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Research Article

Taxonomic Investigations of Freshwater Cyanobacterial Flora in Benghazi with Newly Documented Species from Libya

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About Article

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ABSTRACT

A comprehensive survey of 400 freshwater samples was performed in and around Benghazi, Libya, for taxonomic study of Cyanobacteria at the species level. Samples were collected from different water sites and resources: ponds, rain ponds, sewage ponds, artificial lakes, manmade reservoirs, water tanks, wet soils, and wet walls. During the period between February 2023 and January 2025, samples were randomly collected and preserved by 4% formalin. A total of 55 species belonging to 31 genera, 17 families, and 10 orders of cyanobacteria were recorded, and 44 species are newly reported in Libya. The documentation of 44 species newly reported in Libya significantly expands the known cyanobacterial flora of the country and emphasizes the importance of continued taxonomic exploration in understudied regions. These findings not only contribute valuable data to the field of microbial taxonomy but also provide a foundation for future ecological and biotechnological research involving cyanobacteria in Libya more broadly.

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1. INTRODUCTION

Cyanobacteria, more commonly referred to as blue-green algae, represent a diverse and ecologically significant group of organisms. Photosynthetic prokaryotes have been identified in a wide range of aquatic and terrestrial environments (Jassim *et al.*, 2023). It is evident that they play a pivotal role in global biogeochemical cycles. It has been demonstrated that these organisms are particularly effective in the processes of nitrogen fixation and primary production and have the capacity to flourish in conditions of extremity (Sánchez-Baracaldo *et al.*, 2022). Cyanobacteria are commonly found in freshwater ecosystems such as lakes, ponds, rivers, marshes, and reservoirs (Bilous *et al.*, 2023). In these habitats, they often form planktonic (free-floating) or benthic (attached to surfaces) communities. Under nutrient-rich conditions, particularly with elevated nitrogen and phosphorus levels, they can proliferate rapidly and form harmful cyanobacterial blooms (HCBs), which may produce toxins affecting water quality and public health (Lakshmikandan *et al.*, 2024). In arid and semi-arid regions, cyanobacteria such as *Nostoc* and *Scytonema* form biological soil crusts that stabilize soil and contribute to nitrogen input (Hu *et al.*, 2012). Some cyanobacteria colonize rocks (epilithic) or live within rock pores (endolithic), especially in desert and polar regions. Certain cyanobacteria are epiphytic, living on tree bark or leaves, especially in tropical and subtropical forests (Ambika & Krishnamurthy, 2018).

Benghazi, located in the eastern coastal region of Libya, offers a unique ecological setting characterized by a Mediterranean climate and diverse aquatic habitats, including freshwater bodies, brackish marshes, and coastal lagoons. However, despite the ecological importance of this region, comprehensive studies on the diversity and distribution of cyanobacteria in Benghazi remain limited. This knowledge gap hinders our ability to assess the ecological health of local water systems and evaluate potential risks associated with cyanobacterial blooms and toxin production. The present survey aims to document the cyanobacterial flora in various freshwater and semi-aquatic environments in and around Benghazi. During the course of this investigation, several species were identified, including some not previously reported in Benghazi or even Libya. These new reports contribute to the growing inventory of microalgae diversity in Libya and may have implications for environmental monitoring, water management, and future research on cyanobacterial ecology.

2. LITERATURE REVIEW

Research on freshwater algae in Libya remains relatively limited. One of the earliest studies was conducted by Nizamuddin and Gerloff (1982), who recorded 20 genera and 26 species of Cyanobacteria from various regions across Libya. Subsequent studies have continued to document the diversity of Cyanobacteria in specific freshwater bodies. For instance, Issa *et al.* (2012) identified 18 species of Cyanobacteria in Lake Suluq which located in the northeastern region of Libya. Abobaker and Elsalhene (2016) collected freshwater samples from nine locations in the Green Mountain area, also in eastern Libya, and identified seven Cyanobacterial species. Similarly, Elsalhene and Abobaker (2018) recorded seven species of Cyanobacteria from freshwater habitats in the city of Shahat, in northeastern Libya. In the south of Libya, Loujanqi *et al.* (2020) documented six species of Cyanobacteria in the city of Kufra. More recently, Abobaker *et al.* (2023) reported 14 species of Cyanobacteria from the Derna Waterfall in eastern Libya.

3. METHODOLOGY

Freshwater algae samples were collected from Benghazi city, which lies at 32° 03’ 28.03’’ N and 20° 02 29.18’’ E on the eastern Libyan coast (Cyrenaica). Benghazi is the second largest city in Libya (Figure 1). Borders of sampling points were Al-Talhiya from the south, Sidi Khalifa from the east, and Al-Terria from the west, with a total area of 1031 km², which was measured by (offline maps) smart phone application. 400 Freshwater samples were collected randomly from different sites and different habitats (ponds, rain ponds, sewage ponds, artificial lakes, manmade reservoirs, water tanks, wet soils, and wet walls) in and around the city of Benghazi during the period between February 2023 and January 2025, without determination of seasons and sites to get a comprehensive survey for freshwater cyanobacteria. The algal specimens were collected with the help of forceps by hand. Some specimens were scraped from the surface of moist soil, stones, wet walls, tubes of air conditioners, and other solid substrata. Samples were kept in plastic bottles or in plastic bags. All the collected samples were preserved in 4% formalin (Francoeur *et al.*, 2013). The specimens were kept in the phycology lab at the Department of Botany, University of Benghazi. Each sample was assigned a voucher number along with the date of collection. Microscopic examinations were conducted at a magnification of 40x using a light microscope, and photos of algae were taken by cell phone. Taxa identification was conducted by using keys, monographs, and references (Bellinger & Sigee, 2015; Sheath & Wehr, 2015; Wehr *et al.*, 2015; Matthews, 2016) and the Algae Base website (Guiry & Guiry, 2013; Guiry & Guiry, 2014; Guiry & Guiry, 2024).

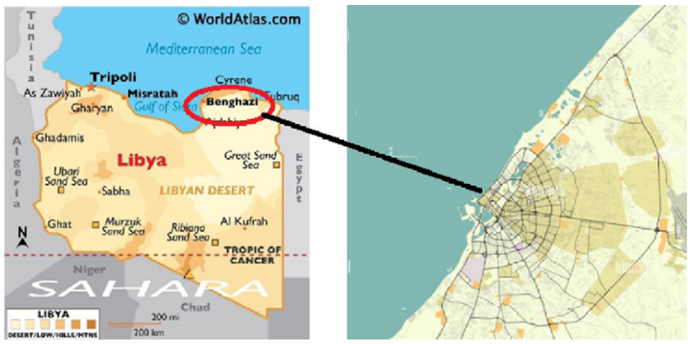


Figure 1. Maps of the study area.

