A Study on Morphological Variations of Bloom-Forming Algae in Stagnant and Flowing Water Ecosystems of Raigarh Block, Chhattisgarh

Shodh Siddhi
A Multidisciplinary & Multilingual Double Blind Peer Reviewed International Research Journal
Volume: 01 | Issue: 03 [July to September : 2025], pp. 82-88

Rashmi Kar Sharma
Bharti Vishwavidyalaya
Durg (Chhattisgarh)

Jagannath Prasad Suryawanshi
Govt. LCS PG College
Ambagarh Chowki, MMAC (Chhattisgarh)

Abstract

This study examines the differences in bloom formation and water quality between stagnant and flowing aquatic systems. Stagnant water bodies showed heavy algal growth with surface scums, strong odors, low oxygen levels, high turbidity, and poor transparency, conditions driven by nutrient enrichment. These factors promoted the dominance of scum-forming cyanobacteria such as *Microcystis*, *Anabaena*, and *Dolichospermum*. In contrast, flowing waters maintained higher oxygen content, lower nutrient loads, and greater clarity, supporting filamentous cyanobacteria like *Oscillatoria* and *Planktothrix* without scum accumulation. The results indicate that stagnant habitats are more prone to eutrophication and harmful algal blooms, while flowing systems remain comparatively stable but still require monitoring. Management efforts should prioritize nutrient control and circulation improvement in stagnant waters, and preventive strategies in flowing systems to maintain ecological health.

Keywords- algal blooms, morphology, stagnant waters, flowing waters, cyanobacteria, Raigarh, India.

Introduction

Algal blooms in freshwater ecosystems are major indicators of eutrophication, often impairing water quality, biodiversity, and ecosystem services. While nutrient enrichment is a primary driver, hydrological conditions—particularly water residence time and flow velocity—play a crucial role in determining bloom morphology, persistence, and community composition (Reynolds 2006; Paerl & Otten 2013).In stagnant ecosystems, prolonged residence time and thermal stratification facilitate buoyant cyanobacterial proliferation, leading to thick scums and surface accumulations. These scums reduce light penetration, deplete dissolved oxygen through decomposition, and release cyanotoxins that pose ecological and public health risks. Flowing systems, however, impose physical stress, limit colony cohesion, and promote filamentous morphotypes that adapt to turbulence (Reynolds & Walsby 1975). Such morphotypes often persist as dispersed populations, altering food-web interactions without always producing visible scums.

Globally, morphological variation among bloom-forming algae has been linked to hydrodynamics, nutrient stoichiometry, and climatic variability. Colonial cyanobacteria such as Microcystis dominate stratified ponds and reservoirs, whereas filamentous taxa like Oscillatoria and Planktothrix are commonly associated with flowing or semi-flowing waters. Chlorophytes such as Scenedesmus and Chlorella often coexist in mixed assemblages, further modifying bloom appearance and ecological function. Morphological characteristics—including colony size, mucilage production, filament flexibility, and buoyancy regulation—are therefore adaptive strategies that directly influence bloom formation, persistence, and dispersal.

The Raigarh Block of Chhattisgarh offers a unique setting where agricultural ponds, tanks, and reservoirs coexist with irrigation canals, rivulets, and stretches of the Shivnath River. Agricultural intensification, fertilizer application, and urban expansion contribute to nutrient enrichment, while contrasting hydrological regimes provide natural laboratories for comparative studies. Despite frequent reports of algal blooms from both farmers and local residents, morphological comparisons across stagnant versus flowing systems remain underexplored in this region. Addressing this gap is essential for developing low-cost, morphology-based monitoring frameworks that can support early warning systems, guide management interventions, and contribute to broader understanding of bloom ecology in tropical freshwater ecosystems.

Review of Literature

Algal blooms in freshwater systems are widely seen as signs of nutrient over-enrichment, also known as eutrophication. Such blooms can degrade water quality, create oxygen-depleted zones, reduce biodiversity, and negatively impact fisheries and drinking water supplies (Paerl & Otten, 2013; Huisman et al., 2018). While excessive nutrients—particularly nitrogen and phosphorus—are the main drivers of bloom formation, hydrological factors such as water flow, turbulence, and residence time also strongly influence the form and survival strategies of bloom-forming cyanobacteria (Reynolds, 2006; Mitrovic et al., 2011).

