

EVALUATION OF WATER QUALITY AND SUSTAINABLE MANAGEMENT STRATEGIES FOR VARTHUR LAKE, BENGALURU

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Abstract

Ecosystems are integral to life on Earth, and lakes play a pivotal role within them. Historically, lakes have served as vital resources for domestic and cultural activities. Varthur Lake, the second-largest lake in Bangalore, is a prime example of a waterbody under significant stress due to rapid urbanization. The development of industries, commercial complexes, residential areas, and apartments has encroached upon the lake's area, compromising its ecological integrity. The environmental degradation of Varthur Lake has been exacerbated by abrupt climatic changes, such as droughts and flash floods, coupled with the unchecked release of wastewater into its ecosystem. These factors have significantly deteriorated the lake's ecological health. To address this issue, water quality management has become essential, utilizing standardized tests to measure parameters such as biological oxygen demand (BOD), chemical oxygen demand (COD), pH, hardness, total solids, and dissolved oxygen. Alarming high levels of contamination have been recorded in surface and groundwater samples across the study area. Comparative analyses of water quality against World Health Organization (WHO) standards reveal that many samples fall below acceptable levels, highlighting the need for urgent intervention. The study emphasizes the importance of sustainable infrastructure development to mitigate waste dumping and the discharge of solid and liquid waste into the lake. Innovative approaches, such as the implementation of membrane bioreactors (MBRs), are proposed as viable solutions for sewage treatment. MBR technology integrates biological processes with permeable and semi-permeable membranes, effectively addressing wastewater management challenges in the study area. Furthermore, strategies for lake rejuvenation and recharge structures are critical for ensuring the sustainable and efficient utilization of lakes while preventing further degradation. These measures aim to restore Varthur Lake as a resilient ecological asset for the community.

Keywords: Water contaminations, Water quality, Chemical tests, impervious surface, Membrane bioreactor (MBR).

Introduction

Bangalore, historically celebrated as the "Land of Thousand Lakes" (V. Balasubramanian, IAS Retd., former Additional Chief Secretary, Govt. of Karnataka), once relied heavily on its lakes and

tanks for meeting the city's water demands. Constructed during the 16th century, these waterbodies served as essential sources for irrigation, drinking water, fishing, and other daily needs. However, the growing population and urban sprawl have placed unprecedented pressure on portable water resources, posing a significant challenge to sustainability.

Located in Bangalore South, Varthur Lake stands as the city's second-largest lake. According to the 1981 Census of India, the population of Varthur was 5,431, making it the largest town in the region at the time. Surrounded by small agricultural villages cultivating rice, ragi, fruits, and vegetables (Government of Karnataka, 1990), the lake once supported a thriving agrarian economy. However, pollution of Varthur Lake has intensified in recent years. Geological environments naturally contribute to some contamination, but anthropogenic activities have emerged as the primary contributors to the lake's degradation (Lubna Kouser et al., 2013). Elevated contamination levels now pose serious health risks to the local communities residing near the lake (Shwetmala et al., 2012).

The western banks of Varthur Lake are heavily urbanized, with numerous apartment complexes, industries, and residential areas discharging untreated effluents directly into the lake. The southern end of the lake connects to other waterbodies, including Bellandur Lake, which is among the most polluted lakes in Bangalore South. Effluent overflow from Bellandur further exacerbates the pollution levels in Varthur Lake, compounding the environmental crisis.

To assess the water quality of Varthur Lake, samples were collected from the lake itself as well as bore wells within a 500-meter radius during both pre-monsoon and post-monsoon seasons. These samples were tested for key parameters such as pH, hardness, biological oxygen demand (BOD), and chemical oxygen demand (COD). The effluent concentrations were recorded and compared against the Bureau of Indian Standards (BIS) to evaluate compliance with acceptable water quality norms. In total, 20 samples were analyzed from the same locations, providing valuable insights into the lake's ecological health and the extent of contamination.

2.1.1 Study Area

Varthur Lake is geographically situated between the latitudes **12°57'24.98"N** to **12°56'31.24"N** and longitudes **77°44'03.02"E** to **77°44'51.1"E** (Fig. 1). Spanning an area of approximately **148 square kilometers** in the southeastern region of Bangalore, the lake has a rich historical significance. It was constructed over a millennium ago by the Ganga dynasty to serve as a vital reservoir for drinking water and irrigation purposes (Durga Madhab Mahapatra et al., 2011).

