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Original Article

Evaluating the Water Quality of Ulsoor Lake, Bengaluru, between 2012 and 2023

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Abstract *- Ulsoor Lake, one of Bengaluru's oldest and well-known lakes, has faced severe ecological pressure over the past few decades. This paper examines the water quality of Ulsoor Lake across a period of 12 years from 2012 to 2023. First, a literature review was conducted to identify the significance of the lake in its geographical context and the problems it faces. Then, secondary data from the Central Pollution Control Board were used to analyze the changes in certain physicochemical parameters across the period, namely: Temperature, D.O., pH, Conductivity, B.O.D., Nitrate + Nitrite, Fecal Coliform, and Total Coliform. The yearly mean values were computed and graphed against time to understand yearly changes in quality. The most alarming elements were the fecal and Total coliform concentrations, with the peak concentrations reaching several million MPM/100ml. The paper identifies alternative approaches to evaluating water quality and solutions that were used across several studies, such as wastewater treatment and constructed floating wetlands. Overall, this paper concludes that the water is unsuitable for domestic purposes, and the lake requires urgent restoration efforts due to risks of disease transmission.*

Keywords *- Contamination, Ecological restoration, Urban lakes, Wastewater management.*

1. Introduction

Water, as a resource, has several key roles in multiple contexts. In a biological context, water constitutes a significant proportion of blood, serving as a medium for the transportation of minerals and nutrients within the human body, and performing regulatory functions [1]. In an ecological context, it can play a crucial role in crop irrigation and the preservation of natural ecosystems [2]. Water, as a substance, possesses unique properties that can be leveraged in various fields, including physiology, engineering, and medicine [3]. Water can come from several sources, but the majority, around 97.4%, comes from the oceans. The total freshwater accounts for around 2.6% of all water supply, of which the majority is frozen. It is estimated that approximately 10% of the world's freshwater supply is available for human consumption [4]. Other sources of freshwater include lakes, rivers, and swamps [5].

Lakes are one of the major water bodies and have several important functions for society. Lakes provide aesthetic value to users. Lakes also play a vital role in sustaining local economies. For some, they serve as a source of food, such as fish. For others, they provide transportation, water for irrigation, and renewable electricity. Lakes are also beneficial in educational contexts, for they can be used to educate students on marine ecology [6]. Lakes also enhance the lifestyle of the local community by providing access to outdoor recreational facilities and boosting local economies through tourism. They also play a crucial role in the lifestyle and customs of certain indigenous peoples [7].

Several sources of water contamination include industrialization, agricultural practices using fertilizers, and natural causes resulting from weathering [8]. Indications of harmful effects on human health include 'neurological disorders, reproductive and endocrine disruptions.' [9]. Other side effects identified include cancer, along with skin and diarrheal infections that impact children significantly [10].

Ulsoor Lake, located in Bengaluru, sustains a local ecosystem and rich biodiversity. It offers several recreational opportunities, holds aesthetic value to the local community, and serves as training grounds for the Army's Corps of Engineers [11].

Ulsoor Lake has seen several developmental activities on its boundaries, which have led to several problems. Effluents and wastewater from surrounding developments have led to excessive algal growth, and water near sewage channels has been described as 'hyper eutrophic'. In contrast, the lake water is described as 'mesotrophic' [12]. Industrialization and rapid population growth in the city have contributed to heavy metal pollution in the lake [13]. Ulsoor Lake water is also not suitable for consumption purposes due to the presence of particulate matter and microorganisms [14].

This study addresses the need to analyze the water quality of Ulsoor Lake in Bengaluru. This will be conducted through secondary data from 2012 to 2023, published by the Central Pollution Control Board, to determine whether the

water of the lake is suitable for domestic purposes. (Temperature, D.O., pH, Conductivity, B.O.D., Nitrate + Nitrite, Fecal Coliform, and Total Coliform). Lastly, the trend will be analyzed.