Morphological Adaptations of Cyanobacteria

Cyanobacteria exhibit several structural features that allow them to thrive under different aquatic conditions:

- Colonial species like Microcystis aeruginosa possess gas vesicles and mucilaginous sheaths that help them adjust buoyancy, allowing dense surface scums to form in calm, nutrient-rich waters (Oliver & Ganf, 2000; Zhang et al., 2020).
- Filamentous species such as Dolichospermum (formerly Anabaena) and Aphanizomenon develop heterocysts for nitrogen fixation and akinetes to survive harsh conditions (Krausfeldt et al., 2020).
- Sheath-forming or mat-forming species like Oscillatoria and Planktothrix can withstand turbulent or low-light environments, forming ribbon-like mats that resist water movement while maintaining nutrient access (Reynolds & Walsby, 1975; Carey et al., 2022).

- **Interaction Between Hydrology and Morphology**
- The hydrological environment strongly affects cyanobacterial community structure and bloom appearance: Still waters (ponds, reservoirs, tanks) often show thermal stratification, allowing buoyant cyanobacteria to migrate vertically and form surface scums (Reynolds, 1984; Sinha et al., 2017).
- Flowing waters (rivers, streams, canals) create mechanical stress, favoring filamentous or mat-forming species that can anchor themselves or align with the current (Mitrovic et al., 2011; Song et al., 2021).
- Laboratory and field studies indicate that flow velocity can influence colony size and mucilage production in Microcystis, with higher shear stress causing colonies to fragment into smaller units (Li et al., 2021).

Regional Context in India

Research in India has observed:

- Microcystis, Anabaena, and Oscillatoria are common in rice-field ponds and irrigation tanks in states like Chhattisgarh, Odisha, and West Bengal (Sinha et al., 2017; Sharma et al., 2020).
- Flowing rivers in central India, such as the Narmada and Mahanadi, host diverse filamentous cyanobacteria, often with lower toxin (microcystin) levels compared to stagnant waters (Nandan & Aher, 2005; Dutta et al., 2022).
- Seasonal changes affect bloom morphology in Indian wetlands, with dry-season stagnation favoring surface scums and rainy-season flushing reducing biomass (Jena et al., 2023).

Practical Implications and Monitoring

Morphological characteristics—such as colour (blue-green or reddish-brown), texture (gelatinous or fibrous), and colony size or arrangement (aggregated vs. dispersed)—remain simple and cost-effective tools for assessing bloom risk (WHO, 2020; Carey et al., 2022). When combined with modern techniques like remote sensing, microscopy, and molecular methods, these observations enhance early warning systems and improve bloom management, especially in areas with limited resources (Puddick et al., 2021; Liu et al., 2022).

Study Area

Raigarh Block (21.8–22.0°N; 83.3–83.6°E) in eastern Chhattisgarh features fertile agricultural plains interspersed with semi-urban settlements. The region experiences a tropical monsoon climate, with an average annual rainfall of around 1200 mm and temperatures ranging from 26 to 35°C. Study sites were categorized as:

- **Stagnant waters:** agricultural ponds, farm tanks, and reservoirs.
- **Flowing waters:** irrigation canals, perennial rivulets, and stretches of the Shivnath tributary.

The area is subject to various land-use pressures, including runoff from fertilizers, livestock activities, and urban wastewater discharge.

Methodology

Eight sites were studied in July–August 2025: four stagnant (ponds, tanks, reservoirs) and four flowing (canals, rivulets, river stretches).

- Field observations included bloom colour, odor, surface scum extent, and buoyancy using settling jar tests.

- Water quality parameters measured were pH, dissolved oxygen, turbidity, Secchi depth, and nutrient levels (total phosphorus and nitrogen).
- Pigment analysis involved chlorophyll-a extraction with 90% acetone and phycocyanin measurement by fluorometry.
- Microscopy was performed on Lugol-preserved samples at 400–1000× magnification, noting colony size, filament length, mucilage traits, and counts using a Sedgewick-Rafter chamber.
- Data analysis compared morphological traits between stagnant and flowing waters, tested pigment and nutrient differences using ANOVA, and assessed correlations between hydrology and cyanobacterial abundance.

Table 1. Observations from stagnant water bodies

Water Type	Bloom Color	Odor	Surface Scum	Buoyancy	pH	DO (mg/L)	Turbidity (NTU)	Secchi Depth (m)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll-a (µg/L)	Phycocyanin (µg/L)	Colony Size / Filament Length	Mucilage Traits	Dominant Taxa Observed
Stagnant	Light green	Slight	Yes	Floating, surface	7.1	4.5	40	0.3	0.25	1.8	55	18	300–600 µm	Thick, gelatinous	Microcystis
Stagnant	Blue-green	Strong	Yes	Floating mats	7	4.2	48	0.2	0.28	2	60	22	Colonies > 500 µm	Gelatinous clumps	Anabaena, Microcystis
Stagnant	Dark green	Foul	Heavy	Floating scum	6.9	3.8	55	0.15	0.3	2.2	70	25	Variable	Mucilaginous	Microcystis, Dolichospermum
Stagnant	Greenish	Slight	Patchy	Slowly settling	7.2	5	35	0.4	0.2	1.5	50	16	250–500 µm	Gelatinous sheet	Microcystis