4. RESULTS AND DISCUSSION

A total of 55 species belonging to 31 genera, 17 families, and 10 orders of cyanobacteria were recorded from different sites and habitats in and around Benghazi. 44 species are newly reported and were not mentioned in previous studies on freshwater algae in Benghazi and Libya. The signal (*) in the next species list indicates that species is new reported in Libya.

Kingdom – Eubacteria

phylum – Cyanobacteria

Class – Cyanophyacea
Order – Oscillatoriales
Family – Oscillatoriaceae

4.1. Genus – *Oscillatoria* (Figure 2)

1. Oscillatoria princeps Vaucher ex Gomont: Unbranched filament, blue-green, more or less brownish, mostly straight, not constricted at the cross-walls, slightly curved at the tops.

*2. *Oscillatoria rubescens (De Candolle ex Gomont) Anagnostidis & Komárek:* Filaments are not branched, straight, not constricted at cross-walls, and end-cell capitate with convex calyptra.

*3. *Oscillatoria limosa C.Agardh ex Gomont:* Filaments are not branched, not constricted at the cross walls or only slightly constricted, and end cells are flatly rounded.

*4. *Oscillatoria brevis Kützing ex Gomont:* Trichome is straight, not constricted at the cross walls, and tapered at the terminal end (New reported in Libya).

*5. *Oscillatoria jenensis G.Schmid:* Trichome is unbranched, wide, and composed of short cylindrical cells. The end of the trichome may be bent/curved.

4.2. Genus – *Phormidium* (Figure 2)

6. Phormidium tenue Gomont: Trichomes are straight with thin gelatinous sheath.

*7. *Phormidium formosum (Bory ex Gomont) Anagnostidis & Komárek:* Trichomes are solitary, straight or flexuous, the apical cell without calyptra.

*8. *Phormidium tergestinum (Rabenhorst ex Gomont) Anagnostidis & Komárek:* Trichomes are without sheaths, solitary, straight or flexuous, the apical cell is rounded.

*9. *Phormidium chalybeum (Mertens ex Gomont) Anagnostidis & Komárek:* Trichomes are straights and somewhat bent.

*10. *Phormidium dictyothallum (Skuja):* Filaments are loosely entangled, flexuous, sheath hyaline, inconspicuous. Trichomes are not attenuated, slightly constricted. Cells up to 2.3 times longer than wide. Cross walls not granulated, the apical cell is conical, without thickened outer membrane.

*11. *Phormidium autumnale Gomont:* Curved trichomes which are usually contained in a colorless sheath. Trichomes contain cells which are roughly isodiametric and usually have a pointed or rounded apical cell sometimes with a calyptra.

4.3. Genus – *Lygnbya*

*12. *Lyngbya wollei (Farlow ex Gomont) Speziale & Dyck:* There are spaces within the sheath without cells, and the ends of the filaments break with the ends of the sheath extending past the cells.
Order – Leptolyngbyales
Family – Leptolyngbyaceae
Genus – *Leptolyngbya*

*13. *Leptolyngbya boryana (Gomont) Anagnostidis & Komárek:* Trichomes are thin, cells are cylindrical, olive-green color.

*14. *Leptolyngbya thermobia Anagnostidis:* Trichomes are long, solitary, arcuated, waved or intensely coiled, thin, usually with colorless sheaths, opened at the apical end.

4.4. Genus –*Planktolyngbya*

*15. *Planktolyngbya limnetica (Lemmermann) Komárková-Legnerová & Cronberg:* Unbranched, straight or slightly curved filaments composed of a single row of narrow trichomes, green color.
Order –Pseudanabaenales
Family –Pseudanabaenaceae
Genus –*Pseudanabaena*

*16. *Pseudanabaena limnetica (Lemmermann) Komárek:* Trichomes is solitary, straight or flexuous, pale blue-green, the end cells are rounded.

*17. *Pseudanabaena catenate Lauterborn:* Trichomes are solitary, usually straight or slightly bend, rarely waved, cylindrical, fine and diffluent mucilage. pical cells not differentiated, without calyptra. Immotile or facultative, usually slow gliding. Cells are cylindrical with round ends, longer than wide.
Order –Spirulinales
Family – Spirulinaceae
Genus –*Spirulina*

18. Spirulina subsalsa Oersted ex Gomont: The bristles are spiral-shaped and bluish-green in color, with spirals very close to each other.
Family – Microcoleaceae
Genus –*Arthrospira*

*19. *Arthrospira fusiformis (Voronichin) Komárek & J.W.G.Lund:* Filamentous, solitary trichomes, generally coiled-shaped.
Order –Geitlerinematales
Family –Geitlerinemataceae
Genus –*Geitlerinema*

*20. *Geitlerinema splendidum (Gomont) Anagnostidis:* Trichomes are solitary, straight, or flexuous; there is no apparent sheath, and cell content is blue-green.
Order –Gomontiellales
Family –Gomontiellaceae
Genus –*Borzia*

*21. *Borzia trilocularis Cohn ex Gomont:* Trichome is not branched, small with few cells, olive-green, with hemispherical apical cells.

4.5. Genus –*Komvophoron*

*22. *Komvophoron constrictum (Szafer) Anagnostidis & Komárek:* The species forms short or long motile trichomes, usually straight and deeply constricted at the cross walls. Cells cylindrical or barrel-shaped. Cell contents separable into. The apical cells rounded or broadly conical.

*23. *komvophoron kgarii G.B. McGregor & B.C. Sendall:* Trichomes are solitary, straight or slightly flexuous, without mucilaginous sheaths. Composed of 4–60 cells, deeply constricted at the cross walls. Cells are cylindrical barrel-shaped with bluntly rounded ends, isodiametric, bright blue-green to yellow in color, and finely granulated; surface pores are located toward the diagonal corners of the cell. The apical cells are cylindrical, often with obtuse-conical ends, later conically elongated and narrowed toward the ends.
Order –Nodosilineales
Family –Cymatolegaceae
Genus –*Romeria*

*24. *Romeria chlorina Böcher:* Trichomes are solitary, arcuated, very short, yellow-green.

Genus –*Lemmermanniella*

*25. *Lemmermanniella terrestris Gama Jr.:* Round to elongated colonies, sub-colonies often present. Sheath gelatinous, hyaline, inconspicuous, following the colony outline. Cells ellipsoid, longer than wide, ends acuminate or round. Pseudo-filaments were found. Cell content granulated, pale blue-green to grey.

4.6. Genus –*Jaaginema* (Figure 3)

26. *Jaaginema geminatum (Schwabe ex Gomont) Anagnostidis & Komárek: Trichome is without sheaths, wavy, very thin, and bright green in color.

Order –Nostocales

Family –Nostocaceae

Genus –*Nostoc*

27. *Nostoc* commune Vaucher ex Bornet & Flahault: The colony is roughly spherical in shape and olive green in color, cells are trichomes spherical, heterocytes are spherical to slightly oval and bigger than vegetative cells, and it shows clearly.

28. **Nostoc* rivulare Kützing ex Bornet & Flahault: Filament is flexible and curved, cells are oval.