2. Methodology

The water quality of Ulsoor Lake, Bengaluru, India, was evaluated using secondary data collected from the Central Pollution Control Board website (https://cpcb.nic.in/nwmp-data/). The following parameters were selected: Temperature (ºC), D.O. (mg/l), pH, Conductivity (µmhos/cm), B.O.D. (mg/l), Nitrate + Nitrite (mg/l), Fecal Coliform (MPN/100ml), and Total Coliform (MPN/100ml).

The yearly mean values were calculated, then compiled, and a graph was plotted for each parameter, with the year on the x-axis and the parameter on the y-axis.

2.1. The Water Quality Parameters Under Study, with their Permissible Range

1. Temperature: It is a measure of the average kinetic energy of particles in a substance. In water, it determines what biological organisms are present and what chemical reactions occur due to each organism having an optimum temperature [15].
2. Dissolved Oxygen (DO): It is a measure of how much gaseous oxygen is dissolved in water. It is an indicator of a water body's ability to sustain aquatic life, specifically the processes of respiration and decomposition that organisms carry out [16].
3. pH: It is a measure of the concentration of H^+ ions of a substance. Fluctuations in pH can lead to disruptions in the local ecosystem. Changes in pH also cause changes in the amount of dissolved oxygen, impacting aquatic life. Drinking water that is too acidic or alkaline can cause detrimental problems to human health [17].
4. Conductivity: Water can conduct electricity due to the presence of dissolved salts or ions. Typically, a water body has a baseline conductivity value that can be compared with newer readings to identify possible emission of substances into the water body [18].
5. Biochemical Oxygen Demand (BOD): It is the amount of oxygen aquatic aerobic microorganisms require to decompose organic matter. Sewage that is discharged into water with a high biochemical oxygen demand can cause a reduction in the concentration of oxygen [19].
6. Nitrate + Nitrite: It is the concentration of nitrogen-based compounds in water. Nitrogen compounds, when in excess, can have impacts on human health and the local ecosystem through eutrophication [20]
7. Fecal Coliform: It is the concentration of intestinal-originating, gram-negative bacteria that can be found in water. Certain strains of fecal coliform bacteria have been associated with waterborne diseases [21].
8. Total coliform is a broad group of bacterial organisms in the soil and vegetation near aquatic environments. Similar to fecal coliform, it is necessary to study total coliform to understand water quality, due to the possibility of waterborne diseases spreading.

2.2. Site Selection

Ulsoor Lake, also known as Halasuru Lake, is one of the most prominent lakes in the city of Bengaluru, Karnataka, India (12.9832° N, 77.6200° E). The lake spans 50 hectares and contains several islands within it. The lake itself has seen vast residential and commercial development along its boundaries. The primary inflows include rainfall and stormwater drains [14], [22]. It is located in the historic neighborhood of Halasuru, and next to the prominent neighborhood of Shivajinagar, near Mahatma Gandhi Road. This study utilizes 12 years of data from one station on the lake established by the Central Pollution Control Board. Namely, "ULSOOR LAKE TRAINING CENTRE OF FISH BREEDING" [23]. The lake is popular among visitors for its several recreational activities: kayaking, nature walks, and photography. Some commonly seen bird species at the lake include kingfishers, swans, storks, and herons. It is also home to several plant species such as banyan, peepal, and acacia trees, along with water lilies and lotus flowers.

Fig. 1 Ulsoor Lake [24]