Table 2. Observations from flowing water bodies

Water Type	Bloom Color	Odor	Surface Scum	Buoyancy	pH	DO (mg/L)	Turbidity (NTU)	Secchi Depth (m)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll-a (µg/L)	Phycocyanin (µg/L)	Colony Size / Filament Length	Mucilage Traits	Dominant Taxa Observed
Flowing	Light green	Slight	No	Slowly settling	7.4	6.2	20	0.8	0.12	1	22	8	200–500 µm	Fibrous	Oscillatoria

Flowing	Green	None	No	Slowly settling	7.3	6.5	18	0.9	0.1	0.9	20	7	150–450 μm	Fibrous	Planktothrix
Flowing	Greenish	Slight	No	Slowly settling	7.5	6.3	22	0.7	0.11	1.1	24	9	180–400 μm	Fibrous	Oscillatoria, Planktothrix
Flowing	Light green	None	No	Slowly settling	7.4	6.4	19	0.8	0.13	1	23	8	160–420 μm	Fibrous	Oscillatoria

Results and Discussion

The assessment of stagnant and flowing water bodies revealed marked contrasts in their ecological characteristics, bloom appearance, and dominant algal groups. In stagnant habitats, blooms were very prominent, with colors ranging from light green to dark green or blue-green,and often produced unpleasant to foul odors. Floating scums and mats were a common feature, as colonies remained buoyant and accumulated on the surface. These bloom conditions coincided with reduced water quality: dissolved oxygen was consistently low (3.8–5.0 mg/L), turbidity was high (35–55 NTU), and water clarity was poor with Secchi depths of only 0.15–0.4 m. Nutrient enrichment was evident, with phosphorus concentrations of 0.20–0.30 mg/L and nitrogen between 1.5–2.2 mg/L. These elevated nutrient levels supported dense algal biomass, reflected in high chlorophyll-a (50–70 μg/L) and phycocyanin (16–25 μg/L) values. The blooms were dominated by Microcystis, Anabaena, and Dolichospermum, which are known for forming mucilaginous colonies or clumps. Such traits not only promote surface scum formation but also contribute to oxygen depletion and potential toxin release, indicating that stagnant systems were in a eutrophic to hypertrophic state.

Flowing water bodies, in contrast, showed milder bloom development. The water was light green to greenish in color, with little or no odor and no evidence of scum. Colonies tended to remain dispersed, settling slowly rather than floating persistently. These conditions were supported by better water chemistry: dissolved oxygen was higher (6.2–6.5 mg/L), turbidity was lower (18–22 NTU), and transparency was improved with Secchi depths of 0.7–0.9 m. Nutrient levels were also lower compared with stagnant systems, with phosphorus between 0.10–0.13 mg/L and nitrogen around 0.9–1.1 mg/L. Chlorophyll-a concentrations (20–24 μg/L) and phycocyanin (7–9 μg/L) confirmed that algal biomass was modest, corresponding to mesotrophic to moderately eutrophic conditions. The cyanobacteria observed were mainly filamentous taxa such as Oscillatoria and Planktothrix. These groups tolerate nutrient enrichment but rarely produce the thick floating scums typical of Microcystis. Their presence reflects more stable water conditions maintained by flow and oxygenation.

Overall, the findings demonstrate the influence of hydrology on cyanobacterial bloom dynamics. Stagnant waters, due to poor circulation and nutrient accumulation, were more prone to harmful blooms, oxygen depletion, and scum formation. Flowing waters, on the other hand, benefited from constant movement, higher oxygen, and nutrient dilution, which reduced bloom severity and favored filamentous forms over colony-forming scum producers. Ecologically, this indicates that stagnant systems are highly vulnerable to eutrophication and harmful algal blooms, whereas flowing systems currently remain in a more balanced state. From a management perspective, stagnant waters require active interventions such as nutrient load reduction, artificial mixing, and aeration to control bloom intensity, while flowing waters must be protected from rising nutrient inputs to maintain their ecological stability.

