	-	-
5.	<i>Scenedesmus 3047anceol –acoleolatas</i> Chodat (Mandakani & Atiya Tal)	+++	-	-
6.	<i>Scenedesmus arcuatus</i> (Lemm) (Mandakani River)	+++	-	-
7.	<i>Chlorella vulgaris</i> (Chabbi pond)	+++	-	-
8.	<i>Chlamydomonas angulosa</i> Dill (Chabbi pond)	+++	-	-
9.	<i>Chaetophora 3047anceolat</i> Hazen (Atiya Tal)	-	++	-
10.	<i>Ulothrix tenuissima</i> Kuetzing (Atiya Tal)	-	++	-
11.	<i>Cosmarium angulosum</i> Breb (Atiya Tal)	-	-	+
12.	<i>Caracium angustum</i> A. Braun (Mandakani River)	-	-	+
13.	<i>Oedogonium</i> sp. (Atiya Tal)	-	++	-
14.	<i>Spirogyra</i> sp. (Atiya Tal)	+++	-	-
15.	<i>Geminella mutabilis</i> (de Breb) Wille (Atiya Tal)	-	-	+
16.	<i>Pediastrum simplex</i> Meyen (Atiya Tal)	-	-	+

+++; Dominant; ++; common; +; rare

Table 2: Relative dominance and floristic diversity of Bacillariophyceae

Sl. No.	Name of organism	Abundance		
		Dominant	Common	Rare
17.	<i>Cymbella affinis</i> kuitz (Ramkund)	-	-	+
18.	<i>Fragillaria</i> sp.(Atiya Tal)	+++	-	-
19.	<i>Cymbella 3047anceolate</i> (Ehr.) V.H., Consp. Crit. Diat. (Ramkund)	-	-	+
20.	<i>Fragillaria capucina</i> Desmazieres (Ramkund)	+++	-	-
21.	<i>Synedra ulna</i> (Nitzsch) Ehrrenberg (Mandakani River)	-	-	+
22.	<i>Gamphonema herculeana</i> (Grunow) cleve (Ramkund)	-	-	+
23.	<i>Navicula cryptocephala</i> kuet-zing (Chabbi Pond)	-	++	-
24.	<i>Syndra ulna</i> (Nitzsch) Ehrrenberg (Mandakani River)	-	++	-

+++; Dominant; ++; common; +; rare;

Table 3: Relative dominance and floristic diversity of Cyanophyceae

Sl. No.	Name of organism	Abundance		
		Dominant	Common	Rare
25.	<i>Oscillatoria</i> sp. (Ramkund)	+++	-	-
26.	<i>Phormidium retzii</i> (Agardh) Gomant (Ramkund)	+++	-	-
27.	<i>Phormidium ambigum</i> Gomont (Ramkund)	+++	-	-
28.	<i>Microcystis aeruginosa</i> kutz (Mahil Pond)	+++	-	-
29.	<i>Merismopedia glauca</i> (Ehrenb.) Nag (Atiya Tal)	-	-	+
30.	<i>Spirulina major</i> kutz. Ex Gomont (Ramkund)	-	++	-

+++; Dominant; ++: common; +: rare;

Relation of the physico-chemical parameters on the distribution of algal community:

Physico- chemical parameters of all the water bodies (**Table 4**) except Mahil pond were close to normal range such as pH from 7.87 to 8.98, Conductivity 431 to 1028 µs/cm, DO 6.87 to 10.04 mg/L, temperature 14.4 to 18.10°C, Nitrate 3.6 to 5.4 mg/L, Sulphate 9 to 37 mg/L, Iron 0 to 0.10 mg/L and Silica 5.5 to 14.5 mg/L, which supported the growth of green algae, brown algae and some blue green algae (Table 1, 2 and 3). In the collected algal samples the highest pH was 9.93 (Mahil pond) whereas lowest pH was 7.87 (Mandakani river). The alkaline pH supported the growth of blue green algae. Higher value of pH attributes the higher growth rate of blue green algal population which utilized CO₂ through the photosynthesis (1). Highest conductivity (2083 µs/cm) highest nitrate (16.9 mg/L) nitrite (0.916 mg/L) phosphate (8.4 mg/L) and sulphate (49mg/L) led to alkalinity of the water in turn support excessive blue green algal growth.

Therefore, Mahil pond infected with blue green alga *Microcystis aeruginosa* and water is polluted not useful for consumption.

In the collected algal samples, the highest temperature was 18.1°C (Jhansi) whereas lowest temperature 14.4°C (Ramkund) as they were collected during winter months of January. In Atiya Tal maximum no. of Chlorophyceae algae were present like *Scenedesmus*, *Cheatothora*, *Ulothrix*, *Cosmerium* and *Spirogyra*. Atiya Tal supports maximum no. of green algae with three types of diatoms and one blue green alga.

Verma et al., 2011 reported 16 species of Chlorophyceae 8 species of Bacillariophyceae and 6 species of Cyanophyceae from Bundelkhand region [20]. The dynamic and heterogeneous relationship gain varied physico-chemical and biological elements in the ecosystem, which can be recorded by regular monitoring to maintain the integrity and conserve the ecosystem [20-21].

Table 4: Physico- chemical analysis of Bundelkhand region

Sl. No.	Parameters	Banda		Chitrakoot	Jhansi	Jalaun	
		Chabbi pond	Kane river	Mandakani river	Atiya Tal	Mahil pond	Ramkund
1.	pH	8.21	8.33	7.87	8.59	9.93	8.98
2.	Conductivity	903µs/cm	431µs/cm	590µs/cm	911µs/cm	2083µs/cm	1028µs/cm
3.	DO	7.80mg/L	8.85mg/L	6.87mg/L	10.04mg/L	8.73mg/L	9.72mg/L
4.	Temperature	14.8°C	16.9°C	16.8°C	18.1°C	15.2°C	14.4°C
5.	Nitrate	3.6mg/L	4.8mg/L	5.4mg/L	4.7mg/L	16.9mg/L	5.0mg/L
6.	Nitrite	0.024mg/L	0.032mg/L	0.116mg/L	0.008mg/L	0.916mg/L	0.001mg/L
7.	Phosphate	4.16mg/L	1.59mg/L	2.45mg/L	2.08mg/L	8.4mg/L	2.48mg/L
8.	Sulphate	37mg/L	9mg/L	26mg/L	46mg/L	49mg/L	26mg/L
9.	Iron	0.01mg/L	0.03mg/L	0.10mg/L	0.00mg/L	0.03mg/L	0.09mg/L
10.	Silica	9.5mg/L	7.5mg/L	8.5mg/L	14.5mg/L	7.2mg/L	5.5mg/L

CONCLUSION

The algal diversity of Bundelkhand region mainly consist of three major classes Cyanophyceae, Chlorophyceae, and Bacillariophyceae. The occurrence of green algae is relatively greater than blue green algae and diatoms.

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