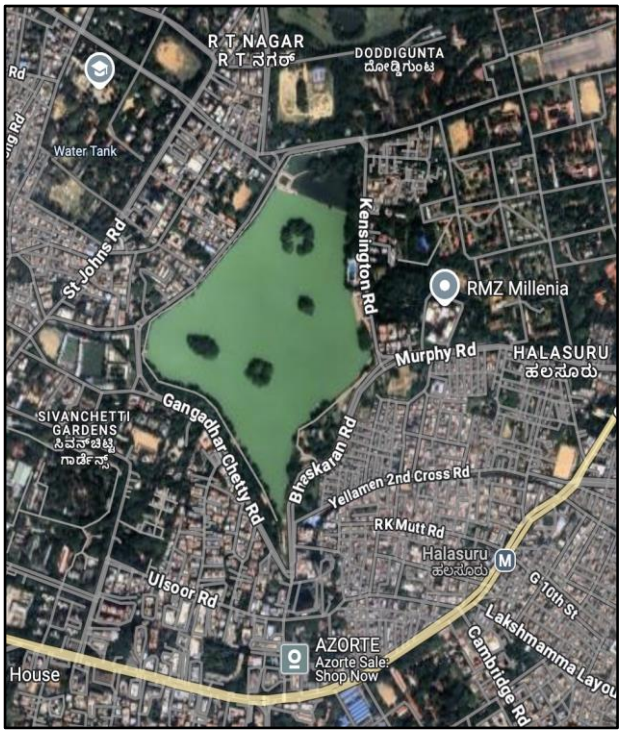

Fig. 2 Bird's eye view of Ulsoor Lake on Google Maps

3. Results & Discussion

Table 1. Annual mean data for water quality parameters for Ulsoor Lake from 2012 to 2023 [23]

	Parameters							
Year	Temperature ºC	D.O. (mg/l)	pH	Conductivity (µmhos/cm)	B.O.D. (mg/l)	Nitrate+ Nitrite (mg/l)	Fecal Coliform (MPN/100ml)	Total Coliform (MPN/100ml)
2012	29	8.1	7.8	506	13.8	17.36	1000	885
2013	29.2	6.5	8.4	504	18.9	7.6	4	1147
2014	28.5	7.2	8.4	339	10.7	2.3	293	1320
2015	24.5	7.5	8.3	833	9.5	4.5	6500271	17400271
2016	28	7.35	7.75	480.5	5.5	1.85	127000	207500
2017	32	7	8.35	538	5.5	1.275	39665	271545
2018	28.8	6.45	7.7	423.5	4.5	1.8	110055	860460
2019	26	5.4	7.8	635.5	39	9.315	39815	272700
2020	26	5.95	8.15	398	31.5	2.405	17470	122700
2021	25	4.4	7.65	411.5	20.5	1.335	246150	1212000
2022	25	3.7	8.3	327	10.7	1	47230	272700
2023	27.5	3.5	8.05	369.5	7.5	3.75	76650	817500

Table 2. Permissible Range for Drinking Water as per WHO & CPCB Standards

Parameter	Permissible Range
Temperature	< 25 ºC
Dissolved Oxygen (D.O.)	> 5 mg/L
pH	6.5 - 8.5
Conductivity	50 - 1500 µmhos/cm
Biochemical Oxygen Demand (BOD)	< 3 mg/L
Nitrate + Nitrite	≤ 1 – 10 mg/L
Fecal Coliform	< 2500 MPN/100ml
Total Coliform	< 5000 MPN/100ml

3.1. Temperature

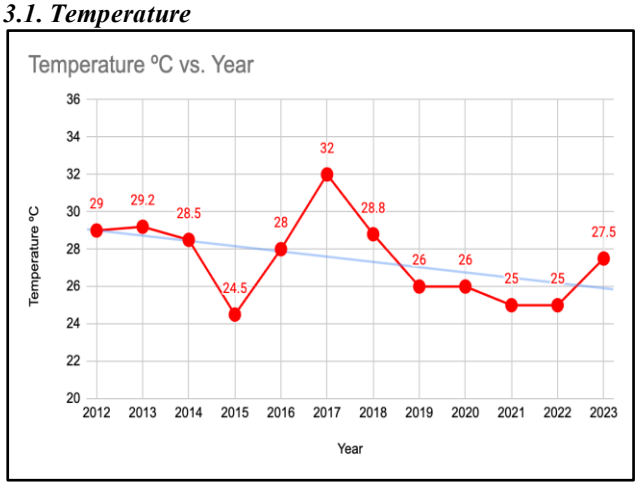

Fig. 3 Yearly temperature readings of Ulsoor Lake from 2012 to 2023

As shown in Table 1, the recorded water temperatures between 2015 and 2022 frequently exceeded the permissible limit of <25ºC (Table 2). A notable spike occurred in 2017, with temperatures reaching 32ºC. The only year with compliant temperature was 2015 (24.5ºC), while 2021 and 2022 touched the upper threshold at exactly 25ºC. Despite a general downward trend illustrated in Figure 3, sustained high temperatures remain a concern. At higher temperatures, the amount of dissolved oxygen can decrease, and certain compounds become more toxic [25]. Treating water before it is discharged into the lake, as seen in one study using phosphorus elimination plants, can dilute water with high nutrient content, consequently reducing stratification effects in the lake, allowing an even distribution of heat [26].