Conclusion

This study demonstrates that stagnant and flowing water bodies differ greatly in bloom intensity, nutrient status, and dominant cyanobacterial communities. Stagnant waters, with high nutrient concentrations, poor oxygen levels, and limited circulation, encouraged the growth of dense, scum-forming species such as Microcystis, Anabaena, and Dolichospermum. These conditions not only reduced water clarity but also increased ecological risks linked to toxin release and oxygen depletion. Flowing waters, on the other hand, showed healthier conditions with better oxygenation, lower nutrient loads, and the presence of filamentous taxa like Oscillatoria and Planktothrix, which did not form thick surface scums. The findings suggest that stagnant habitats are highly prone to eutrophication and harmful algal blooms, while flowing systems remain relatively stable but still need careful monitoring. Management should therefore focus on reducing nutrient enrichment and improving circulation in stagnant waters, while maintaining low nutrient levels in flowing systems to safeguard their ecological balance.

References

1. Paerl, H. W., & Otten, T. G. (2013). Harmful cyanobacterial blooms: Causes, consequences, and controls. Microbial Ecology, 65(4), 995–1010.
2. Reynolds, C. S. (2006). The ecology of phytoplankton (p. 535). Cambridge University Press.
3. Reynolds, C. S., & Walsby, A. E. (1975). Water-blooms. Biological Reviews, 50(4), 437–481.
4. Carey, C. C., Ibelings, B. W., Hoffmann, E. P., Hamilton, D. P., & Brookes, J. D. (2022). Eco-physiological adaptations of cyanobacteria to changing freshwater environments. Frontiers in Microbiology, 13, 845123.
5. Dutta, S., Kumar, A., & Singh, R. (2022). Diversity and distribution of filamentous cyanobacteria in central Indian rivers. Environmental Monitoring and Assessment, 194(3), 213.
6. Huisman, J., Codd, G. A., Paerl, H. W., Ibelings, B. W., Verspagen, J. M., & Visser, P. M. (2018). Cyanobacterial blooms. Nature Reviews Microbiology, 16(8), 471–483.
7. Jena, B., Sahoo, B., & Tripathy, S. (2023). Seasonal dynamics of cyanobacterial blooms in Indian wetlands. Journal of Environmental Biology, 44(2), 189–198.
8. Krausfeldt, L. E., Allison, S. D., & Wilhelm, S. W. (2020). Functional adaptations of bloom-forming cyanobacteria. FEMS Microbiology Ecology, 96(9), fiaa155.
9. Li, H., Xie, P., & Wang, W. (2021). Effects of flow velocity on Microcystis colony morphology and mucilage production. Water Research, 197, 117046.
10. Liu, Y., Zhang, X., & Chen, L. (2022). Integrating remote sensing and microscopy for cyanobacterial bloom monitoring. Science of the Total Environment, 834, 155391.
11. Mitrovic, S. M., Williamson, C. E., & Paerl, H. W. (2011). Hydrological influences on cyanobacterial blooms in freshwater ecosystems. Hydrobiologia, 676(1), 49–66.
12. Nandan, U., & Aher, S. (2005). Cyanobacterial diversity in rivers of central India. Current Science, 89(11), 1912–1918.

13. Oliver, R. L., & Ganf, G. G. (2000). Freshwater blooms. In Whitton, B. A., & Potts, M. (Eds.), The ecology of cyanobacteria (pp. 149–194). Springer.
14. Paerl, H. W., & Otten, T. G. (2013). Harmful cyanobacterial blooms: Causes, consequences, and controls. Microbial Ecology, 65(4), 995–1010. Puddick, J., Prinsep, M. R., & Wood, S. A. (2021). Advances in cyanotoxin monitoring in freshwater systems. Toxins, 13(6), 430.
15. Reynolds, C. S. (1984). The ecology of freshwater phytoplankton.CambridgeUniversity Press.Reynolds, C. S. (2006). The ecology of phytoplankton. Cambridge University Press.Reynolds, C. S., & Walsby, A. E. (1975). Water-blooms. Biological Reviews, 50(4), 437–481. Sharma, S., Sinha, R., & Singh, A. (2020). Cyanobacterial blooms in Indian irrigation tanks: Composition and seasonal patterns. Environmental Monitoring and Assessment, 192(5), 319. Sinha, R., Thakur, R., & Sharma, S. (2017). Cyanobacteria in freshwater ecosystems of India: Distribution and ecological significance. Journal of Applied Phycology, 29(3), 1615–1629.
16. Song, L., Zhang, Y., & Li, J. (2021). Influence of flow conditions on filamentous cyanobacteria in rivers. Hydrobiologia, 848(12), 2821–2836.
17. WHO. (2020). Guidelines for safe recreational water environments, volume 2: Swimming pools and similar environments. World Health Organization.
18. Zhang, Q., Liu, Y., & Li, W. (2020). Morphological plasticity of Microcystis in response to environmental stress. Harmful Algae, 98, 101888.

❑❑❑