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Toxic Algal Blooms in Semi-Arid Lakes of Chitradurga District, Karnataka: Ecological Risks and Monitoring Approaches

Niharika U. K., and Parameswara Naik T.*

Department of Botany and Seed Technology, Sahyadri Science College, Kuvempu University, Shivamogga – 577203, Karnataka, India

ABSTRACT

Freshwater ecosystems in semi-arid regions of India are increasingly vulnerable to harmful algal blooms (HABs), driven by nutrient enrichment, hydrological stagnation, and climate variability. This study systematically evaluated toxic algae in selected stagnant lakes of Chitradurga district, Karnataka namely Gonur Lake, Mallapura Lake, Matadahatti Kere Lake, and Chandravalli Lake between 2025 and 2026. Physico-chemical analyses revealed mesotrophic conditions, with pH ranging from 7.02 to 8.3, temperatures between 19.6 °C and 24.2 °C, and phosphate levels fluctuating from 0.33 to 4.87 mg/L, indicating nutrient enrichment from sewage inflows, agricultural runoff, and urban waste disposal.

Microscopic documentation identified 54 phytoplankton species under 36 genera, classified into Bacillariophyceae, Chlorophyceae, Cyanophyceae, and Euglenophyceae. Seasonal succession patterns showed Chlorophyceae dominance across all lakes, while Cyanophyceae (Microcystis aeruginosa, Oscillatoria spp., Spirulina major, Nostoc calcicola, Phormidium cebennense, and Scytonema spp.) emerged as the most significant group in terms of toxicity. Pre-monsoon and post-monsoon periods exhibited higher phytoplankton densities, highlighting bloom risk during stagnant water conditions. Cyanotoxins such as microcystins and anatoxins pose serious ecological and health hazards, including fish kills, livestock poisoning, and unsafe drinking water.

The findings underscore the ecological and socio-economic importance of Chitradurga's lakes, which sustain agriculture, groundwater recharge, fisheries, and rural livelihoods, but face escalating threats from eutrophication and pollution. By integrating ecological surveys, toxin assays, and environmental parameter analysis, this research provides critical insights into bloom dynamics and risk assessment. The study emphasizes the urgent need for systematic monitoring, community awareness, and sustainable management strategies to mitigate HABs in semi-arid inland waters. Ultimately, these results contribute to early warning systems and policy frameworks aimed at safeguarding freshwater ecosystems and public health in India.

Keywords: *Harmful Algal Blooms (HABs), Cyanobacteria, Mesotrophic Lakes, Nutrient Enrichment, Chitradurga District, Water Quality Monitoring.*

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Corresponding Author: *Parameswara Naik T.*

E-mail Address: *maravanjiparameswara@gmail.com*

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Introduction

Freshwater lakes in Chitradurga district are increasingly vulnerable to harmful algal blooms (HABs), with cyanobacteria posing ecological and health risks. Recent studies highlight nutrient enrichment, hydrological stagnation, and climate variability as key drivers, underscoring the need for systematic monitoring and management.

Freshwater lakes in semi-arid regions of India are critical for agriculture, groundwater recharge, fisheries, and rural livelihoods. In Chitradurga district, lakes such as Gonur, Mallapura, Matadahatti Kere, and Chandravalli serve as vital water sources for irrigation and domestic use. However, these ecosystems are increasingly threatened by nutrient enrichment from sewage inflows, agricultural runoff, and urban waste disposal, leading to eutrophication and bloom formation [1, 19]. HABs are characterized by the rapid proliferation of algae, particularly cyanobacteria (blue-green algae), which produce toxins such as microcystins and anatoxins. These toxins can cause fish kills, livestock poisoning, and unsafe drinking water, posing serious risks to both ecological balance and public health [2]. In Chitradurga's lakes, species such as *Microcystis aeruginosa*, *Oscillatoria spp.*, and *Nostoc calcicola* have been documented as dominant bloom-forming taxa. Seasonal succession studies reveal that Chlorophyceae dominate overall phytoplankton diversity, while Cyanophyceae emerge as the most toxic group, especially during stagnant pre-monsoon and post-monsoon periods [7].