3.2. Dissolved Oxygen (D.O)

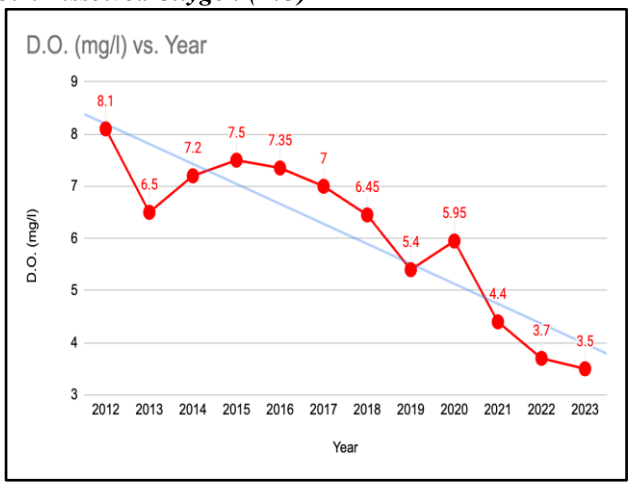

Fig. 4 Yearly Dissolved Oxygen readings of Ulsoor Lake from 2012 to 2023

DO is a key indicator of a water body's ability to sustain aquatic life, supporting essential processes such as respiration and decomposition [16]. WHO guidelines recommend a minimum DO concentration of 5 mg/L. As illustrated in Figure 4, DO levels remained above this threshold until 2020, after which a noticeable decline occurred. The overall trend indicates a gradual decrease in DO across the observed period. Post-2020 values fall below the critical limit, potentially leading to hypoxic conditions harmful to aquatic organisms, particularly fish. Low DO levels can also signal increased organic pollution or elevated temperatures. To mitigate these impacts, measures such as mechanical aeration, reduction of nutrient inflow, and control of invasive aquatic vegetation have been recommended to restore DO concentrations [27]. Continuous monitoring is essential to maintain DO within ecologically safe margins.

3.3. pH

pH indicates the concentration of hydrogen ions in water and directly affects aquatic life and water chemistry. According to the WHO, the acceptable pH range for drinking water is 6.5 to 8.5. As illustrated in Figure 5, the lake's pH over the past 12 years ranged from 7.65 to 8.4, well within the WHO permissible range, but consistently on the alkaline side. A slight decreasing trend is observed, suggesting a gradual movement toward neutrality. The mild alkalinity may be due to ammonification or inputs rich in carbonates [28]. Shifts in pH influence dissolved oxygen levels and the solubility of metals, affecting aquatic health and water quality. If pH falls below the permissible range, toxic metals may leach into the water [29]. To maintain optimal pH, it is essential to manage discharges of untreated sewage and carbonate-rich effluents and, when necessary, adjust pH through treatment processes.

