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## CERTAIN RARE NON-HETEROCYSTOUS BLUE-GREEN ALGAE OF PSEUDANABAENACEAE (OSCILLATORIALES, CYANOPROKARYOTE) FROM POLLUTED HABITATS OF MEERUT, UTTAR PRADESH, INDIA

Jyoti Singh, Kuntal Sarma, Amrish Saini, Sunil Kumar, Doli, Nirlep Kour, Deepti Gupta, Gauri and Rama Kant\*

Department of Botany, Chaudhary Charan Singh University, Meerut, India 250004

\*Corresponding Author's Email: [ramakant.algae@gmail.com](mailto:ramakant.algae@gmail.com); [rkojha\\_1@rediffmail.com](mailto:rkojha_1@rediffmail.com)

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### ABSTRACT

Water pollution is a major problem in India and most of the major rivers of the country are heavily polluted by different types of pollutants and invite the growth of various organisms including microalgae. The aim of the present investigation was to explore the biodiversity of the Blue-green algae from different polluted habitats of Meerut, Uttar Pradesh, India. The present paper deals with the diversity of non-heterocystous filamentous taxa of the family Pseudanabaenaceae. Water samples collected from three different polluted water reservoirs of Meerut, U.P., India were subjected to microscopic observations and identification. The present study revealed the occurrence of total 45 strains of 15 species and 8 genera belonging to three sub families including Pseudanabaenoideae, Spirulinoideae and Leptolyngbyoideae of the family Pseudanabaenaceae viz. *Geitlerinema lemmermannii*, *G. nematode*, *Jaaginema gracile*, *Leptolyngbya aspera*, *L. foveolarum*, *L. geysericola*, *L. gracilis*, *L. mycoidea*; *Limnothrix planctonica*, *Planktolingbya contorta*, *Pseudanabaena limnetica*, *P. minima*, *P. Recta*, *Romeria mexicana* and *Spirulina subsalsa*. The study also revealed the unexplored diversity of non-heterocystous filamentous blue green algae from three polluted water reservoirs of Meerut, U.P., India.

**Keywords** : Blue-green Algae, Habitats, Pollution, Water

### Introduction

The water is considered an essential element for all living being including aquatic and terrestrial plants. The water is used for different purposes including creational and non creational activities viz. drinking, bathing, irrigation etc., but polluted water is consumed because it causes different types of diseases on human beings. The pollutants affect the water quality and invite growth of different types of organisms including both prokaryotic and eukaryotic microalgae. The algae are very simple photosynthetic organisms and play important role as ecological indicator in the ecosystem. They can be exploited for the production of many value products. The prokaryotic microalgae (cyanoprokaryotes/ Blue-green algae / Cyanobacteria) are arranged mainly into orders Chroococcales (Komárek and Anagnostidis, 1998), Oscillatoriales (Komárek and Anagnostidis, 2005) and Nostocales (Komárek, 2013) under the Cyanoprokaryota. The non-heterocystous filamentous blue-green algae are widely distributed all over the globe and their growth can be observed in a wide range of habitats including aquatic, terrestrial and sub-aerial environments biotopes (Whitton and Potts, 2000). Komárek and Anagnostidis (2005) arranged all the non-heterocystous cyanoprokaryotes into single order Oscillatoriales, 6 families,

12 subfamilies and 50 genera. The Pseudanabaenaceae is small family with four subfamilies including Pseudanabaenoideae, Spirulinoideae, Leptolyngbyoideae and Heteroleibleiniodeae and 12 genera. The members of family Pseudanabaenaceae are characterised by the presence of sheathless trichomes or one trichome per sheath. Further the family has been divided into four subfamilies on the basis of sheath and trichome polarity. The aim of the present investigation was to explore the Blue-green algal diversity from various polluted biotopes of Meerut, Uttar Pradesh, India and to find out potential candidate to use them for phycoremediation in future.

In this present work we have collected the water samples from three different water reservoirs located at three different potted sites of Meerut (U.P.) India. The study sites included in the present study were **1.** Kali River, near Garh Road, **2.** Seasonal small and temporary water reservoir, Lala Lajpat Rai Memorial (LLRM) Medical College and **3.** Water reservoir, Meerut Cantonment, U.P. India. All the three water bodies were polluted by different sources, Kali River was polluted by municipal and industrial waste; LLRM Medical College site was polluted by organic material and Meerut Cantt site was polluted by dairy waste. All the collected samples were examined microscopically and their

morphological details were recorded, and identified upto the species level. In the present paper, fifteen members of family Pseudanabaenaceae are being reported and described.