Physicochemical analyses of Chitradurga lakes show mesotrophic conditions, with pH ranging from 7.0–8.3, temperatures between 19–24 °C, and phosphate levels up to 4.87 mg/L. Elevated nutrient concentrations, particularly phosphates and nitrates, are strongly linked to bloom risk. Similar findings in Gopalaswamy Tank, Chitradurga, revealed low transparency, high alkalinity, and eutrophic indicator species, confirming the role of nutrient enrichment in bloom dynamics and also even in our finding many of the parameters were comprehensively matching and became environmental issue in special reference aquatic system [7, 13].

HABs disrupt aquatic ecosystems by depleting dissolved oxygen, shading submerged vegetation, and altering food web interactions. The socio-economic impacts are equally severe: reduced fisheries yield, increased water treatment costs, and risks to rural communities dependent on lakes for drinking water and agriculture [2]. In semi-arid regions like Chitradurga, where water scarcity is already a challenge, HABs exacerbate vulnerability by compromising water quality and ecosystem services.

Effective monitoring of HABs requires integrating ecological surveys, toxin assays, and environmental parameter analysis. Remote sensing and GIS tools can help identify bloom hotspots, while community-based awareness programs are essential for reducing pollution inputs. Policy frameworks such as the National Bio-Energy Mission [3] and local conservation strategies emphasize sustainable management of inland waters. International studies also highlight the importance of early warning systems and adaptive management to mitigate bloom risks [4].

By integrating physico-chemical analysis with algal bloom profiling, this study seeks to elucidate the ecological status of Chitradurga's lakes and provide actionable insights for sustainable freshwater management. The research emphasizes the role of nutrient enrichment, seasonal succession, and cyanotoxin production in driving harmful algal blooms (HABs), particularly in stagnant semi-arid waters. Findings will contribute to regional bloom monitoring databases, inform public health strategies addressing risks from microcystins and anatoxins, and support ecological restoration efforts in vulnerable inland water bodies. Ultimately, this work aims to strengthen early warning systems and policy frameworks for mitigating HABs, ensuring the resilience of freshwater ecosystems and safeguarding rural livelihoods in Karnataka.

Materials and Methods

Study Area and Sampling Duration

Water Sample Collection

Water samples were collected on particular dates of every month from the various selected lakes considered for the algal bloom study. Water from the surface was collected using clean and sanitized BOD bottles and for culturing the algae for the taxonomic characterization and nomenclature of available diversity in the study area. Collections were done from the Gonur Lake, Mallapura Lake, Matadahatti Kere Lake, and Chandravalli Lake, Chitradurga, during morning at around 9 - 11am for the months of July 2025 to December 2025.

Figure 1: Water sampling area maps of various lakes for the algal bloom studies of Chitradurga, Karnataka, India

Sampling Protocol for the Algal Bloom Studies

For algal bloom studies in lakes, water sample collection must follow standardized ecological and limnological protocols to ensure accurate assessment of phytoplankton diversity, toxin presence, and environmental drivers. Sampling is typically conducted at multiple points across the lake (inlets, mid-lake, and outlets) to capture spatial heterogeneity. Surface water samples are collected at depths of 0.5–1 m using sterilized polyethylene or glass bottles, while integrated samples from different depths may be obtained using a Ruttner sampler or Van Dorn bottle to account for vertical stratification [5].

To prevent contamination, bottles are rinsed with lake water before collection, and samples are stored in cool, dark conditions during transport. For phytoplankton analysis, 1–2 L of water is collected and preserved with Lugol's iodine or formalin (4%), enabling microscopic identification and enumeration [6]. For toxin assays, unpreserved water samples are filtered through GF/C filters to concentrate algal biomass, which is later extracted for cyanotoxin quantification using ELISA or LC-MS/MS methods [9]. Physico-chemical parameters such as pH, temperature, dissolved oxygen, and nutrients (phosphates, nitrates) are measured in situ using portable meters and spectrophotometric kits, as these strongly influence bloom dynamics [7]. Seasonal sampling is essential, with collections during pre-monsoon, monsoon, and post-monsoon periods, since bloom intensity often peaks under stagnant water conditions. Replicates (triplicate samples per site) are recommended to ensure statistical robustness [8]. Together, these methods provide a comprehensive dataset linking environmental parameters, phytoplankton succession, and toxin production, forming the basis for ecological risk assessment and management of harmful algal blooms in semi-arid lakes [8, 21-22].