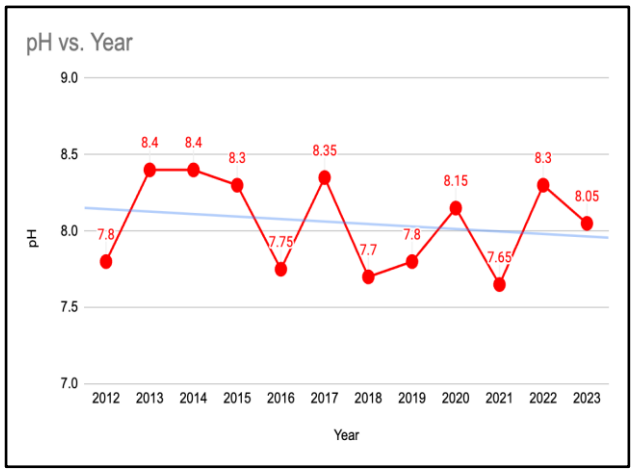

Fig. 5 Yearly pH readings of Ulsoor Lake from 2012 to 2023

3.4. Conductivity

Conductivity represents the ability of water to conduct electrical current, which is directly related to the concentration of dissolved ions such as chlorides, sulfates, nitrates, and other salts [18]. It serves as a useful indicator for assessing the ionic content of water and detecting potential contamination from agricultural runoff, industrial discharge, or sewage. According to WHO guidelines, the acceptable conductivity range for drinking water is 50–1500 µmhos/cm.

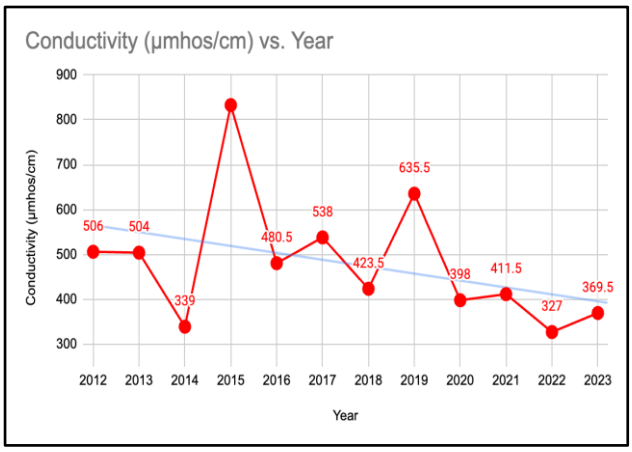

Fig. 6 Yearly Conductivity readings of Ulsoor Lake from 2012 to 2023

The data shows that the lake's conductivity values have consistently remained within this permissible range throughout the 12 years. A general declining trend is observed, suggesting a possible reduction in ion concentration over time.

This could be attributed to improved waste management practices, reduced discharge of untreated effluents, or natural dilution during high rainfall periods. Stable or decreasing conductivity levels typically reflect good water quality; sudden changes could signal new pollutant inputs or ecological shifts. Continued monitoring is essential to ensure the lake remains within safe conductivity levels and to trace any unusual deviations in ionic content.

3.5. Biochemical Oxygen Demand (B.O.D)

BOD is the amount of oxygen required by aquatic aerobic microorganisms to decompose organic matter. Sewage that is discharged into water with a high biochemical oxygen demand can cause a reduction in the concentration of oxygen [19]. The permissible limit for BOD in drinking water is < 3 mg/L.

The data shows that the BOD of the lake is generally higher than the permissible range. From 2016 to 2018, however, the BOD was close to the permissible limit. There was a large spike in BOD from 2018 to 2019 at 39 mg/L/, followed by a steep reduction to 7.5 mg/l in 2023, indicating an alarmingly high concentration of microorganisms in the lake that year.

This can reduce oxygen availability for aquatic life. The overall trend is variable between extremely high and near-permissible concentrations. The lake would benefit from improved sewage treatment, restricted inflows, and the establishment of buffer zones. Furthermore, chemical methods, such as coagulation, and biological methods, such as biodiscs, reduce BOD [30].

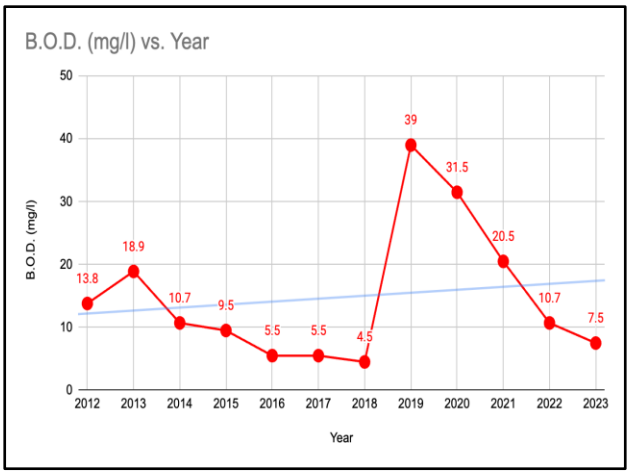

Fig. 7 Yearly Biochemical Oxygen Demand readings of Ulsoor Lake from 2012 to 2023