4.7. Genus –*Anabaena*

*29. *Anabaena solitaria Lemmermann:* Trichomes can be solitary or form into groups; the cells are spherical to cylindrical in shape, and their color is olive green.

Family –*Scytonema*taceae

Genus –*Scytonema*

*30. *Scytonema arcangelii Frémy:* Filaments are cylindrical, at the ends not or very rarely slightly widened (only in sheaths), sometimes slightly and shortly narrowed. Sheaths are thin, firm, colorless. Trichomes cylindrical, not or very slightly constricted at cross walls, blue–green or greyish green.

Family –Rivulariaceae

Genus –*Rivularia*

*31. *Rivularia minutula Bornet & Flahault:* Filament is asymmetric, with basal heterocystes, green in color.

4.8. Genus –*Calothrix* (Figure 4)

*32. *Calothrix fusca Bornet & Flahault:* Filament is unbranched, single or in small groups, straight or bent ending, and heterocyst is basal.

33. Calothrix parietina (NÄGELI) THUR: Filaments are olive-green with clear sheath. Cells of the trichomes are constricted at cross walls.

Family –Stigonemataceae

Genus –*Stigonema*

*34. *Stigonema ocellatum Thuret ex Bornet & Flahault:* Filament is surrounded by a thick yellowish mucilage, one row of cells, cells are spherical, oval, or cylindrical.

Order –Chroococcales

Family -Cyanothrichaceae

Genus –*Limnococcus*

*35. *Limnococcus limneticus (Lemmermann) Komárková, Jezberová, O. Komárek & Zapomelová:* Colonies are composed of mucilaginous sheath, cells are spherical, subspherical, and blue-green in color.

Family -Chroococcaceae

Genus –*Chroococcus*

36. Chroococcus turgidus (Kützing) Nägeli: Spherical or elongated cells, single or in groups, usually 2 or 4 (often 2), bright blue-green or olive-green, and very large.

37. Chroococcus minutus (Kützing) Nägeli: Cells are spherical or hemispherical, usually 2-8 cells. and yellowish-green in color.

*38. *Chroococcus minor (Kützing) Nägeli:* Cells are spherical or hemispherical, blue-green or olive green, singly or in pairs.

Family –Microcystaceae

4.9. Genus –*Microcystis* (Figure 5)

*39. *Microcystis wesenbergii (Komárek) Komárek ex Komárek:* Irregular colonies, the cells are close together at the edge of the colony.

40. Microcystis aeruginosa (Kützing) Kützing: Irregular lobed colonies, highly granular, blue-green color.

*41. *Microcystis novacekii (Komárek) Compère:* Colonies are not lobed and with tightly aggregated cells.

*42. *Microcystis ichthyoblabe (G.Kunze) Kützinge:* Sponge-like colonies, dark brown in color, the edge of the colony is not lobed.

4.10. Genus –*Aphanocapsa*

*43. *Aphanocapsa elachista West & G.S.West:* Colonies are small, cells are spherical or ovoid, often diffluent, blue-green in color.

*44. *Aphanocapsa incerta (Lemmermann) G.Cronberg & Komárek:* Colonies are small, irregularly arranged cells, pale blue-green color.

*45. *Aphanocapsa holsatica (Lemmermann) G.Cronberg & Komárek:* Colonies are large and irregular shape, cells spherical, pale blue-green color.

4.11. Genus –*Synechocystis*

*46. *Synechocystis aquatilis Sauvageau:* Spherical cells, solitary or in pairs, without a mucilaginous sheath being apparent.

4.12. Genus -*Merismopedia*

47. Merismopedia punctata Meyen, nom. Illeg: Cells are spherical or ovoid close to each other, colonies small, 4-64 cells.

48. Merismopedia elegans A.Braun ex Kützing: Cells are spherical or oblong, colonies are small or big, 16-40 cells.

4.13. Genus – *Aphanothece* (Figure 6)

*49. *Aphanothece clathrata West & G.S.West:* Colonies are irregular, composite of numerous cylindrical cells.

*50. *Aphanothece densa Lemes-da-Silva, L.H.Z. Branco & Necchi-Júnior:* Round colonies. Sheath firm, hyaline to slightly brownish, conspicuous. Cells densely disposed, ellipsoidal. Cell content homogenous to slightly granulated, blue-green color.

Genus – *Woronichinia*

*51. *Woronichinia naegeliana (Unger) Elenkin:* Colonies are densely packed, brown, blue-green or olive-green cells, irregular shape.

Genus –*Snowella*

*52. *Snowella lacustris (Chodat) Komárek & Hindák:* Colonies are irregular, spherical radially, cells joined to the ends of stalks, pale green color.

Order –Synechococcales

Family –Synechococcaceae
Genus –*Synechococcus*

53. Synechococcus elongatus (Nägeli) Nägeli: Cells are cylindrical, single or in groups.

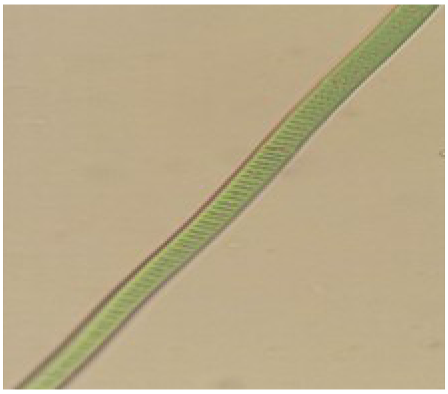
*54. *Synechococcus capitatus A.E.Bailey-Watts & Komárek:* Cells are singular or in duple cluster, bright green color in the middle of the cell.

Order –Chroococcidiopsidales

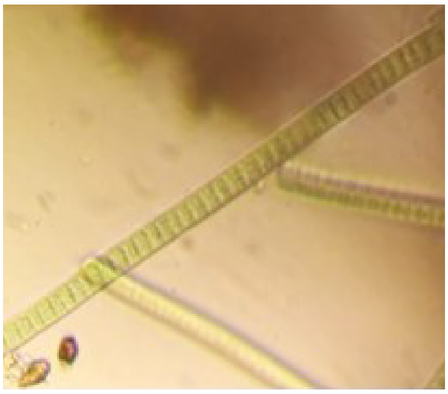
Family –Gloeocapsaceae
Genus –*Gloeocapsa*

*55. *Gloeocapsa atrata Kützing, nom. illeg:* C olonies are variable in size depending on age and habitats. Unicellular or in colonies. Colonies are small in a form of irregular aggregations. Colonies composed of groups of cells, which are closed in mucilaginous sheath (Figure 6).