Taxonomic Studies and Nomenclature of Algal Diversity

For the taxonomic identification of algal blooms, a structured methodology is required to ensure accurate classification of phytoplankton species and bloom-forming cyanobacteria.

Water samples collected from different lake sites are first preserved with Lugol's iodine solution (1–2%) or formalin (4%) to maintain cell integrity. Microscopic examination is then carried out using compound and inverted microscopes at magnifications of 400×–1000×. Identification relies on morphological features such as cell shape, colony formation, pigmentation, presence of heterocysts, akinetes, and filamentous structures [6].

Taxonomic classification follows standard algal keys and manuals, including Prescott's Freshwater Algae Keys and the APHA Standard Methods (2017). Phytoplankton are grouped into major classes such as Bacillariophyceae (diatoms), Chlorophyceae (green algae), Cyanophyceae (cyanobacteria), and Euglenophyceae, with further identification to genus and species level. Bloom-forming cyanobacteria such as *Microcystis aeruginosa*, *Oscillatoria spp.*, *Nostoc calcicola*, and *Phormidium spp.* are recognized by their colonial morphology, mucilage presence, and toxin-producing potential [9, 20].

For confirmation, molecular techniques such as PCR amplification of 16S rRNA genes and toxin-related genes (e.g., *mcy* for microcystins) may be employed, providing higher taxonomic resolution and linking morphology with toxin production [10]. Seasonal succession analysis is performed by quantifying cell densities using a Sedgwick–Rafter counting chamber or Utermöhl method, enabling statistical evaluation of bloom dynamics [5].

This integrated taxonomic approach—combining morphological, ecological, and molecular methods—ensures reliable identification of bloom-forming taxa and supports ecological risk assessment in semi-arid lakes.

Results and Discussion

Seasonal Diversity Patterns of Algal Bloom of Chitradurga Lakes

The seasonal diversity patterns of algal blooms in Chitradurga lakes highlight how hydrology and nutrient enrichment drive ecological succession. Pre-monsoon periods showed maximum diversity, with Mallapura recording 30 Bacillariophyceae, 31 Chlorophyceae, and 21 Cyanophyceae taxa, while monsoon dilution reduced counts sharply (e.g., Matadahatti dropped to 5 Bacillariophyceae). Post-monsoon recovery was moderate, with Gonur regaining 17 Bacillariophyceae and 21 Chlorophyceae taxa, alongside bloom-forming cyanobacteria such as *Microcystis aeruginosa* and *Oscillatoria limosa*. These seasonal shifts demonstrate that pre-- and post-monsoon periods are peak bloom risk windows, while monsoon inflows provide temporary relief. Ecologically, blooms suppress sensitive diatoms, reduce biodiversity, and destabilize food webs; environmentally, they degrade water quality, release cyanotoxins, and threaten fisheries and livelihoods. Overall, the study confirms that Mallapura and Chandravalli are bloom hotspots, while Matadahatti is most sensitive to monsoon dilution, underscoring the urgent need for monitoring, nutrient management, and conservation strategies to safeguard freshwater ecosystems.

Pre-Monsoon

- **Bacillariophyceae:** Highest richness was observed in Mallapura (30 taxa) and Chandravalli (26 taxa), followed by Matadahatti (27 taxa) and Gonur (22 taxa). Dominant diatoms included *Cyclotella meneghiniana* (3 counts in Gonur and Mallapura) and *Gomphonema lanceolatum* (4 counts in Gonur).
- **Chlorophyceae:** Mallapura again led with 31 taxa, while Chandravalli (27 taxa), Matadahatti (25 taxa), and Gonur (13 taxa) showed moderate diversity. *Chlorella vulgaris* (3 counts in Mallapura, 3 in Matadahatti) and *Pediastrum simplex* (2 counts in Mallapura) were common.
- **Cyanophyceae:** Mallapura recorded 21 taxa, Chandravalli 18, Gonur 17, and Matadahatti 16. *Microcystis aeruginosa* (3 counts in Mallapura) and *Aphanocapsa biformis* (2–3 counts across lakes) were bloom-forming taxa.