## Materials and Methods

### Study sites and Sampling

The study sites included in the present investigation were 1. Kali River, Near Garh Road, Meerut, 2. Temporary seasonal small water reservoir from LLRM Medical College and 3. Meerut Cantt, Meerut, U.P. India. Total 798; Polluted water samples were collected from the three selected sites in 50 ml vials (Polylab) during May 2018-December, 2022.

### Enrichment culturing

All the collected samples were thoroughly mixed with the help of homogenizer (RQT-127A/D, REMI) and 5 ml from each sample were transferred into the nitrogenous and nitrogen deficient liquid BG-11 medium (Stanier *et al.*, 1971) and subjected for incubation for one week under the controlled culture conditions (Temperature 28±2°C; light-4000-6000 Lux, 14:10 h light: dark cycle regime).

### Morphological observations

Specimens from collected water samples, enriched cultures and unialgal cultures were subjected for microscopic observations with the help of Trinocular Research Microscope (Olympus, CH21i) attached with digital Camera (Magnus, Magcam-DC10) and their morphological details were recorded with the help of image analysis software (MagVision).

### Identification

For morphological observations, slides were prepared from natural materials collected from all the three sites, enrichment cultures and unialgal cultures. All the isolated strains were identified with the help of available literatures (Geitler, 1932; Desikachary 1959; Komárek and Anagnostidis, 2005). The Oscillatoriales (Komárek and Anagnostidis, 2005) has been followed for the morphological description of all the taxa included in the present study and details of all the fifteen taxa are described in this paper (Figs.1-18).

### Morphological Description (Figs.4-18):

The members of the family Pseudanabaenaceae of order Oscillatoriales are characterised by the presence of sheathless trichomes or one trichome per sheath.

### Oscillatoriales

#### 1. Family: Pseudanabaenaceae

#### Sub-family: Pseudanabaenoideae

*Geitlerinema lemmermannii* (Woloszyńska) Anagnostidis (Fig.8)

[syn.: *Oscillatoria lemmermannii* Woloszyńska; *Jaaginema lemmermannii* (Woloszyńska) Anagnostidis et Komárek]

Thallus filamentous and blue green. Trichomes solitary, light blue-green, slightly bent, 2-2.5 µm wide, not constricted at the granulated cross-walls, gradually attenuated at the ends and curved. Cells longer than wide, 4-6 µm long and 2.2-2.4 µm wide; cell content homogeneous. Apical cell slightly narrowed, hooked, rounded.

(Sample No. MTC-328; Collection Date:20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

*G. nematodes* (Skuja) Anagnostidis (Fig. 9)

*Oscillatoria nematodes* Skuja; *Pseudanabaena nematodes* (Skuja) Anagnostidis et Komárek.

Thallus filamentous and blue green. Trichomes solitary and forming thin, membranaceous mat on mud, partly clathrate, olive green; irregularly loosely screw-like coiled, motile, 0.6-0.7 µm wide, 70-140 µm long, curved, shortly attenuated and pointed at the straight ends. Cells isodiametric; indistinctly granulated, light blue green. Apical cell conical-rounded or pointed, not capitates without thickened cell wall or calyptas.

(Sample No. MTC-332; Collection Date: 20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

*Jaaginema gracile* (Böcher) Anagnostidis et Komárek (Fig.10)

*Oscillatoria gracilis* Böcher

Thallus filamentous and blue green. Trichomes pale blue-green, forming layers on muddy surfaces, 0.7-1.5 µm wide, not constricted at the cross-walls. Cells 2-6 µm long and 0.8-1.4 µm wide; with one granule on each side of the cross-walls. Apical cells rounded.

(Sample No. MTC-329; Collection Date: 20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

*Limnothrix planctonica* (Woloszyńska) Meffert (Fig. 7)

*Oscillatoria planctonica* Woloszyńska

Thallus filamentous and blue green. Trichomes solitary, free-floating, straight, pale blue-green, 1.5-3 µm wide, not constricted at the indistinctly visible cross-walls, without sheaths. Cells 6-10 µm long and 1.3-2.8 µm wide, mainly blue-green, with one spherical, aerotop in the middle of the cell. Apical cells cylindrical and rounded.