Oscillatoria princeps

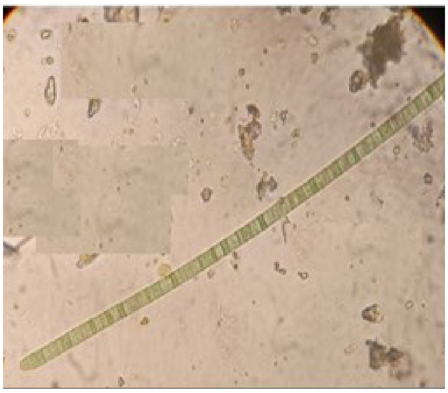


Oscillatoria rubescens

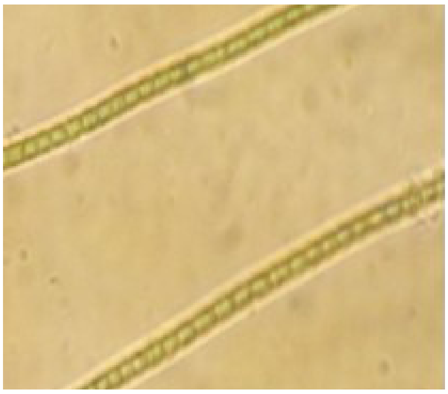


Oscillatoria limosa

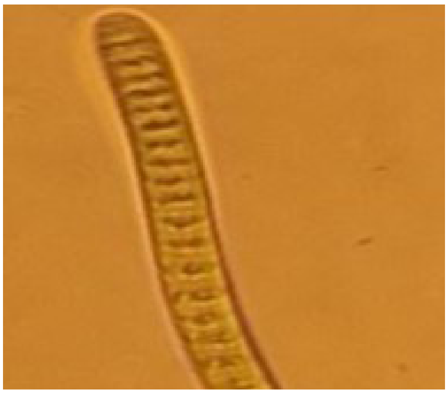
Oscillatoria brevis



Oscillatoria jenensis

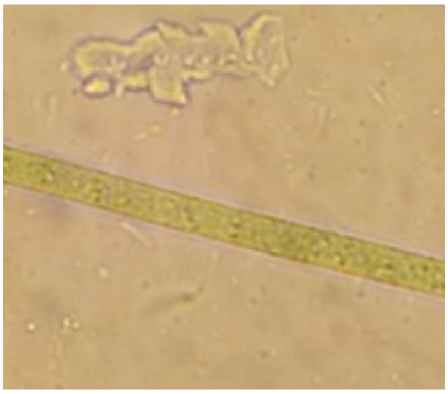


Phormidium formosum

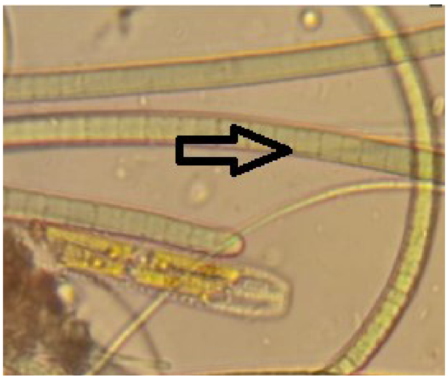


Phormidium tergestinum

Phormidium dictyothallum

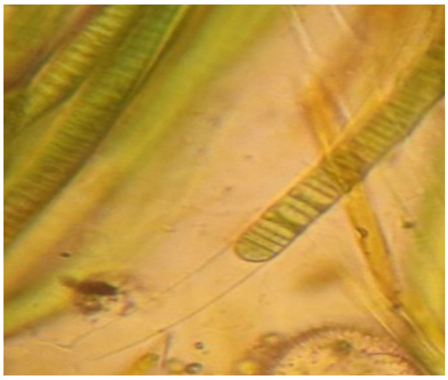


Phormidium tenue



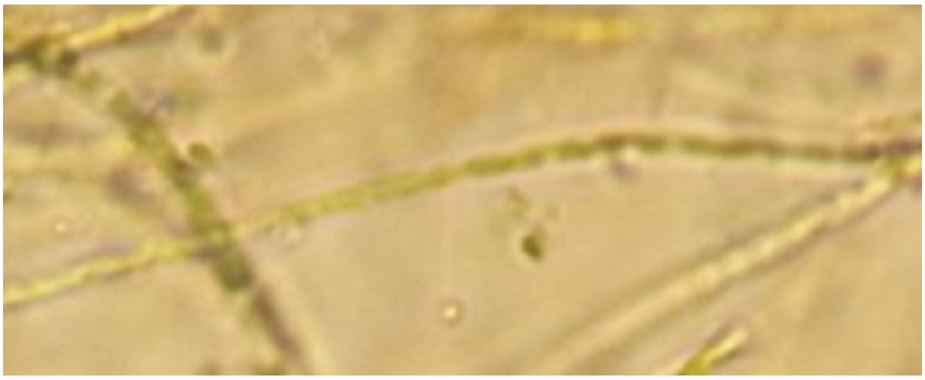
Phormidium chalybeum

Phormidium autumnale



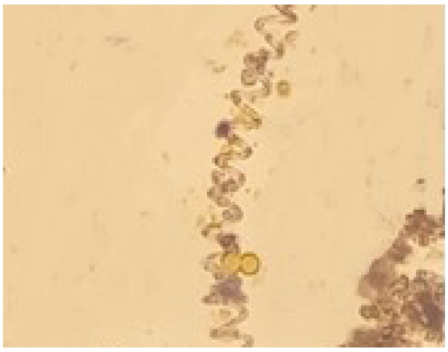
Lyngbya wollei

Borzia trilocularis



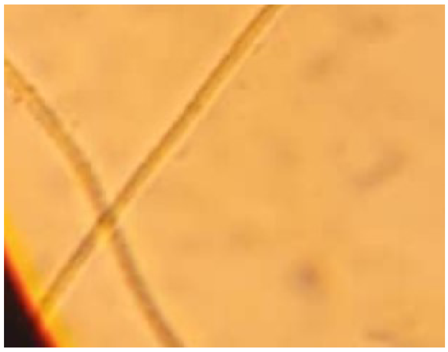
Geitlerinema splendidum

Figure 2. Filamentous cyanobacteria collected from Benghazi, Part I.