This season reflects nutrient enrichment and stagnant hydrology, favoring bloom initiation. Similar pre-monsoon bloom intensification has been reported in semi-arid tanks of Karnataka [7].

Monsoon

- **Bacillariophyceae:** Diversity dropped sharply, with Matadahatti (5 taxa) lowest, Gonur (9), Chandravalli (9), and Mallapura (12). Sensitive taxa like *Cymbella affinis* disappeared in Gonur and Matadahatti.
- **Chlorophyceae:** Reduced richness, with Gonur (6 taxa), Mallapura (8), Matadahatti (7), and Chandravalli (10). Dilution suppressed *Cladophora glomerata* and *Spirogyra elliptica*.
- **Cyanophyceae:** Lowest diversity observed, with Gonur (5 taxa), Mallapura (7), Matadahatti (7), and Chandravalli (5). *Microcystis aeruginosa* nearly disappeared, showing monsoon flushing effects.

This decline highlights the flushing effect of rainfall, reducing bloom intensity but allowing opportunistic taxa (*Fragilaria intermedia*, *Chroococcus disperses*) to persist. Comparable monsoon-driven declines are documented in Indian reservoirs [10].

Post-Monsoon

- **Bacillariophyceae:** Recovery observed, with Gonur (17 taxa), Mallapura (11), Matadahatti (12), and Chandravalli (11). *Navicula lanceolata* resurged (3 counts in Gonur, 2 in Matadahatti).
- **Chlorophyceae:** Diversity increased again, with Gonur (21 taxa), Mallapura (14), Matadahatti (14), and Chandravalli (16). *Coelastrum cambricum* (3 counts in Gonur) and *Micrasterias foliacea* (2 counts in Matadahatti) showed bloom recovery.
- **Cyanophyceae:** Moderate recovery, with Gonur (10 taxa), Mallapura (11), Matadahatti (9), and Chandravalli (7). *Oscillatoria limosa* and *Phormidium cebennense* reappeared across lakes.

This recovery underscores the resilience of bloom-forming taxa under nutrient recycling and stagnant water conditions, consistent with succession patterns in eutrophic lakes of North India [11].

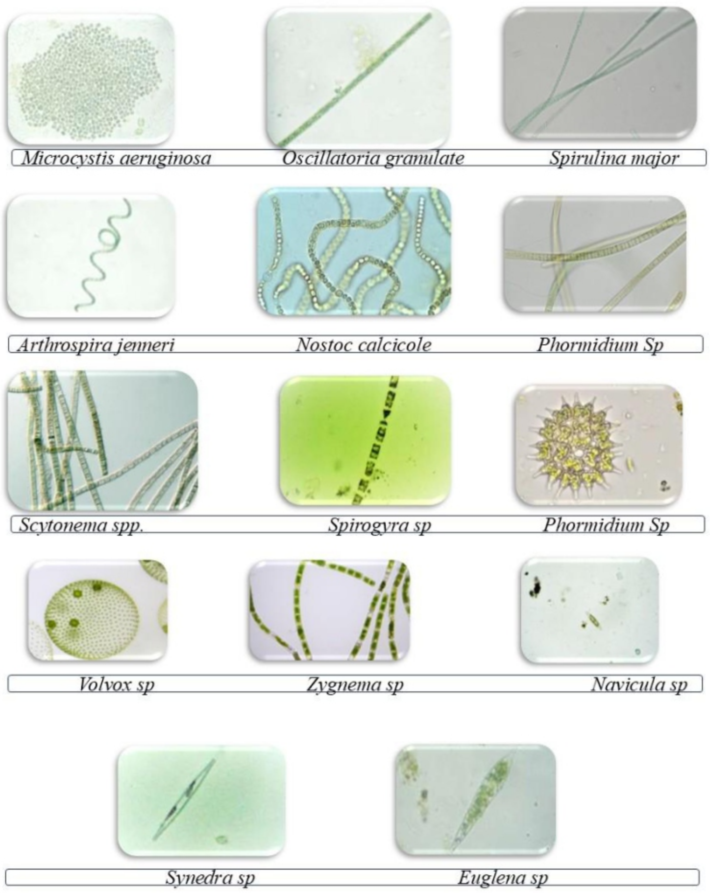

Figure 2: Toxic Algae Diversity of Selected Chitradurga Lakes

Environmental Impacts

1. Water Quality Degradation Cyanotoxins (*microcystins, anatoxins*) compromise drinking water safety. High pre-monsoon cyanophyceae counts (Mallapura 21, Chandravalli 18) indicate bloom risk. Similar toxin hazards have been reported globally [9, 14].