However, the quality of water in Varthur Lake has undergone a significant decline over time. Rapid urbanization, unregulated wastewater discharge, and insufficient conservation measures have contributed to its current degraded state. This study aims to analyze the lake's water quality and evaluate the extent of environmental challenges it faces.

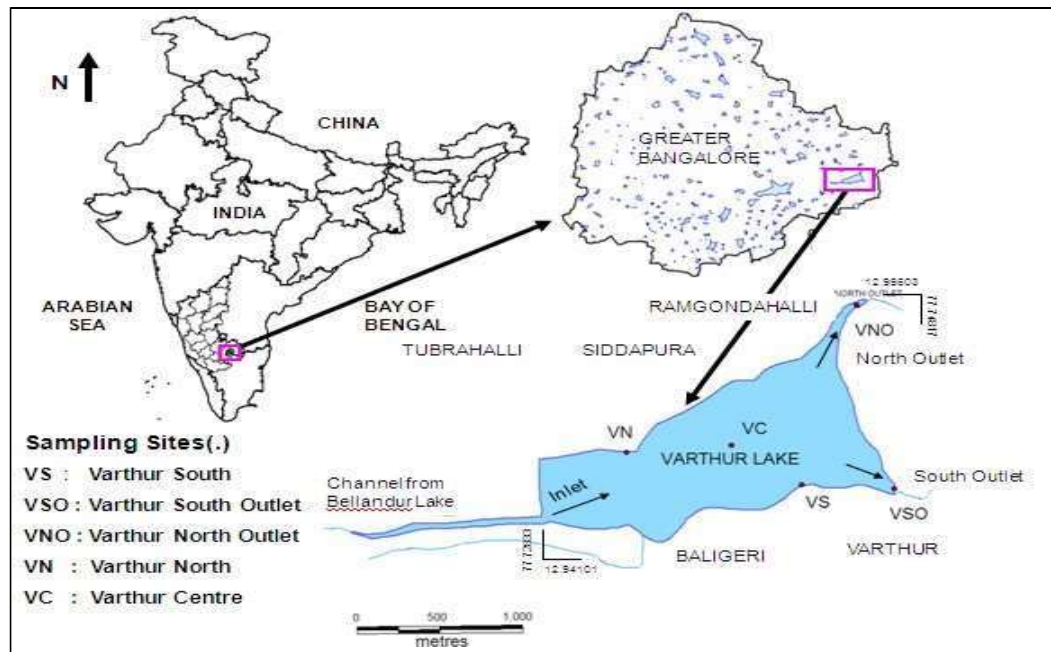


Figure1: The Location Map of the Varthur Lake

2.1.2 Data used and methodology:

2.1.3 Collection of Samples

Field investigations and sample collection were conducted to ensure a comprehensive representation across the entire study area (refer to Fig. 2 and Fig. 3). Sampling locations were strategically selected to provide an even spatial distribution and capture variability in water quality across the lake and surrounding areas. The latitude and longitude coordinates of each sample location are detailed in **Table 1** for precise geographical reference. This systematic approach facilitates a robust analysis of water quality parameters across the study area.