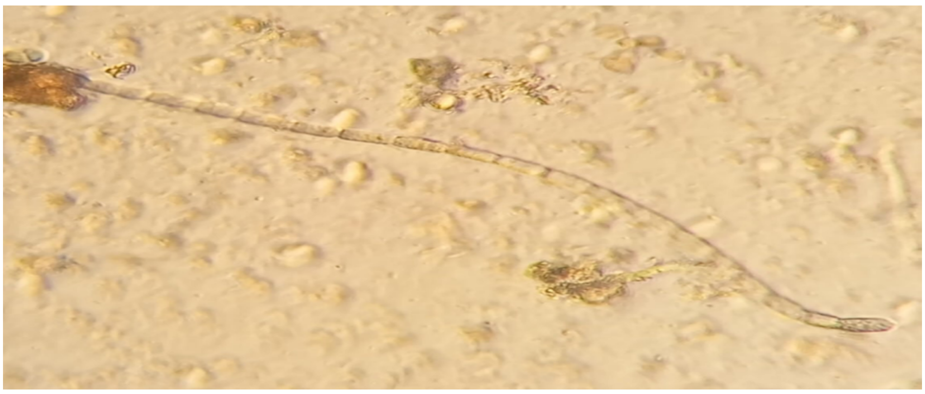


Arthrospira fusiformis

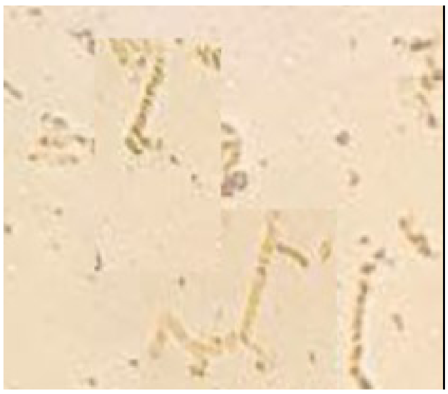
Spirulina subsalsa



Pseudanabaena limnetica

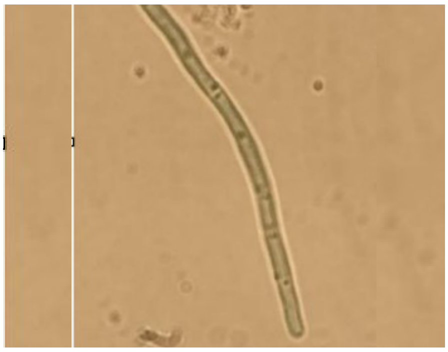


Pseudanabaena catenata



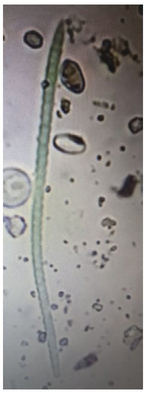
Romeria chlorina

Leptolyngbya thermobia



Leptolyngbya boryana

Komvophoron kgarii



Komvophoron constrictum

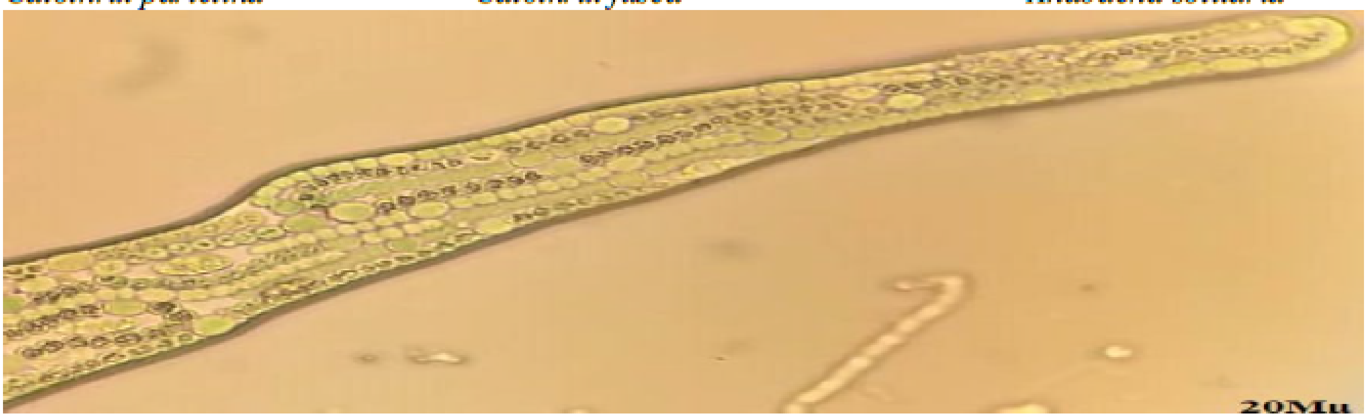
Jaaginema geminatum

Figure 3. Filamentous cyanobacteria collected from Benghazi, Part II.

Calothrix parietina

Calothrix fusca

Anabaena solitaria



Nostoc commune

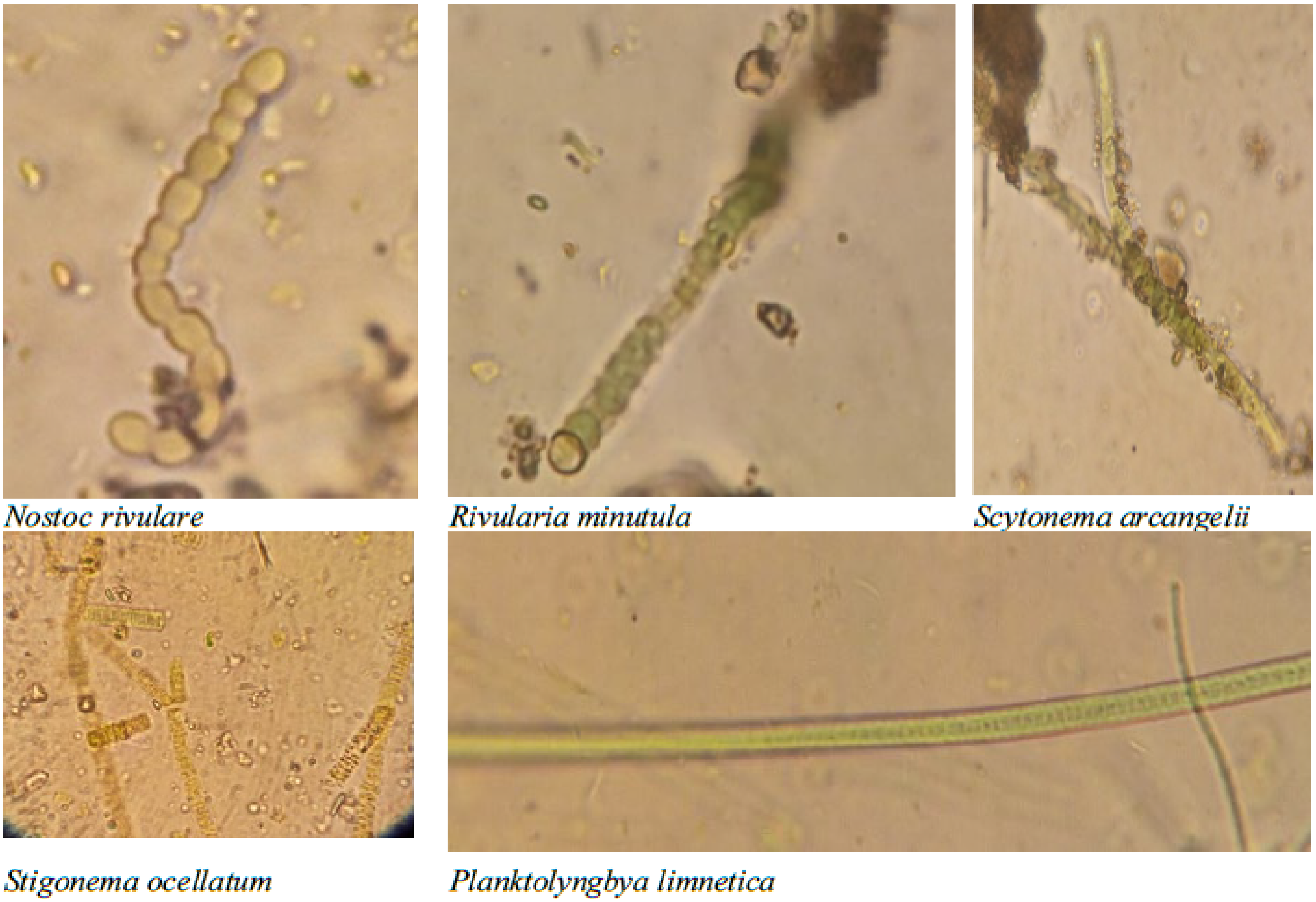


Figure 4. Filamentous cyanobacteria collected from Benghazi, Part III.