(Sample No. MTC-331; Collection Date:20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

*Pseudanabaena limnetica* (Lemmermann) Komárek (Fig. 11)

=*Oscillatoria limnetica* Lemmermann

Thallus filamentous, light blue green. Trichomes solitary, straight or slightly curved, motile, 1.2-2.5 µm wide, constricted at the thick, hyaline transparent cross walls, with thin, indistinct mucilaginous sheath. Cells long-cylindrical,

olive blue-green, 1-2µm wide, 2-10 µm long; cell content homogeneous. Apical cells rounded.

(Sample No. MTC-336; Collection Date:20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

***Pseudanabaena minima***(G. S. An) Anagnostidis (Fig. 12)

*Achroonema minima* (G. S. An)

Thallus filamentous, blue green. Trichomes densely arranged in clusters, straight, pale blue-green, intensely constricted at cross-walls, straight at the ends. Cells longer than wide, 1.5-4 µm long, 1.3-2.5 µm wide; cell content homogeneous. Apical cells mostly rounded.

(Sample No. MTC-339; Collection Date:20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

***Pseudanabaena recta*** Komárek et Cronberg (Fig. 6)

Thallus filamentous, light blue green. Trichomes solitary, straight, with 3-14 cells, constricted at cross-walls; cells cylindrical, 2-3µm long, 1-1.5µm wide, with small aerotopes near the cell ends.

(Sample No. MTC-471; Collection Date:05-09-2019; Habitat: Seasonal water reservoir; Site: MeerutCantt, U.P., India; 29°00'12.2"N; 77°42'38.4"E)

***Romeria mexicana*** (Rouchijainen) Komárek in Anagnostidis (Fig. 13)

[syn.: *Oscillatoria mexicana* Rouchijainen]

Thallus filamentous, yellowish blue green. Trichomes solitary, free floating, curved or wavy, 2-8 celled, hetero-cellular, constricted at cross-walls; distinct mucilaginous sheath; cells light blue-green, long cylindrical, 8-20 µm long and 2-3 µm wide; cell ends slightly wide and capitate.

(Sample No. MTC-335; Collection Date:20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

**Sub-family: Spirulinoideae**

***Spirulina subsalsa*** Oersted ex Gomont (Fig. 4)

*Spirulina tenuissima* Kützing; *Oscillatoria oceanica* Crouan; *Spirulina subsalsa* f. *genuina* Gomont; *Spirulina subsalsa* f. *oceanica* (Crouan) Gomont; *Spirulina neumannii* Schmidle; *Spirulinacompacta* Perfilev ; *Spirulina tenuissima* var. *salina* Wislouch; *Arthrospira subsalsa* Crow; *Spirulina supersalsa* Schiller; *Spirulina condesata* Welsh, *Oscillatoria subsalsa* (Oersted) Bourrelly; *Oscillatoria neumannii* (Schmidle) Iltis

Thallus filamentous, soft, thin, crumbling, expanded, mucilaginous, bright blue-green, emerald green, olive-green to blackish, frequently also only in solitary trichomes among other cyanoprokaryotes. Trichomes pale to bright blue-green, 0.8-2.2 µm wide, regularly densely screw-like coiled (rarely with irregularities), straight or variously curved, sometimes spirally coiled, 150-700 µm long. Coils dextral, regularly tightly joined to one another, nearly parallel arranged,

irregularly loosely coiled, 3-5 µm wide, 2-6 µm high, short to long; fast motile, with very intense right-handed screw-like rotation and simultaneous gliding. Apical cells rounded.

(Sample No. MTC-472; Collection Date: 05-09-2019; Habitat: Seasonal water reservoir; Site: Meerut Cantt, U.P., India; 29°00'12.2"N; 77°42'38.4"E)

**Sub-family: Leptolyngbyoideae**

***Leptolyngbya aspera***(Schwabe) Anagnostidis (18)

[syn.: *Lyngbya ferruginea* f. *aspera* Schwabe

Thallus filamentous, filaments mixed within deep layers of other blue-green algae. Sheaths uncommon, thick, opaque, yellow-brown, outside rough. Trichomes pale blue-green, 0.6-0.7µmwide, not constricted at the sometimes granulated cross-walls. Cells 0.6-0.7µm wide and 1.2-1.4 µm long. Apical cells rounded.

