

Limnological Study of Lakes in Palghar, Pune and Thane Districts of Maharashtra, India: A Comparative Physico-Chemical Review

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www.jrasb.com || Vol. 4 No. 6 (2025): December Issue

Received: 17-12-2025

Revised: 21-12-2025

Accepted: 26-12-2025

ABSTRACT

Lentic ecosystems, such as Ponds, lakes and reservoirs are vital freshwater resources, facing increasing pressure from rapid urbanization, industrialization, and agricultural runoff in developing regions. This review synthesizes and comparatively analyzes the limnological and physicochemical characteristics of selected freshwater bodies across three distinct districts of the Maharashtra state in India: Palghar, Pune, and Thane. These districts represent a gradient of environmental settings from the coastal and relatively newer industrial region of Palghar, to the densely urbanized and industrial Thane, and the rapidly expanding urban-agricultural landscape of Pune. Key physicochemical parameters like pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), and nutrient levels Nitrates, Phosphates are examined. The comparative analysis reveals distinct water quality profiles for each district, often reflecting their dominant anthropogenic activities and geographical characteristics. Lakes in Thane and parts of Pune signs of eutrophication and organic pollution (high BOD, COD, and nutrients), particularly near urban centers. Conversely, lakes in Palghar, while showing seasonal fluctuations, often maintain comparatively better water quality, though localized contamination from agricultural runoff is noted.

This review underscores the urgent need for progress made in conservation and management efforts, identifying gaps in knowledge and areas requiring further research. By synthesizing existing studies, this review aims to enhance our understanding of India's freshwater ecosystems and support the development of effective strategies for their protection restoration, conservation and management strategies to safeguard these critical water resources for sustainable use.

Keywords- Lentic ecosystems, urbanization, industrialization, agricultural runoff, Palghar, Pune, Thane, anthropogenic, conservation.

I. INTRODUCTION

Freshwater ecosystems represent one of the most valuable yet vulnerable natural resources on Earth. Inland water bodies such as lakes, reservoirs, ponds, and wetlands perform essential ecological, hydrological, and

socio-economic functions, including regulation of the hydrological cycle, nutrient recycling, carbon sequestration, biodiversity conservation, and provision of water for domestic, agricultural, industrial, and recreational purposes (Wetzel, 2001; Mitsch and Gosselink, 2015). Among the scientific disciplines

devoted to understanding these systems, limnology plays a central role by integrating physical, chemical, geological, and biological perspectives to assess ecosystem structure, functioning, and responses to natural and anthropogenic pressures.

Limnology has evolved from descriptive studies of inland waters to a highly integrative science addressing global challenges such as eutrophication, climate change, biodiversity loss, and water scarcity (Dodds and Whiles, 2020). Parameters such as temperature, transparency, pH, dissolved oxygen, nutrients, organic matter, and biological productivity serve as critical indicators of ecosystem health and trophic status. Long-term limnological datasets are particularly valuable, as they allow the detection of gradual ecological shifts and the formulation of evidence-based water management strategies (Wetzel, 2001).

In developing countries like India, freshwater ecosystems are under mounting stress due to rapid population growth, urbanization, industrialization, and intensification of agriculture. India supports nearly 18% of the global human population but possesses only about 4% of the world's freshwater resources, making efficient and sustainable water management a national priority (CPCB, 2018). Lakes and reservoirs constitute an important component of India's freshwater infrastructure, acting as sources of drinking water, irrigation, fisheries, groundwater recharge, and flood moderation. However, these lentic systems are increasingly threatened by pollution, encroachment, siltation, invasive species, and hydrological alterations (Kumar *et al.*, 2017).

Lakes are delicate ecosystems that are highly susceptible to environmental degradation. To determine if water is suitable for critical applications such as drinking, irrigation, industrial use, or fishing, it is necessary to analyze its physico-chemical parameters. Furthermore, combining this physico-chemical data with biological characteristics allows researchers to accurately assess the water's trophic status and identify pollution impacts. According to Jadhav *et al.*, (2013), the health of these ecosystems is contingent upon favorable environmental factors—such as temperature and dissolved oxygen— as well as the abundance of food sources like a rich food supply composed of bacteria, plankton, and suspended detritus.

Raut *et al.*, (2013) says that Safe drinking water is a human birth right as much a birthright as clean air however much of the world's population does not have access to safe drinking water. Substances that affect odour, taste and colour may produce undesirable physiological responses to human beings, fishes and other animals and plants.