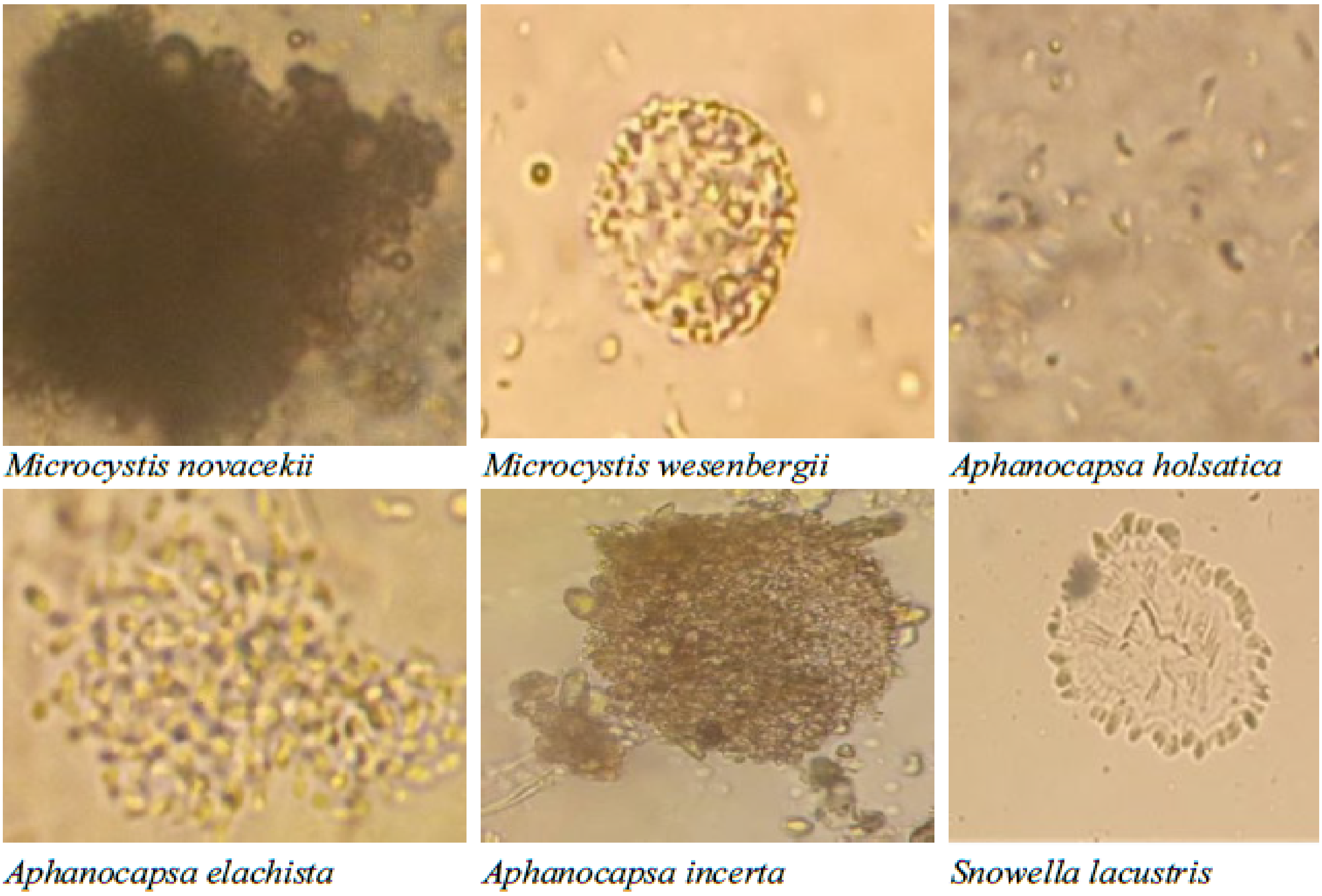
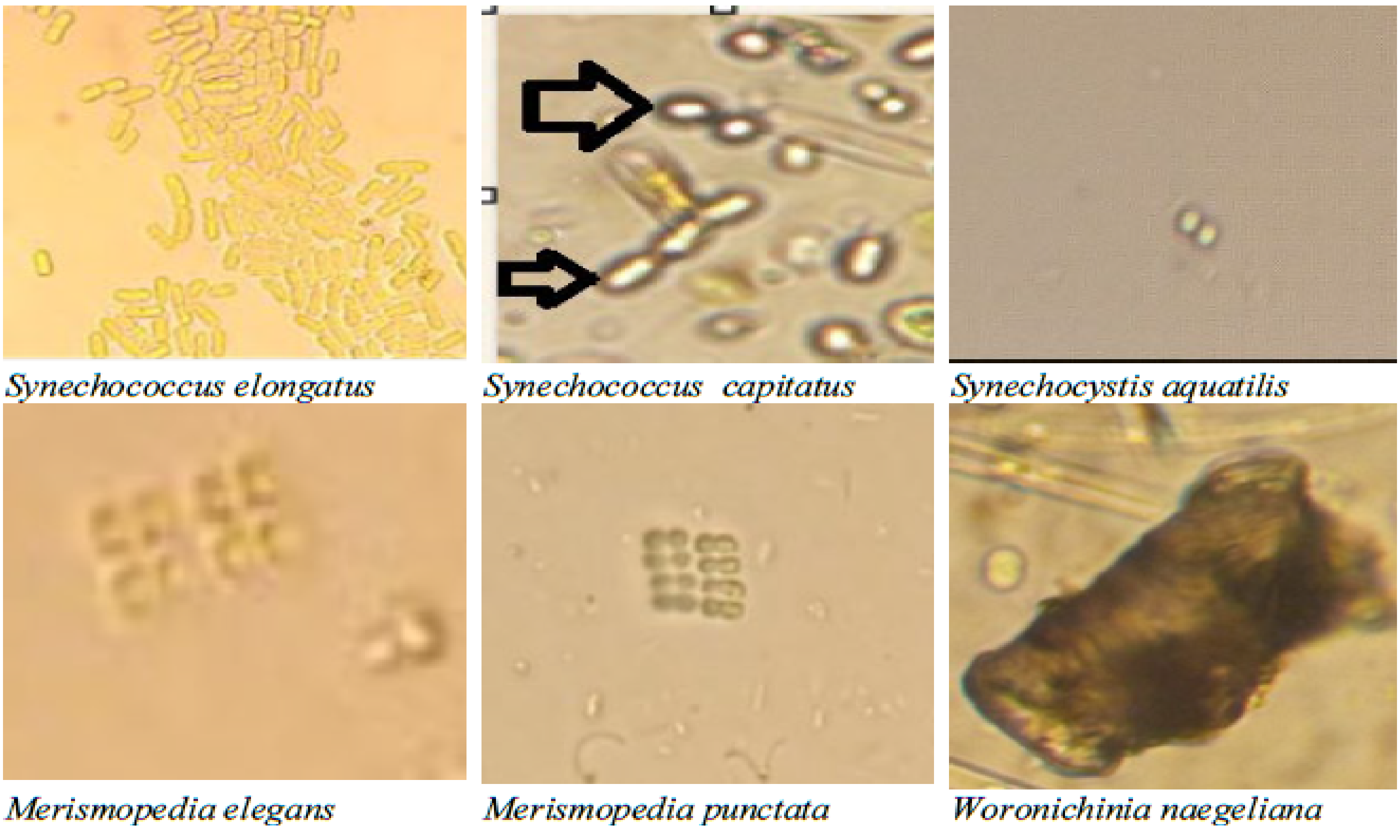
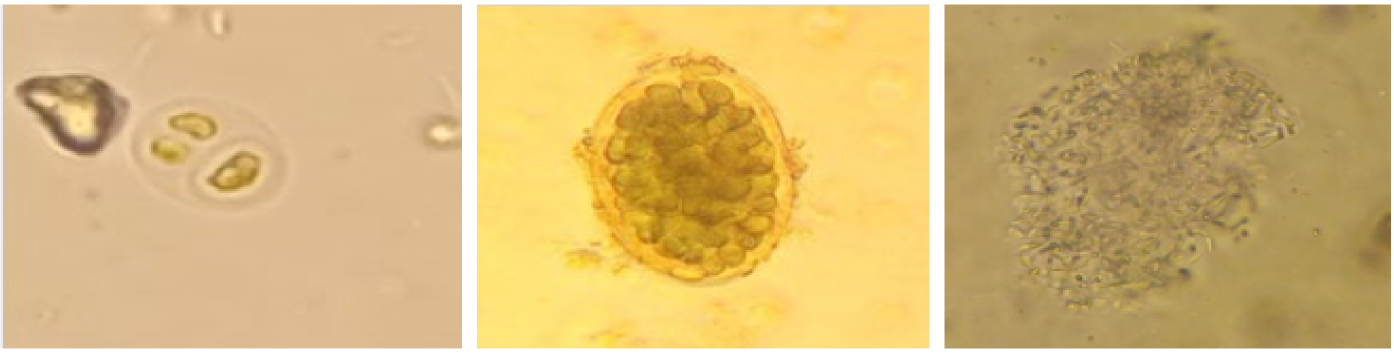