(Sample No. MTC-331; Collection Date:20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

***Leptolyngbya foveolarum***(Rabenhorst ex Gomont) Anagnostidis et Komárek (17)

*Phormidium foveolarum* Gomont, *Lyngbya foveolarum* [Montagne] Hansgirg; *Phormidium foveolarum* f. *maior* Elenkin.

Thallus filamentous, thin, fine, gelatinous, blue-green extended. Filaments variously curved, sometimes straight and parallel arranged, or tangled together, very rarely pseudobranchied. Sheaths thin, firm, attached to the trichome, colourless, or soft, diffluent, mucilaginous, forming an amorphous, gelatinous mass. Trichomes light to bright blue-green, 0.5-2.5µmwide, mostly distinctly constricted at the cross-walls, which are translucent and not granulated; not attenuated at the ends. Cells moniliform, slightly barrel-shaped, isodiametric, or shorter, rarely longer than wide; 0.8-2.2 µm long. Cell content homogeneous or with sparsely distributed granules. Apical cells rounded almost hemispherical without calyptras or thickened outer cell wall.

(Sample No. MTC-335; Collection Date:20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

***Leptolyngbya geysericola***(Copeland) Anagnostidis (Fig. 16)

[syn.: *Phormidium geysericola* Copeland]

Thallus filamentous, tough, fibrous, not lamellated, up to 3cm in thickness, with corded streamer-like projections, up to 10 cm long and up to 1 cm in diameter, light yellowish, whitish in the lower part. Filaments very long, straight and mostly parallel arranged, not crowded. Sheaths hyaline/colourless, confluent, 0.4-0.6 µm wide, not constricted at the inconspicuous and mostly slightly visible, ungranulated cross-walls, not attenuated at the ends, not capitates. Cells isodiametric, 0.4-1 µm long and 0.2-0.5 µm wide; cell content homogeneous. Apical cells rounded without calyptra.(Sample No. MTC-471; Collection Date:05-09-

2019; Habitat: Seasonal water reservoir; Site: Meerut Cantt, U.P., India; 29°00'12.2"N; 77°42'38.4"E)

***L. gracilis*** (Lindstedt) Anagnostidis et Komárek (Fig.15)

*Phormidium gracile* Lindstedt

Thallus filamentous, thin and bright blue green. Filaments ± curved, densely entangled. Sheaths mucilaginous, diffluent, homogeneous, colourless. Trichomes blue-green, 1.3-2 µm wide, not or slightly constricted at the inconspicuous cross-walls, not attenuated at the ends, straight. Cells 2.6-8 µm long; cell content homogeneous, but with distinct chromatoplasma. Apical cells rounded, without calyptra.

(Sample No. MTC-471; Collection Date:05-09-2019; Habitat: Seasonal water reservoir; Site: Meerut Cantt, U.P., India; 29°00'12.2"N; 77°42'38.4"E)

***L. mycoidea*** (Frémy) Anagnostidis (Fig. 14)

*Phormidium mycoideum* Frémy

Thallus filamentous, mucilaginous, pale, dirty white or yellowish, forming usually flat mats, thick. Filaments very long, coiled or irregularly wavy, sometimes spirally coiled, or ± parallel arranged. Sheaths indistinct, very thin, sometimes diffluent in amorphous gelatinous mass. Trichomes very pale blue-green, 1.5-2 µm wide, straight at the ends, not attenuated, not constricted at cross-walls, without granulation. Cells cylindrical, 2-5 times longer than wide, 3-10 µm long, with homogeneous or very slightly granular content, or with few granules. Apical cells rounded.

(Sample No. MTC-473; Collection Date:05-09-2019; Habitat: Seasonal water reservoir; Site: Meerut Cantt, U.P., India; 29°00'12.2"N; 77°42'38.4"E)

***Planktolyngbya contorta*** (Lemmermann) Anagnostidis et Komárek (Fig. 5)

= *Lynghya contorta* Lemmermann; = *Spirocoleus contortus* (Lemmermann) Compère

Thallus filamentous, filaments solitary, free-floating, irregularly spirally coiled, with nearly circular coils, 1-2.5 µm wide. Sheaths firm, narrow, colourless, 0.3-0.4 µm wide. Trichomes cylindrical, light blue-green or blue-green, 1-2 µm wide, not constricted at cross-walls, not attenuated at the ends, rarely with solitary granules. Cells longer than wide, 2.5-6 µm long and 1-2.5 µm wide. Apical cell rounded, not attenuated.