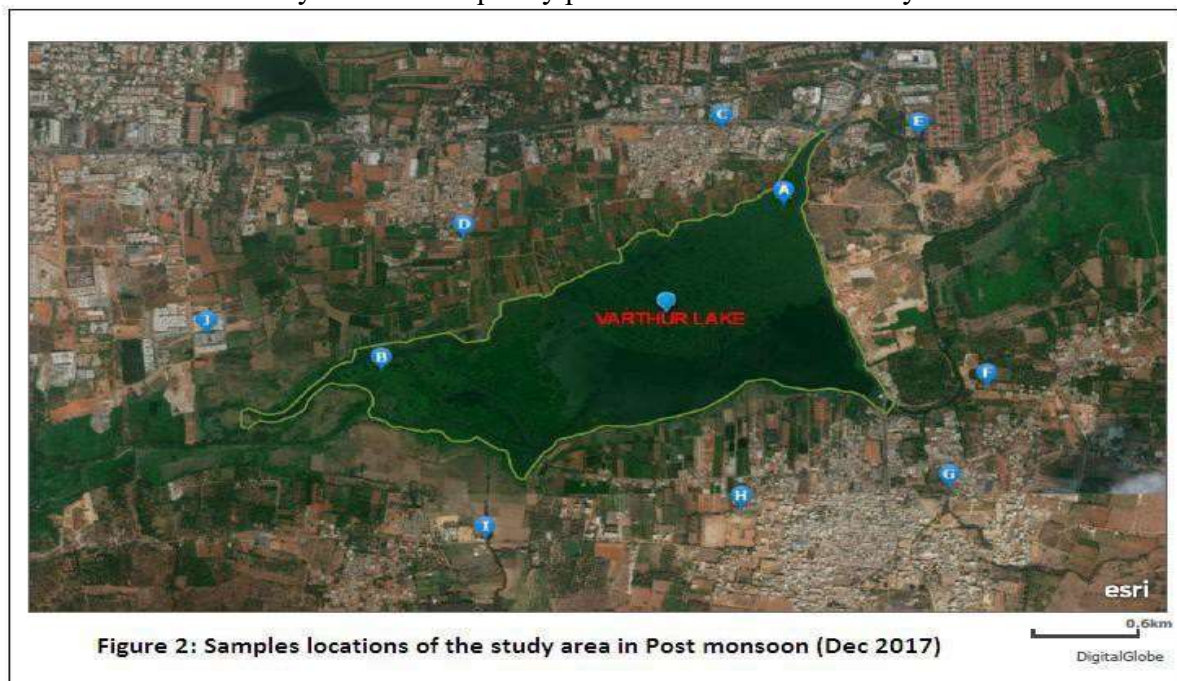


Figure 2: Samples locations of the study area in Post monsoon (Dec 2017)



Figure 3: Samples locations of the study area in Pre monsoon (April 2018)

Table 1: Location of the sample collected

Sample No	Latitude of Location	Longitude of Location	Distance from the lake banks	Sample collection
A	12.9533	77.7434	0	The sample was collected during Post Monsoon (Dec 2017) & Pre monsoon (Apr 2018)
B	12.9457	77.7276	0	
C	12.9567	77.7408	310-320	
D	12.9519	77.7317	500-510	
E	12.9568	77.7486	470-480	
F	12.9463	77.7508	450-465	
G	12.9415	77.7492	480-500	
H	12.9405	77.7414	495-510	
I	12.9390	77.7326	450-475	
J	12.9478	77.7228	480-500	

Several visual observations were documented during the field investigation, providing direct evidence of the lake's deteriorating condition. The water exhibited a **sandy coloration**, accompanied by a **foul odor** and the presence of **foam** on the surface (refer to Fig. 4). These indicators highlight the significant levels of contamination and organic pollution affecting Varthur Lake. Such observations underscore the urgent need for effective intervention and restoration measures.



Fig.4 photos of lake and water samples

2.1.4 Chemical Analysis and Objectives

Chemical measurements were conducted on both groundwater and surface water samples collected from the study area. These values were compared against standard permissible limits to assess the lake's current water quality. The findings also aimed to evaluate the level of rejuvenation required for Varthur Lake and identify suitable treatment methods for restoration.

2.1.5

2.1.6 Methodology

Physicochemical parameters, including **Biological Oxygen Demand (BOD)**, **Chemical Oxygen Demand (COD)**, **hardness**, and **pH**, were tested in the laboratory for the collected samples. Sampling locations were selected randomly, with proximity to Varthur Lake being a critical consideration. Standardized procedures were followed during sample collection, ensuring reliability and consistency.

For each sampling cycle, a **1:4 ratio** was maintained, with **one sample drawn directly from the lake** and **four samples collected from nearby groundwater sources (bore wells)**. This approach provided a balanced representation of both surface and subsurface water quality. Considering the large size of Varthur Lake, samples were taken strategically to ensure comprehensive analysis of its water characteristics.

2.1.7 Sampling Details

Samples were collected at both the **inlet** and **outlet** of Varthur Lake, along with groundwater samples from bore wells in the surrounding area. The collection was conducted during two distinct periods: **post-monsoon (December 2017)** and **pre-monsoon (April 2018)**. These timeframes were selected to capture seasonal variations in water quality. Chemical tests were performed on key parameters, and contamination levels were compared against standard permissible limits for water quality.

The analysis of physiochemical parameters for both monsoon periods provided critical insights into the lake's water quality. The results, as shown in **Table 2** and **Table 3**, include a comparison of the measured values against the standard values for unpolluted water bodies. The tables also reference relevant water quality guidelines, offering a clear benchmark for assessing the extent of contamination and identifying areas requiring intervention. These findings serve as a foundation for recommending effective rejuvenation and treatment strategies for Varthur Lake.