Figure 5. Coccoid Cyanobacteria collected from city of Benghazi, part I.





Gloeocapsa atrata *Aphanothece densa* *Aphanothece clathrata*

Figure 6. Coccoid Cyanobacteria collected from city of Benghazi, part II.

4.14. Discussion

It is rare to find a source of water or moist area on the earth that is not home to algae. These organisms can be considered as ubiquitous as bacteria, which are possibly the most extensively distributed organisms on the planet. The diversity in form and color exhibited by algae is seemingly infinite. There are no exclusively freshwater groups of algae, but cyanobacteria are more abundant and diverse in freshwater (Sheath & Wehr, 2015).

Cyanobacteria often dominate freshwater ecosystems under certain environmental conditions. Cyanobacterial blooms represent a naturally occurring phenomenon in many freshwater ecosystems around the world. Nonetheless, there has been a significant increase in the frequency and severity of such blooms over the last few decades, primarily due to two main factors: climate change and eutrophication (Zorrilla *et al.*, 2024). Cyanobacteria thrive in nutrient-enriched environments, often resulting from agricultural runoff, wastewater discharge, and urbanization. These nutrients fuel their rapid growth, resulting in harmful algal blooms (HABs). It has also recently been proven that benthic cyanobacteria live in oligotrophic (Bauer *et al.*, 2023). Due to their capacity for adaptation to a wide range of environmental conditions, they constituted the second most abundant group of algae in the present study. While they play important ecological roles, their overgrowth can have severe ecological and economic consequences. Managing their dominance requires a combination of nutrient control, ecosystem restoration, and public awareness to protect freshwater resources.

Cyanobacteria are well-adapted to warm temperatures, which is why they often dominate during summer months. Climate change and rising water temperatures exacerbate their growth. Many cyanobacteria produce toxins or form filamentous colonies that are less palatable to zooplankton grazers, reducing top-down control on their populations. The genus *Oscillatoria* was common in a variety of habitats in this study. Some *Oscillatoria* spp. are tolerant to high levels of organic pollution and produce toxins which may cause many diseases (VanVuuren *et al.*, 2006), It has been observed in bogs and walls. *Snowella lacustris* is also common in collected samples, as it was not observed in previous studies in Libya. *Snowella* widespread in the plankton of eutrophic standing. In favourable hydrological and environmental conditions, the cyanobacterium *Phormidium* forms cohesive mats which can cover extensive areas of substrate. Expansive *Phormidium* mats have been recorded in both oligotrophic and eutrophic environments (McAllister *et al.*, 2016), *Phormidium* as well current in some samples.

The dominance of *Microcystis* was observed in water systems across the world variable proportions. A lot of researches gave an updated understanding of the global geographic distribution of *Microcystis* blooms and dominance of *Microcystis* spp., A total of 1,130 freshwater ecosystems, encompassing lakes, rivers, reservoirs and ponds, were subjected to investigation across all continents except Antarctica. The worldwide distribution of *Microcystis* from low to middle latitudes reflects a wide temperature tolerance and suggests an increasing likelihood of more frequent blooms of this genus under a warming climate (Paerl & Paul, 2012). The global success of *Microcystis* spp. is partly attributable to the physiological characteristics of their colony morphology. This is consistent with our study where *Microcystis* spp. dominates.

5. CONCLUSION

This taxonomic investigation of freshwater cyanobacteria in the Benghazi region has significantly expanded the current understanding of the area's microbial biodiversity. A total of 55 cyanobacterial species were identified from various freshwater habitats, among which 44 species are newly documented for this region. These findings underscore the rich and previously underexplored diversity of cyanobacteria in Libya. The documentation of such a high number of previously unrecorded species highlights the need for continued taxonomic and ecological studies, particularly in regions like Benghazi where freshwater systems have not been extensively surveyed. These insights contribute not only to the regional biodiversity database but also provide a valuable reference point for future research on cyanobacterial taxonomy, ecology, and their potential biotechnological applications.