3.6. Nitrate+Nitrite

Nitrate + Nitrite is the concentration of nitrogen-based compounds in water. Nitrogen compounds, when in excess, can have impacts on human health and the local ecosystem through eutrophication [20]. The permissible limit for Nitrate+Nitrite in drinking water is between 1 and 10 mg/l. The data shows that in general, the BOD of the lake is within the permissible range, except for the year 2012. There is also a general declining trend in the concentration across the period.

The years 2012 and 2019 saw a high concentration of nitrogen compounds in the lake. Generally, this can be attributed to an increase in agricultural runoff with the overuse of fertilizers in agriculture [31]. This can contribute to eutrophication through algal blooms, consequently reducing the availability of oxygen for aquatic wildlife, along with other harmful conditions like methemoglobinemia [32]. One study found that forest wetlands were a suitable solution to naturally improve water quality through the absorption of these nutrients [33].

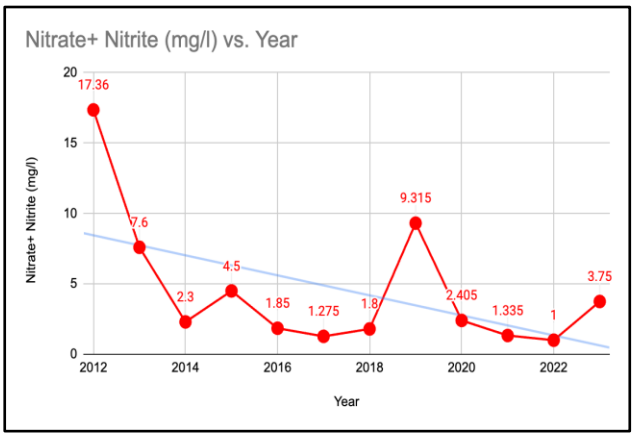

Fig. 8 Yearly Nitrate + Nitrite readings of Ulsoor Lake from 2012 to 2023

3.7. Fecal Coliform

Fecal Coliform bacteria are a type of intestinal-originating, gram-negative bacteria that can be found in water. They generally pertain to fecal contamination from animals. The permissible range for fecal coliform is 2500 MPN/100ml. From 2012 to 2014, the concentration of fecal coliform remained within the permissible range. However, in 2015, there was a surge in the concentration to almost 6.5 million MPN/100ml, followed by a reduction. Despite the reduction, the concentration remained above the permissible range. Possible causes of fecal coliform contamination in water include septic tanks with leakages, sewage overflows, industries, and animal waste [34]-[35].

Moreover, certain strains can lead to waterborne diseases, and illnesses such as diarrhea, urinary tract infections, dysentery, nausea, vomiting [8], [36]-[38] Some methods to remove include chlorine disinfection, aeration, activated sludge plants, or even through eco-friendly methods like the use of bioretention cells [39]-[41].

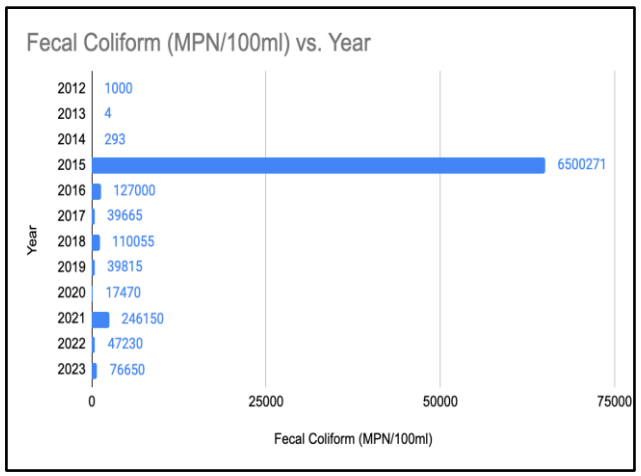

Fig. 9 Yearly Fecal Coliform readings of Ulsoor Lake from 2012 to 2023

3.8. Total Coliform

Total coliform is a broad group of bacterial organisms in the soil and vegetation near aquatic environments. Moreover, some strains of total coliform can have stronger resistance to disinfectants than strains of fecal coliform, like E. *coli*. [42]. The permissible limit for total coliform bacteria is < 5000 MPN/100ml. Analogous to the data for fecal coliform, the levels of total coliform were within the permissible range from 2012 to 2014.