Table 2: Results for the samples collected in the month of Dec 2017												
Parameter	Unit	Location points of samples										BIS Limit for Drinking Water
		A	B	C	D	E	F	G	H	I	J	
pH	Moles/l	4.0	4.3	5.8	5.9	6.1	6.8	6.6	5.9	5.7	6.4	6.5-8.5
Hardness	mg/l	158	167	230	248	349	355	267	297	225	230	600
COD	mg/l	853	719	628	649	752	658	621	732	785	723	250
BOD	mg/l	150	138	122	109	91	134	106	111	98	135	30

Table 3: Results for the samples collected in the month of Apr 2018												
Parameter	Unit	Location points of samples										BIS Limit for Drinking Water
		A	B	C	D	E	F	G	H	I	J	
pH	Moles/l	5.3	5.8	6.2	5.9	6.7	6.6	6.9	6.2	6.1	6.8	6.5-8.5
Hardness	mg/l	109	129	206	214	299	319	231	252	202	211	600
COD	mg/l	359	372	497	435	439	397	462	523	660	510	250
BOD	mg/l	124	119	103	92	74	109	96	100	79	115	30

2.1.8 Water Temperature and its Impact

The temperature of water is a critical factor influencing biochemical reactions in aquatic organisms. An increase in water temperature accelerates chemical reactions, reduces the solubility of dissolved gases, and intensifies unpleasant tastes and odors in the water (Ramesh N & Krishnaiah S, 2014). These changes can disrupt the ecological balance of the lake and affect the overall aquatic ecosystem.

2.1.9 Contamination Levels

Chemical analyses reveal alarmingly high levels of contaminants in both the lake and the surrounding groundwater. When compared against standard parameters for drinking water quality, the results indicate significant pollution in these water sources (refer to Fig. 5). This underscores the urgent need for implementing corrective measures to mitigate contamination and protect both the aquatic ecosystem and public health.