One of the most widespread and severe problems affecting Indian lakes is eutrophication, driven primarily by nutrient enrichment from domestic sewage, agricultural runoff, and industrial effluents. Elevated concentrations of nitrogen and phosphorus stimulate excessive algal growth, leading to reduced water clarity,

hypoxia, fish kills, and loss of biodiversity (Smith *et al.*, 1999; Carpenter *et al.*, 1998). Many urban and peri-urban lakes in India have transitioned from oligotrophic or mesotrophic states to eutrophic or hypereutrophic conditions within a few decades, reflecting the intensity of anthropogenic pressure and inadequate wastewater treatment infrastructure (Ramachandra *et al.*, 2014).

Maharashtra, one of India's most industrialized and urbanized states, presents a compelling case for regional limnological assessment. The state spans diverse physiographic zones, including the Western Ghats mountain range, the Deccan Plateau, and the Konkan coastal belt, each with distinct climatic, hydrological, and ecological characteristics. As a result, Maharashtra hosts a wide range of freshwater ecosystems, from high-altitude reservoirs and plateau lakes to coastal wetlands and urban ponds. Most lakes in the region are warm monomictic or monomictic, exhibiting summer thermal stratification followed by complete mixing during the monsoon and winter months (Zutshi and Khan, 1988). The districts of Palghar, Pune, and Thane are of particular interest due to their strategic location, rapid socio-economic development, and high dependence on surface water resources. Although geographically contiguous, these districts differ markedly in terms of topography, land use, degree of urbanization, and industrial intensity. Their freshwater ecosystems thus provide an opportunity to examine how varying anthropogenic pressures shape limnological characteristics across a regional gradient.

Lakes are inland water bodies with no direct exchange with an ocean and are a part of freshwater

ecosystem which are very useful to man. Lake ecosystems is made up of physical, chemical and biological properties hence provide an important habitat to study ecosystem dynamics. (Singh and Gupta, 2019), (Bhateria and Jain, 2016). Fresh water lakes and rivers are fragile ecosystems that face the problem of water pollution. Assessment of biological properties along with physico-chemical properties provides a clear idea about trophic status and quality of water bodies. In India, several studies have been done on lentic and lotic limnology (Mule *et al.*, 2019; Kakvipure and Yeragi, 2005; Gupte *et al.*, 2009 Raj *et al.*, 2016).

Palghar district, located in the Konkan coastal region, was carved out of Thane district in 2014 and is comparatively less urbanized. The district receives high annual rainfall, typically ranging between 2000 and 3000 mm, which significantly influences lake hydrology and water renewal rates (IMD, 2020). Lakes such as Sinchan, Vandri, and Shirgaon serve as important resources for irrigation, fisheries, and local domestic use. The dominant land-use activities in Palghar include agriculture, fishing, and small-scale industries, with relatively limited heavy industrial development. Limnological studies from this district generally report moderate organic loading, seasonal fluctuations in physicochemical parameters, and water quality that remains suitable for irrigation and, in some cases, aquaculture (Patil *et al.*, 2019; More and

Sawant, 2021). The perennial nature of many lakes and substantial monsoonal inflows contribute to a natural dilution effect, enhancing the system’s resilience to pollution. Nevertheless, increasing agricultural intensification and unplanned rural settlements pose emerging threats to water quality.

In contrast, Pune district represents a highland urban-agricultural landscape situated on the Deccan Plateau and the foothills of the Western Ghats. Pune is a major metropolitan city and an important center for information technology, manufacturing, education, and research. The district contains a mix of natural and man-made water bodies, including urban lakes (e.g., Pashan and Katraj) and large reservoirs such as Khadakwasla, which form part of the city’s drinking water supply system. Rapid urban expansion, encroachment on catchment areas, and the discharge of untreated or partially treated sewage have severely degraded several urban lakes in Pune (Bhide and Karve, 2017; Yardi *et al.*, 2019; Singh and Jadhav, 2021). Limnological investigations of Pashan and Katraj lakes have consistently reported high nutrient concentrations, low dissolved oxygen levels, high biochemical oxygen demand, and frequent algal blooms, indicative of hypereutrophic conditions (Joshi *et al.*, 2016; Kulkarni and Kher, 2018; Singh *et al.*, 2018). These conditions not only reduce ecological integrity but also limit the recreational and aesthetic value of urban lakes. Reservoirs such as Khadakwasla generally exhibit better water quality due to larger storage capacity and regulated inflows, yet localized impacts from agricultural runoff and urban effluents are evident, particularly during low-flow periods (Deshpande *et al.*, 2020).