2. Biodiversity Loss Sensitive diatoms (*Cymbella ventricosa*, *Pinnularia divergens*) declined during bloom dominance, reducing ecological diversity. This homogenization destabilizes food webs and nutrient cycling [6].

3. Fisheries and Livelihoods: Monsoon bloom recovery (e.g., *Synedra ulna* 3 counts in Matadahatti, 2 in Chandravalli) increases risk of oxygen depletion and fish kills, directly impacting rural and urban livelihoods dependent on lake fisheries [7, 15 - 18].

4. Socio-Economic Costs: Increased water treatment costs and reduced agricultural productivity are consequences of bloom-driven eutrophication. The ecological services of lakes—groundwater recharge, irrigation, and cultural value—are compromised [3].

Table 1: Seasonal Observation and Distribution of Bacillariophyceae Algae Diversity of selected lakes of Chitradurga

Algal Diversity	**Gonur lake**			**Mallapura Lake**			**Matadahatti Kere Lake**			**Chandravalli Lake**		
Bacillariophyceae	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**
Cyclotella meneghiniana	3	1	2	3	1	1	2	0	2	1	1	2
Cymbella affinis	2	0	1	2	2	1	2	0	0	1	0	0
Cymbella turgidula	2	0	1	3	0	0	2	1	2	2	1	0
Cymbella ventricosa	2	0	0	2	0	0	2	0	1	2	0	0
Fragilaria intermedia	2	1	0	2	1	1	2	1	2	2	1	1
Gomphonema lanceolatum	4	2	3	1	1	1	2	0	0	2	1	1
Navicula cuspidata	3	2	0	3	2	2	1	0	0	1	1	1
Navicula lanceolata	0	0	3	2	0	1	1	1	2	2	1	1
Navicula viridula	2	1	1	3	3	2	2	0	0	1	1	1
Pinnularia braunii	0	0	3	2	0	0	2	0	1	2	0	1
Pinnularia divergens	1	0	1	2	0	0	2	0	0	3	0	1
Pinnularia graciloides	0	1	1	1	1	1	2	0	0	3	1	1
Synedra ulna	0	0	0	2	0	0	3	1	1	2	1	1
Tabellaria flocullosa	1	1	1	2	1	1	2	1	1	2	1	0
Total	**22**	**9**	**17**	**30**	**12**	**11**	**27**	**5**	**12**	**26**	**9**	**11**

Table 2: Seasonal Observation and Distribution of Chlorophyceae Algae Diversity of selected lakes of Chitradurga

Algal Diversity	**Gonur lake**			**Mallapura Lake**			**Matadahatti Kere Lake**			**Chandravalli Lake**		
Chlorophyceae	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**
Arthrodesmus convergens	2	1	1	2	1	1	1	1	1	2	1	1
Chlorella vulgaris	1	1	1	3	1	1	3	0	0	2	0	1
Cladophora glomerata	1	0	1	2	1	0	2	0	1	1	0	1
Closterium acutum	1	0	1	1	1	1	3	1	1	2	1	1
Coelastrum cambricum	0	0	3	1	0	1	2	0	1	1	1	1
Crucigenia quadrata	1	0	1	2	1	2	2	0	0	1	1	1
Euastrum coralloides	0	0	2	3	0	0	2	1	1	2	0	0
Micrasterias foliacea	0	0	1	1	0	0	3	1	2	2	1	1
Pediastrum simplex	1	1	2	2	1	1	1	1	1	1	1	1
Pediastrum tetras	1	0	1	1	0	1	1	0	0	2	1	1
Scenedesmus perforatus	1	1	1	2	1	1	1	0	0	1	0	1
Spirogyra elliptica	1	0	1	2	0	0	0	0	1	2	1	1
Staurastrum gracile var.	1	0	1	2	0	1	0	0	1	2	0	1
Tetradron trigonum	0	0	1	2	1	0	0	0	1	2	0	1
Ulothrix cylindricum	1	1	1	1	0	1	1	1	1	2	1	1
Volvox aureus	0	0	1	2	0	1	2	1	1	0	0	1
Zygnema pectinatum	1	1	1	2	0	1	1	0	1	1	1	1
Total	**13**	**6**	**21**	**31**	**8**	**14**	**25**	**7**	**14**	**27**	**10**	**16**