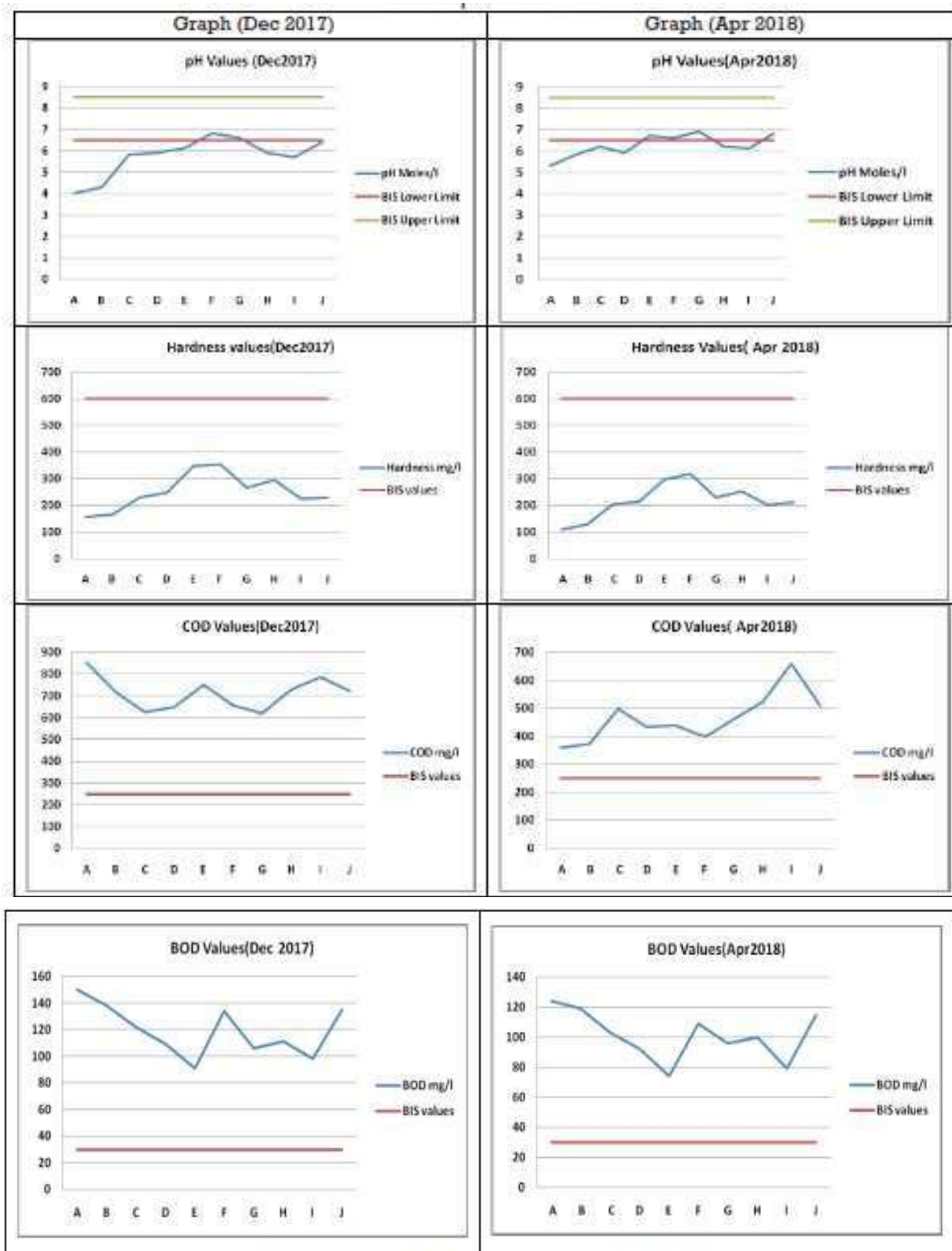


Fig 5: Comparative Graph for the chemical parameters tested during the post and pre monsoon season.

2.1.10 Results and Discussion

The results confirm that the water in Varthur Lake is unsuitable for drinking, as it does not meet Bureau of Indian Standards (BIS) criteria. Key observations from the analysis are as follows:

Biological Oxygen Demand (BOD)

The lake exhibits elevated BOD levels, exceeding the recommended values, primarily due to the presence of nitrates and phosphates. These nutrients encourage rapid growth of algae and aquatic weeds, which consume the limited dissolved oxygen (DO) available in the water. Consequently, DO levels are significantly reduced, adversely affecting aquatic life (Pattusamy V et al., 2013). The high BOD is also attributed to untreated organic waste entering the lake.

Chemical Oxygen Demand (COD)

Post-monsoon COD levels show marked differences compared to pre-monsoon, with particularly high values after rainfall. This indicates the intrusion of industrial waste containing substances like hydrogen peroxide (H_2O_2), which causes fluctuations in COD levels. The variability points to irregular waste management practices contributing to water quality deterioration.

Hardness

The hardness of the lake water is consistently classified as very hard, with values exceeding 180 mg/L. This high hardness indicates significant levels of calcium and magnesium, posing severe health risks such as cardiovascular diseases, cancer, diabetes, and neurological issues. It also has detrimental effects on aquatic ecosystems.

Transparency and Turbidity

The lake's transparency, a measure of turbidity and light penetration, ranges from 24 cm (summer) to 28 cm (monsoon). Lower transparency in summer is caused by suspended particles from decomposed organic debris, elevated temperatures, and reduced water flow (Durga Madhab Mahapatra et al., 2010). Increased turbidity hinders photosynthesis and degrades water quality.

Effluent Levels

Effluent levels in post-monsoon and pre-monsoon samples significantly exceed BIS standards. The deterioration is caused by untreated sewage, municipal waste, solid waste, and industrial effluents, which contribute to the lake's degradation. Contaminants from the lake also seep into the surrounding groundwater, reducing its quality and usability.

Conclusions

The study's findings unequivocally demonstrate that the BOD and COD levels in Varthur Lake far exceed BIS standards, confirming severe pollution. The lake's degradation has resulted in the loss of its direct and indirect benefits, leading to foul odor, health hazards, polluted groundwater, and a decline in aquatic biodiversity.

Proposed Remedial Measures:

1. Implementation of Membrane Bio-Reactor (MBR) Technology
 - MBR can be integrated into the lake's water treatment system to bring water quality up to required standards.
 - The system allows contaminated water containing bacteria, sludge, and suspended particles to pass through an aeration unit and membrane filters.
 - The filtered water is free from contaminants, making it suitable for domestic use, while sludge is removed separately.
2. Portable Activated Carbon Filters for Groundwater

- Groundwater drawn from bore wells can be treated using activated carbon filters to reduce BOD and COD levels.
 - Filtered water can then be safely used for domestic purposes, improving the overall quality of groundwater.
3. Lake Rejuvenation for Aesthetic and Ecological Benefits
- Develop the lake as a recreational park with an island at its center to facilitate natural aeration.
 - Enhanced aeration will boost DO levels, supporting aquatic life and reducing foul odors.
 - These measures will also enhance the lake's aesthetic value, improving the environmental and social atmosphere of the surrounding area.

By adopting these strategies, the ecological health of Varthur Lake and the surrounding groundwater can be significantly improved, ensuring sustainable use and reducing the impact on local residents.

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