Thane district, forming a major part of the Mumbai Metropolitan Region (MMR), exemplifies the extreme end of urban-industrial influence on freshwater ecosystems. The district hosts numerous small lakes or talaos within densely populated city limits, along with larger lakes in peri-urban and rural fringes. High population density, extensive industrial estates, and inadequate sewage treatment infrastructure have resulted in heavy nutrient loading, organic pollution, and contamination by toxic substances, including heavy metals (MPCB, 2019 and CPCB, 2018). Lakes such as Masunda Talao and Varhala Lake are subject to continuous inflow of domestic wastewater and urban runoff, leading to chronic ecological stress.

Several studies from Thane district have documented elevated concentrations of nutrients, reduced water transparency, frequent algal blooms, and accumulation of heavy metals such as lead, cadmium, and chromium in water and sediments (Gaikwad and Shinde, 2019; Pawar *et al.*, 2022). These findings raise concerns not only for aquatic biodiversity but also for public health, as many lakes are used for recreation, religious activities, and, in some cases, secondary water supply. The cumulative impact of urbanization and industrialization has rendered many Thane lakes highly degraded,

necessitating urgent restoration and management interventions.

Despite the abundance of individual limnological studies conducted across Palghar, Pune, and Thane districts, the existing literature remains largely fragmented and site-specific. There is a notable lack of integrated, comparative reviews that synthesize findings across districts to identify regional patterns, common stressors, and differential responses of lake ecosystems to anthropogenic pressure. Such comparative assessments are essential for understanding how geography, land use, and development trajectories influence limnological processes and water quality outcomes.

A consolidated review is particularly important in the context of policy frameworks such as the National Lake Conservation Plan (NLCP) and the National Mission for Clean Ganga, which emphasize evidence-based planning and region-specific management strategies (MoEFCC, 2017). By comparing lakes across coastal, plateau, and metropolitan settings, it becomes possible to distinguish natural variability from human-induced changes and to prioritize interventions accordingly.

Therefore, the present review aims to systematically compile and synthesize existing limnological studies from lakes in Palghar, Pune, and Thane districts of Maharashtra. The specific objectives are: (i) to summarize physicochemical and biological characteristics reported for lakes in the three districts; (ii) to conduct a comparative assessment of key water quality parameters and trophic status; (iii) to identify dominant natural and anthropogenic drivers of water quality degradation; and (iv) to propose region-specific conservation and management strategies to enhance the ecological sustainability of freshwater ecosystems in these rapidly developing regions. Through this synthesis, the review seeks to contribute to improved scientific understanding, informed policymaking, and sustainable freshwater resource management in Maharashtra and similar socio-ecological settings.

II. COMPARATIVE PHYSICO-CHEMICAL ANALYSIS OF LAKE WATER

The following section presents a comparative summary of key physicochemical parameters, highlighting the differences and similarities across the three districts. The data is aggregated from various studies conducted over different time periods and specific lakes within each district (e.g., Katraj, Pashan in Pune; Varhala in Thane; Sinchan, Vandri in Palghar) (APHA, 2005)

Temperature:

District	Seasonal Range (°C)	Primary Influencing Factors
Palghar	19 to 30	Seasonal air temperature, surface-to-volume ratio.

Pune	21 to 31	Seasonal air temperature, urban heat island effect (urban lakes).
Thane	26 to 33	Seasonal air temperature, high surface exposure in city lakes.

Comparative Insight: Water temperature in all three districts follows a typical seasonal pattern, being lowest in winter and highest in summer, which affects the rate of chemical reactions and Dissolved Oxygen (DO) solubility. Urban lakes in Pune and Thane may experience slightly higher mean temperatures due to the urban heat island effect and reduced shade compared to more rural Palghar lakes.

Hydrogen Ion Concentration (pH):

District	Typical pH Range	Interpretation
Palghar	7.32 to 7.89	Slightly alkaline, conducive to aquatic life.

Pune	7.4 to 9.3	Wide range; urban lakes often highly alkaline (pH > 8.5) due to high photosynthetic activity and sewage input.
Thane	7.1 to 8.5	Moderately alkaline, with seasonal peaks due to high biological activity (phytoplankton blooms).