(Sample No. MTC-335; Collection Date:20-12-2018; Habitat: Kali River; Site: Garh Road, Meerut, U.P., India; 28°56'52.1"N; 77°45'53.4"E)

## Discussions

Since it was revealed by De (1939) that Blue-green algae fix diazotrophic nitrogen and contribute significantly in maintaining soil fertility, this group of microbe became more fascinating and heterocystous blue-green were taken up for detailed study worldwide (Roger and Kulasooria; 1980,

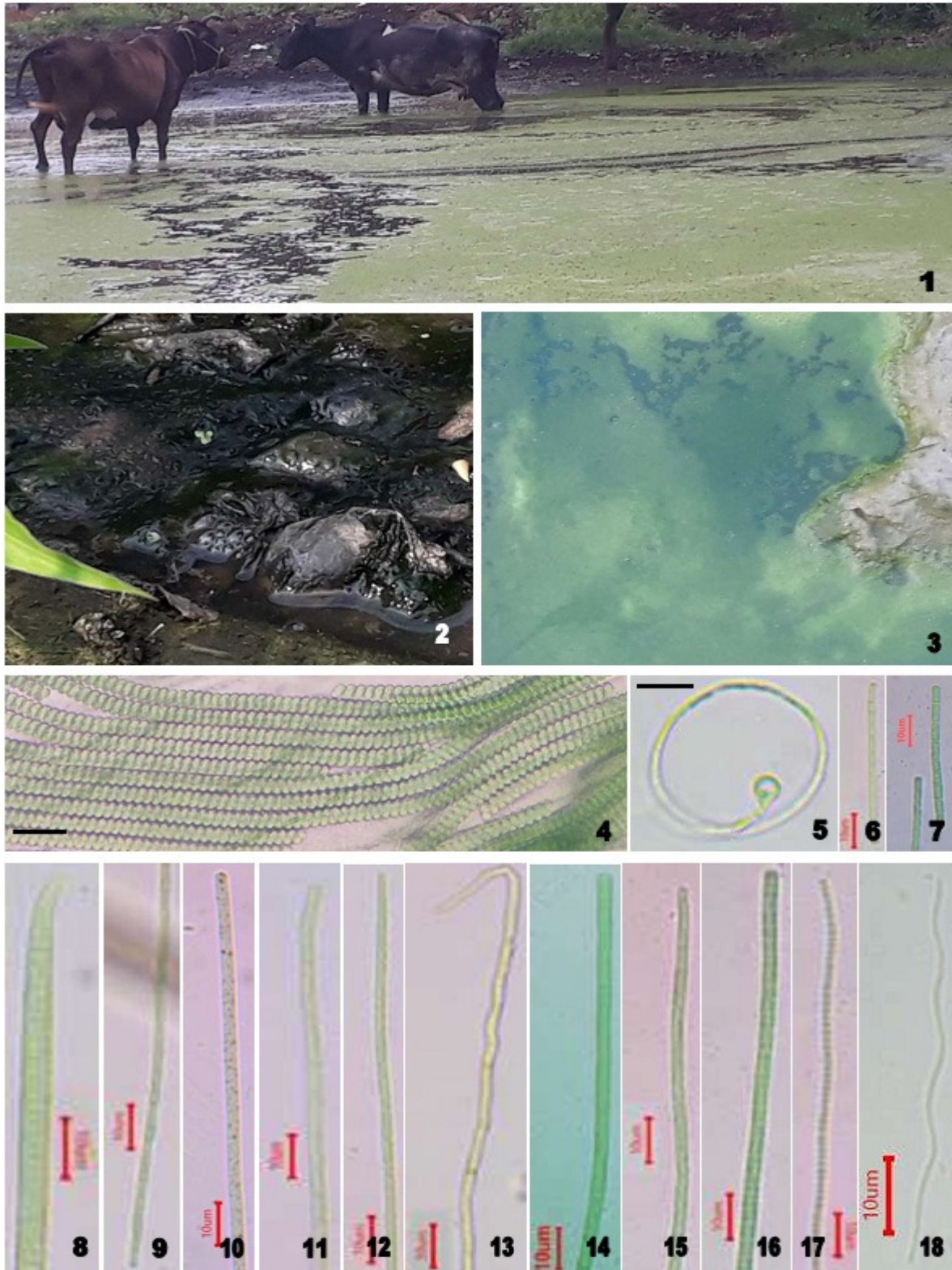
Roger, 1991). In India, there are several floristic papers of blue-green algae (Mitra, 1951; Desikachary, 1959; Kamat, 1962; Pandey and Mitra, 1965; Kumar, 1970; Bendre and Kumar, 1975; Tiwari and Pandey, 1976; Shukla and Shukla, 1986; Pandey and Tripathi, 1988; Anand, 1989; Tiwari et al., 2004; Mishra and Srivastava, 2005; Kant, 2011, 2012, 2013; Kant et al., 2003, 2004a-c; 2005a-e, 2006a-b; 2008a-c, 2014; 2020a-b; 2021; 2022; Adhikary, 2007; Dhingra and Ahluwalia, 2007; Kesharwani et al., 2008; Tiwari et al., 2007, 2009, 2013; Singh et al., 2008; Dwivedi et al., 2010; Neha et al., 2021; Sarma et al., 2020a; 2022a-b; Tandon et al., 2014, 2021) but none of them could carry out such type observations on non-heterocystous blue-green algae from any polluted habitats and never revealed the facts of polluted water reservoirs of Meerut, U.P., India.