The highlight points of the manuscript

1. The taxonomic investigation led to the identification of previously unreported cyanobacterial species in the freshwater ecosystems of Benghazi, Libya. This expands the known biodiversity of the region and contributes valuable records to global cyanobacterial taxonomy.
2. The study employed detailed morphological analysis using

light microscopy and standard taxonomic keys. The researchers classified species based on characteristics such as cell shape, filament structure, sheath presence, and reproductive features.

3. The presence of diverse cyanobacterial taxa—including both common and rare genera—indicates that freshwater habitats in Benghazi support a rich and complex microbial community. These organisms play a crucial role in aquatic ecosystems, including oxygen production, nitrogen fixation, and forming the base of the food web.

REFERENCES

Abobaker, H. M., Ibrahim, N. M., & Shaieb, F. M. (2023). *Distribution of Algae and Water Quality in Waterfall Derna–Libya.*

Abobaker, H. M., & Elsalhine, H. (2016). *Diversity of fresh water algae in some side of Green Mountain.* http:// doi.org/10.37376/1570-000-012-003

Ambika, H. D., & Krishnamurthy, S. R. (2018). Algal flora of barks of tropical forests of Western Ghats-Perspectives of research. *The Journal of Indian Botanical Society, 97*(3and4), 1-13. http:// doi.org/10.5958/2455-7218.2018.00010.4

Bauer, F., Wolfschlaeger, I., Geist, J., Fastner, J., Schmalz, C. W., & Raeder, U. (2023). Occurrence, distribution and toxins of benthic cyanobacteria in German lakes. *Toxics, 11*(8), 643. https://doi.org/10.3390/toxics11080643

Bellinger, E. G., & Sigee, D. C. (2015). *Freshwater algae: identification, enumeration and use as bioindicators.* John Wiley & Sons. http:// doi.org/10.1002/9781118917152

Bilous, O. P., Nezbrytska, I., Zhezherya, V., Dubniak, S., Batoh, S., Kazantsev, T., ... & Cantonati, M. (2023). Interactions between aquatic plants and cyanobacterial blooms in freshwater reservoir ecosystems. *Water, 15*(4), 672. https://doi.org/10.3390/w15040672

Elsalhine, H., & Abobaker, H. M. (2018). Collection and definition of freshwater algae in City of Shahat-Libya. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), 12*(12), 37-41.

Francoeur, S. N., Rier, S. T., & Whorley, S. B. (2013). Methods for sampling and analyzing wetland algae. *Wetland Techniques: Volume 2: Organisms*, 1-58. https://doi.org/10.1007/978-94-007-6931-1_1

Guiry, M. D. (2024). How many species of algae are there? A reprise. Four kingdoms, 14 phyla, 63 classes and still growing. *Journal of Phycology, 60*(2), 214-228. https://doi.org/10.1111/jpy.13431

Guiry, M. D., & Guiry, G. M. (2014). *AlgaeBase.* World-wide electronic publication, National University of Ireland, Galway. https://doi.org/10.7872/crya.v35.iss2.2014.105

Guiry, M. D., & Guiry, G. M. (2013). *AlgaeBase.* Galway: world-wide electronic publication, National University of Ireland. http://www.algaebase.org

Hu, C., Gao, K., & Whitton, B. A. (2012). Semi-arid regions and deserts. In *Ecology of Cyanobacteria II: their diversity in space and time* (pp. 345-369). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-3855-3_12

Issa, A. A., Attitalla, I. H., & El-Mesmary, H. M. (2012). A first report of fresh water algae at Suluq lake, Libya. *Top class Journal of Microbiology, 1*(1), 18-24.

Jassim, Y. A., Awadh, E. F. A., & Al-Amery, S. M. H. (2023). A review of general properties of blue-green algae (Cyanobacteria). Biomedicine and Chemical Sciences, 2(2), 143-148. https://doi.org/10.48112/bcs.v2i2.397

Lakshmikandan, M., Li, M., & Pan, B. (2024). Cyanobacterial blooms in environmental water: Causes and solutions. *Current Pollution Reports, 10*(4), 606-627. https://doi.org/10.1007/s40726-024-00322-w

Loujanqi, A., Alteerah, M., & Godeh, M. (2020). Identification of Freshwater Algae from Kufrah, Libya. *Libyan Journal of Ecological & Environmental Sciences and Technology (LJEEST), 2*(1), 13-17. https://doi.org/10.63359/05rv9m80

Matthews, R. A. (2016a). *Freshwater Algae in Northwest Washington* (Volume I). Cyanobacteria. https://doi.org/10.25710/awgt-cp35

McAllister, T. G., Wood, S. A., & Hawes, I. (2016). The rise of toxic benthic Phormidium proliferations: a review of their taxonomy, distribution, toxin content and factors regulating prevalence and increased severity. *Harmful Algae, 55*, 282-294. https://doi.org/10.1016/j.hal.2016.04.002

Nizamuddin, M., & Gerloff, J. (1982). Freshwater algae from Libya. Nova hedwigia. *Lehre, 36*(1), 129-150.

Paerl, H. W., & Paul, V. J. (2012). Climate change: links to global expansion of harmful cyanobacteria. *Water research, 46*(5),1349-1363. https://doi.org/10.1016/j.watres.2011.08.002

Sánchez-Baracaldo, P., Bianchini, G., Wilson, J. D., & Knoll, A. H. (2022). Cyanobacteria and biogeochemical cycles through Earth history. *Trends in Microbiology, 30*(2), 143-157. https://doi.org/10.1016/j.tim.2021.05.008

Sheath, R. G., & Wehr, J. D. (2015). Introduction to the freshwater algae. In *Freshwater Algae of North America* (pp. 1-11). Academic Press. https://doi.org/10.1016/B978-0-12-385876-4.00001-3

Van Vuuren, S. J., Taylor, J., Gerber, A., & van Ginkel, C. (2006). Easy identification of the most common freshwater algae: a guide for the identification of microscopic algae in South African freshwaters: Resource Quality Services (RQS).

Wehr, J. D., Sheath, R. G., & Kociolek, J. P. (Eds.). (2015). *Freshwater algae of North America: ecology and classification.* Elsevier. https://doi.org/10.1016/C2010-0-66664-8

Zorrilla, J. G., Siciliano, A., Petraretti, M., Saviano, L., Spampinato, M., Cimmino, A., & Masi, M. (2024). Ecotoxicological assessment of cyclic peptides produced by a Planktothrix rubescens bloom: Impact on aquatic model organisms. *Environmental Research, 257*, 119394. https://doi.org/10.1016/j.envres.2024.119394