Comparative Insight: Lakes in all three districts are generally alkaline (pH > 7.0). The highest pH values (up to 9.3) are often reported in the urban lakes of Pune (e.g., Pashan Lake), which is a clear indicator of intense diurnal photosynthetic activity from algal blooms, a classic sign of advanced eutrophication (Joshi *et al.*, 2016; Kulkarni and Kher, 2018).

Dissolved Oxygen (DO) and Oxygen Demand (BOD/COD):

Parameter	Palghar (mg/L)	Pune (mg/L)	Thane (mg/L)	Interpretation
DO	4.02 to 4.15	0.00 to 7.3	6.5 to 8.0	Thane and Palghar show moderate DO (often > 4mg/L), while Pune urban lakes frequently report anoxic conditions (0.0mg/L) due to high organic decay.
BOD	4.07 to 4.83	66 to 96	Not consistently reported (high)	Pune's urban lakes show <i>extremely</i> high BOD values, indicating severe organic pollution (e.g., untreated sewage).
COD	10 to 15.10	156 to 190	Not consistently reported (high)	Similar to BOD, COD is significantly elevated in Pune, reflecting high levels of both biologically degradable and non-biodegradable organic matter.

Comparative Insight: This is the most differentiating set of parameters. Pune's urban lakes exhibit catastrophic levels of organic pollution as evidenced by very high BOD and COD, coupled with periods of zero DO, making them highly stressed or dead ecosystems for most fish and sensitive aquatic life. Palghar lakes show moderate BOD/COD, suggesting lesser but still present organic contamination, likely from agricultural or domestic

sources. Thane lake data, where available, points to similar high pollution levels as Pune's urban lakes. The BOD/COD ratio can be used to infer the biodegradability of pollutants, but the absolute high values in Pune are alarming (Bhide and Karve, 2017; Gaikwad and Shinde, 2019).

Nutrients (Nitrate and Phosphate):

Parameter	Palghar (mg/L)	Pune (mg/L)	Thane (mg/L)	Interpretation
Nitrate NO ₃ ⁻)	Not consistently reported	0.55 to 0.75	0.12 to 0.42	Pune lakes show high NO ₃ ⁻ levels, likely due to a mix of sewage and agricultural runoff. Thane also shows moderate levels.
Phosphate (PO ₄ ³⁻)	Not consistently reported	0.022 to 0.024	Not consistently reported (elevated)	Phosphate, often the limiting nutrient, is high in urban lakes of Pune, driving eutrophication.

Comparative Insight: The consistently elevated nutrient levels (Nitrate and Phosphate) in Pune and Thane are directly responsible for the eutrophic or hypereutrophic status of their urban water bodies. These nutrients originate from untreated sewage, detergents, and fertilizer

runoff from the surrounding catchments. Eutrophication leads to reduced water clarity, DO depletion, and the proliferation of undesirable algal species (Ramachandra *et al.*, 2014).

Total Dissolved Solids (TDS) and Electrical Conductivity (EC)

Parameter	Palghar (Range)	Pune (Range)	Thane (Range)	Interpretation
TDS (mg/L)	Not consistently reported	410 to 639	Not consistently reported	Pune lakes have higher TDS, reflecting higher concentrations of dissolved inorganic salts, a result of municipal and industrial waste.
EC	391.9 to 438.2	660 to 680	Not consistently reported	Higher EC in Pune indicates a higher total ionic concentration, often correlated with pollution.