Heterocystous filamentous Blue-green algae have been classified into single order, single family and 18 genera by Geitler (1932). Based on classification of Geitler (1932) and Fritsch (1945), Desikachary (1959) arranged all non-heterocystous filamentous forms from India into single order Nostocales, single family Oscillatoriaceae and 16 genera but Drouet (1968) classified non-heterocystous filamentous blue-green algae into single family, 6 genera and 24 species. Recently, Komárek and Anagnostidis (2005) reviewed non-heterocystous forms and arranged all the taxa in a single order, 6 families and 12 sub-families; 50 genera. Kumar (1970), surveyed Sardhana adjoining area of Meerut (U.P.), India and reported total 106 species of 22 genera of blue-green algae but he could not report members of Pseudanabaenaceae. Although Bendre and Kumar (1975) made exhaustive floristic survey and reported 131 taxa of blue-green algae from Meerut and adjoining area but members of Pseudanabaenaceae were ignored in their study.

Singh et al (2021, 2022a-b) very recently have compiled the information of blue-green algae of polluted habitats located at Meerut and adjoining area of western Uttar Pradesh, India. They explored various polluted water reservoirs of Meerut and reported total forty four species belonging to six genera including *Arthrospira*, *Oscillatoria*, *Phormidium*, *Planktothrix*, *Planktothricoides* and *Tychonema*. In present study, we are reporting 15 taxa of the family Pseudanabaenaceae of order Oscillatoriales of cyanoprokaryotes from four different polluted water reservoirs of Meerut, U.P., India.

## Conclusions

On the basis of the present study, it is concluded that polluted habitats of Meerut, U.P., India harbour a good numbers of many useful blue-green algae and some of these blue-green algal strains may be potential candidate for their commercial exploitation for value added natural products.



**Photoplate-01:** Figures 1-3: Collection sites; 4-18: Morphological details of Blue green algae collected from three different polluted water reservoirs of Meerut, U.P., India. **Scale Bar 10 µm**

**Explanation of Figures 1-18:**

Fig.1. Seasonal Water reservoir, Meerut Cantt site with dairy waste, domestic animals and with algae bloom

Fig.2. Kali river site with polluted water and growth of mixed pollution of blue-green algae

Fig.3. Seasonal Water reservoir, LLRM Medical College, Meerut site with mixed pollution of algae bloom

Fig.4. *Spirulina subsalsa*

Fig.5. *Planktolyngbya contorta*

Fig.6. *Pseudanabaena recta*

Fig.7. *Limnothrix planctonica*

Fig.8. *Geitlerinema lemmermannii*

Fig.9. *G. Nematodes*

Fig.10. *Jaaginema gracile*

Fig.11. *Pseudanabaena limnetica*

Fig.12. *P. minima*

Fig.13. *Romeria mexicana*

Fig.14. *Leptolyngbya mycoidea*

Fig.15. *L. gracilis*

Fig.16. *L. geysericola*

Fig.17. *L. foveolarum*

Fig.18. *L. aspera*

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