However, in 2015, there was a surge in the concentration to almost 17.4 million MPN/100ml, followed by a sharp reduction. Nonetheless, the concentration remained above the permissible range. Total coliform bacteria may not reveal the presence of fecal coliform bacteria in water [43]. Stormwater runoff, the number of birds, the trophic level of the lake, and the size of the lake are some of the factors that can indicate total coliform presence [43]-[44]. Total coliform bacteria themselves may not induce illnesses. Meanwhile, they may be indicative of the possibility of more harmful strains of bacteria in the water [45]-[46]. Total coliform concentrations can be reduced through effective stormwater treatment, management, and nutrient reduction. Natural solutions can include constructed wetlands [47].

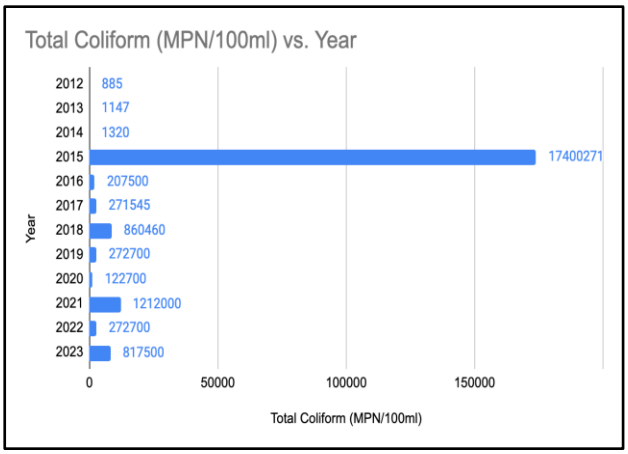

Fig. 10 Yearly Total Coliform readings of Ulsoor Lake from 2012 to 2023

4. Conclusion

This study assesses the water quality of Ulsoor Lake, Bengaluru, India, through selected parameters from 2012 to 2023 using secondary data from the Central Pollution Control Board of the Government of India. The data shows a decline in the lake's water quality, deeming it unsuitable for domestic usage. Although the pH, Conductivity, and Nitrate + Nitrite levels are within the permissible range, other factors like B.O.D. and Dissolved Oxygen are not within the permissible range. The most concerning factor appears to be the concentration of Fecal and Total Coliforms. The permissible range for these parameters is < 2500 and < 5000 MPN/100ml, respectively, and they each saw their peak concentrations in the year 2015, with the concentrations reaching several million MPN/100ml. Although there was a decline, the concentrations consistently remained above the permissible range for both parameters. As seen through exploring earlier studies, high concentrations of coliform bacteria pose a major health risk to the neighboring communities due to the possibility of waterborne diseases spreading amongst the community. The most common way to improve the water quality across all parameters of the lake is to treat stormwater before allowing it to flow into the lake. Moreover, constructed wetlands can also be another viable, eco-friendly solution to this problem.

This study has its limitations. The secondary data used does not reflect the water quality at multiple points along the lake and at multiple depths. Furthermore, the data does not reflect seasonal changes across the lake, where a lot of variability in the concentration of specific parameters can be seen, especially in the pre- and post-monsoon time frames. Further studies may utilize on-site sensors or sample collections to get real-time water quality data along multiple locations around the lakeshore and other areas inside the lake; this may improve the overall accuracy. Apart from that, it may be beneficial to collect data readings continuously and regularly across a fixed time frame to mitigate variations caused by seasonality. More parameters could also be measured, such as heavy metal concentrations, Chemical Oxygen Demand (COD), turbidity, and total dissolved solids.

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