Table 3: Seasonal Observation and Distribution of Cyanophyceae Algae Diversity of Selected Lakes of Chitradurga

Algal Diversity	Gonur lake			Mallapura Lake			Matadahatti Kere Lake			Chandravalli Lake		
Cyanophyceae	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**
Aphanocapsa biformis	2	1	2	3	0	2	2	1	1	3	0	1
Arthrospira jenneri	2	0	0	1	0	1	2	1	1	2	0	1
Chroococcus disperses	2	1	1	1	0	1	3	1	1	2	1	1
Merismopedia elegans	2	1	0	2	1	1	2	1	1	1	0	0
Microcystis aeruginosa	1	0	1	3	1	1	1	0	0	1	0	0
Nostoc calcicola	1	0	1	1	1	1	1	1	1	1	0	0
Oscillatoria amphigranulata	1	0	1	2	1	1	1	0	1	2	1	1
Oscillatoria limosa	1	0	1	2	1	1	1	1	1	1	1	1
Phormidium cebenense	2	1	1	2	1	0	1	0	1	2	1	1
Scytonema millet	2	1	1	3	0	1	1	1	1	1	0	0
Spirulina major	1	0	1	1	1	1	1	0	0	2	1	1
Total	**17**	**5**	**10**	**21**	**7**	**11**	**16**	**7**	**9**	**18**	**5**	**7**

Conclusion

The present study on algal bloom dynamics in the semi-arid lakes of Chitradurga district—namely Gonur, Mallapura, Matadahatti Kere, and Chandravalli—demonstrates clear seasonal succession patterns and their ecological consequences. Across the three major algal groups, Bacillariophyceae, Chlorophyceae, and Cyanophyceae, numerical data reveal that pre-monsoon periods consistently recorded the highest diversity, with Mallapura showing peak richness (30 Bacillariophyceae, 31 Chlorophyceae, and 21 Cyanophyceae taxa), followed by Chandravalli (26, 27, and 18 taxa respectively). Gonur and Matadahatti displayed moderate diversity (22–27 taxa pre-monsoon), but were more vulnerable to monsoon dilution, with Matadahatti dropping to only 5 Bacillariophyceae and 7 Chlorophyceae taxa. Monsoon inflows reduced diversity across all lakes (Gonur 9, Mallapura 12, Chandravalli 9 Bacillariophyceae taxa), reflecting hydrological flushing and nutrient dilution. Post-monsoon recovery was moderate, with Gonur regaining 17 Bacillariophyceae and 21 Chlorophyceae taxa, while Mallapura and Chandravalli stabilized at lower levels (11–16 taxa). Cyanophyceae, the most ecologically significant group due to toxin production, showed strong pre-monsoon presence (*Microcystis aeruginosa* 3 counts in Mallapura, *Aphanocapsa biformis* 2–3 counts across lakes), declined during monsoon (5–7 taxa), and partially recovered post-monsoon (7–11 taxa). These seasonal shifts highlight that pre- and post-monsoon periods are peak bloom risk seasons, while monsoon temporarily suppresses bloom intensity. Ecologically, bloom dominance reduced sensitive diatoms (*Cymbella affinis*, *Pinnularia divergens*), homogenized phytoplankton communities, and increased risks of oxygen depletion and fish kills, directly impacting biodiversity and rural livelihoods. Environmentally, high cyanophyceae counts in Mallapura and Chandravalli indicate unsafe drinking water potential, with cyanotoxins such as microcystins and anatoxins posing public health hazards. Overall, the study underscores that Chitradurga's lakes are highly vulnerable to harmful algal blooms, with Mallapura and Chandravalli identified as bloom hotspots and Matadahatti most sensitive to monsoon dilution, necessitating urgent monitoring, nutrient management, and community awareness to safeguard freshwater ecosystems and socio-economic sustainability.

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