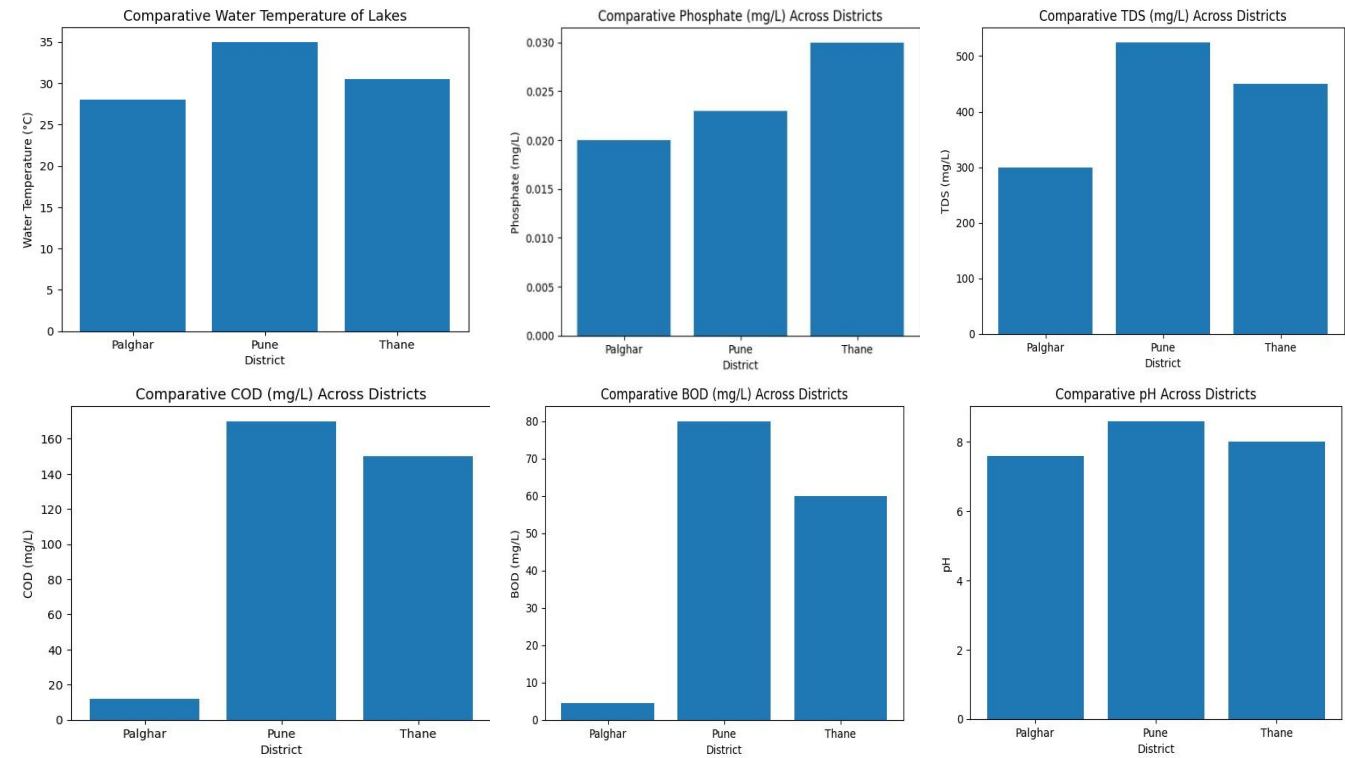
Comparative Insight: Pune's lakes exhibit significantly higher TDS and EC values compared to the available data for Palghar, indicating a greater accumulation of salts, minerals, and soluble pollutants. High TDS can impact

the taste of the water and limit its use for certain industrial and agricultural purposes.

Other Parameters (Hardness, Alkalinity, Chlorides):

Parameter	Palghar (mg/L)	Pune (mg/L)	Thane (mg/L)
Total Hardness	52 to 172	111 to 286	Up to 400 (Kharpudi Lake)
Total Alkalinity	134 to 240	112 to 366	Not consistently reported
Chlorides (Cl ⁻)	Not consistently reported	16 to 82.02	Not consistently reported

Comparative Insight: Hardness is high in all three districts, with Kharpudi Lake in Thane reporting a very high value of 400 mg/L, classifying it as very hard water. This is likely due to the geological substratum (basaltic rock) and the dissolution of Ca²⁺ and Mg²⁺ ions. Alkalinity is also high, particularly in Pune, reflecting the water's buffering capacity, which is essential but can also be influenced by sewage input. Chloride levels are moderate in some Pune lakes, but elevated Cl⁻ is generally considered an indicator of sewage contamination.



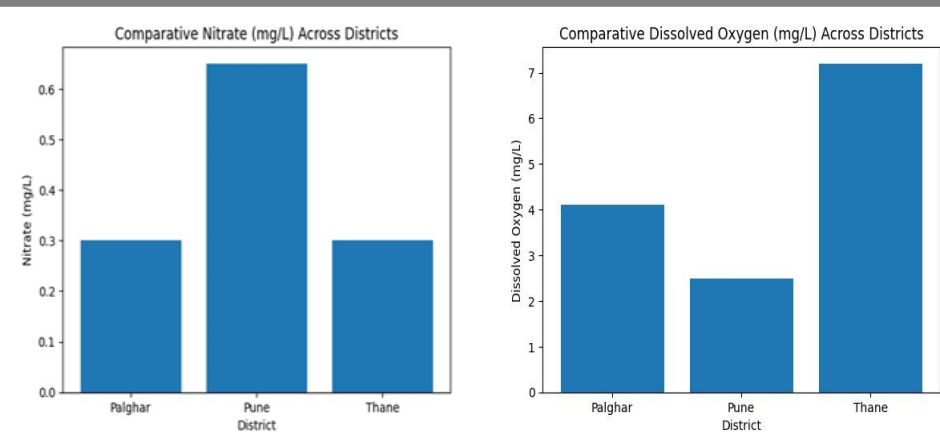


Fig. 1 Graphical Representation of Comparative Physicochemical Analysis of Lake Water

Trophic Status and Pollution Drivers:

The limnological data clearly points to a varying degree of degradation across the three districts, primarily driven by land use and population density (Joshi *et al.*, 2016)

Trophic Status Classification

Based on the highly elevated nutrient levels, low DO in hypolimnion, and high BOD/COD, the lakes can be broadly classified:

- Palghar (Village reservoirs): Predominantly Mesotrophic to Eutrophic, with manageable organic loads.
- Pune (Urban Lakes): Hypereutrophic, characterized by severe organic pollution, recurrent anoxia, and high pH peaks.
- Thane (City Lakes): Eutrophic to Hypereutrophic, with evidence of heavy metal contamination and advanced nutrient enrichment.

Primary Pollution Drivers:

District	Primary Drivers of Water Quality Deterioration
Palghar	Agricultural runoff (fertilizers/pesticides), seasonal domestic sewage
Pune	Untreated/Partially Treated Sewage Inflow (major factor in urban lakes), industrial effluent, urban runoff.
Thane	Industrial and Municipal Effluent (including heavy metals), high-density urban runoff, waste dumping.

The direct discharge of untreated sewage into urban water bodies in Pune and Thane remains the single most significant factor contributing to their poor water quality, leading to rampant eutrophication.

III. CONCLUSION AND RECOMMENDATION

The comparative limnological analysis of lakes in Palghar, Pune, and Thane districts reveals a critical

correlation between the level of urbanization and industrialization and the ecological health of the water bodies. Lakes in Palghar currently show better water quality, though seasonal pressures exist. Pune's urban lakes (Katraj, Pashan) are in a state of severe environmental distress, exhibiting characteristic features of hyper eutrophication and heavy organic loading (BOD and COD in the 100mg/L range). Thane's city lakes face similar nutrient loading issues, compounded by concerns over heavy metal contamination from surrounding industrial areas. The high variability in physicochemical parameters, especially DO, pH, and BOD/COD, points towards a highly unstable and stressed aquatic ecosystem across the urban centers of Pune and Thane.

IV. FUTURE MANAGEMENT AND CONSERVATION STRATEGIES

To reverse the trend of degradation and ensure the long-term sustainability of these vital resources, the following management strategies are recommended:

- Source Control (Pune and Thane): The immediate priority must be the complete diversion and treatment of municipal sewage. Construction and upgrade of Sewage Treatment Plants (STPs) with tertiary treatment capabilities to remove nutrients (Nitrogen and Phosphorus) are essential.
- Catchment Area Management (All Districts): Implementation of Best Management Practices (BMPs) in agricultural areas of Palghar and Pune to reduce fertilizer and pesticide runoff. Buffer zones creation around the lakes to filter pollutants and prevent direct surface runoff.
- Restoration Techniques (Pune and Thane): For highly polluted lakes, active restoration techniques such as biomanipulation (using the food web to control algal blooms), dredging (to remove nutrient-rich sediments), and aeration (to increase DO during anoxic periods) should be considered.
- Regulatory Enforcement (Thane): Stricter monitoring and enforcement of industrial effluent discharge standards, with a focus on heavy metals,

are necessary for the industrial zones of Thane.

- Public Awareness: Engaging local communities and stakeholders in monitoring and conservation efforts is crucial for the long-term protection of these resources.

In conclusion, the limnological status of lakes in Palghar, Pune, and Thane districts serves as a stark barometer of regional environmental health. While Palghar offers a glimpse of relatively healthier ecosystems, the hyper-stressed water bodies in Pune and Thane demand urgent, integrated, and science-based management interventions to restore their ecological function and secure their value as indispensable freshwater resources for Maharashtra.

ACKNOWLEDGMENT

The authors would like to thank the Principal of Vidyavardhini's, Annasaheb Vartak College of Arts, Kedarnath Malhotra College of Commerce, E. S. Andrades College of Science, Vasai Road (West)-401202, Dist.: Palghar, M.S., India as well as Research Guide Dr. Rahul Jadhav sir who provided assistance throughout the research for this publication.

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