Lake Health Index

Contents

Acknowledgements

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We are grateful to the countless volunteers, organizations, and institutions, such as the Foundation for Environmental Monitoring (FFEM), for their unwavering efforts in monitoring water quality, restoring habitats, and implementing conservation measures in lakes and biomes. Your selfless contributions, through citizen science programs, ecological restoration projects, and community engagement activities, have had a tangible impact in protecting and preserving these fragile ecosystems.

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Hari Prasad H.K and Team
Friends of lakes

1. Introduction

The history of Bangalore lakes dates back several centuries, with the region originally known for its numerous natural lakes, which were an integral part of the city's landscape and culture. These lakes were primarily rainwater harvesting tanks and played a crucial role in meeting the water needs of the local communities for drinking, agriculture, and other domestic purposes.

Water pollution, lake drying, and urban flooding are a few of the more obvious issues Bangalore's lakes face. We have achieved only modest visible progress in resolving these issues, despite substantial effort and financial investment from both the public and commercial sectors. However, the lack of advancement is not the result of a lack of sincere efforts. Stakeholders may occasionally simply disagree on what needs to be done. They disagree for a variety of reasons: differing values and differing facts. Urbanization has reduced the direct reliance on lakes for foraging, fishing, washing, and other uses. Lakes are a source of connection for urban middle- and upper-classes primarily due to their aesthetic, cultural, and conservation values. Residents use lakes for morning walks, bird watching, and other leisure activities. Lakes feature walking pathways and parks. Lakes are prized by conservationists for their biodiversity. People who live close to lakes appreciate their contribution to groundwater recharging. Lakes are used by some societies for cultural and religious rituals like idol immersions. The addition of effluents from urbanized Bangalore city has changed the characteristics of the Lakes from being a natural ecological hotspot to an artificial reservoir of domestic sewage and industrial effluents [Chandrashekar, 2003]. Diverse solutions, including sewage treatment facilities, floating islands, and aerators, are being implemented in various lakes to alleviate lake pollution. We lack evidence, though, about the best ways to address the city's lakes. Despite the potential for these solutions to be scaled up throughout India, there are no distinct design principles.

Setting democratic lake management objectives is possible with the help of participatory lake visioning. By working together, the public, civil society, academics, and the government may come to an agreement and resolve lake concerns. To analyze the water quality features, investigation of physico-chemical parameters is base. According to IPCC (2007), water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change. Although it is incredibly impressive that Bengaluru residents have taken proactive measures to revitalize lakes, there is still a long way to go. The government must do more to guarantee that citizen initiatives have access to the resources they need to complete their projects.

The present study focuses on driving lake health into the conscience of the citizens and the stakeholders using data driven citizen program that will engage them directly by giving them the tools required to make the observations (pH, TDS, P, N etc.) with final goal being the creation of a tool or a portal which anyone can use to gain knowledge of the lake surrounding them and give guidance on the steps necessary for maintaining sustainability.

2. Background

2.1. BANGALORE CITY AND ITS RELATION WITH LAKES

Bangalore, the capital city of Karnataka, is home to many lakes that serve as crucial sources of water for the city's residents, agriculture, and industries. However, rapid urbanization and industrialization have severely impacted the water quality of these lakes, leading to increased pollution levels, declining biodiversity, and the spread of waterborne diseases. The main pollutants in Bangalore's lakes include untreated sewage, industrial effluents, and solid waste, which are dumped directly into the water bodies. These pollutants lead to high levels of nutrients, algae blooms, and depletion of dissolved oxygen, causing eutrophication and water quality degradation. The government and various NGOs have taken initiatives to clean up the lakes and improve their water quality, including setting up sewage treatment plants, introducing eco-friendly measures, and undertaking lake rejuvenation projects. Despite these efforts, the water quality of many Bangalore lakes still remains a matter of concern, highlighting the need for continued efforts towards their restoration and conservation.

2.2. HISTORY OF BANGALORE LAKES

The origin of many Bangalore lakes can be traced to the era of the Kempegowda dynasty, who founded the city in the 16th century. They constructed several lakes, also known as tanks, by building bunds (earthen dams) across the natural valleys to store rainwater and regulate its flow. These tanks were interconnected through channels and served as a network of water bodies, providing water to different parts of the city and facilitating irrigation for agriculture.

During British colonial rule in the 19th century, the city witnessed rapid urbanization and industrialization, which led to the construction of more tanks and reservoirs to meet the increasing water demands. Many of these lakes were built by the British administration as a source of water supply for the growing city's needs. For instance, the Hesaraghatta Lake, located on the outskirts of Bangalore, was built in the late 19th century as a source of drinking water for the city.

However, with rapid urbanization and population growth in the 20th century, the once-pristine lakes of Bangalore started facing significant challenges. Unplanned urban expansion, encroachments, sewage discharge, industrial pollution, and solid waste dumping gradually degraded the water quality of these lakes, leading to severe pollution and environmental degradation.

2.3 AWARENESS

In recent years, there has been a growing awareness about the need to protect and restore Bangalore's lakes. Several lake rejuvenation and conservation initiatives have been undertaken by the government, non-governmental organizations (NGOs), and citizen groups to clean up the lakes, restore their water quality, and conserve their biodiversity. These efforts include lake desilting, solid waste management, sewage treatment, lake beautification, and community engagement in lake conservation activities.

While significant progress has been made in some cases, the challenges of restoring the water quality of Bangalore lakes remain complex and multifaceted. Continued efforts are needed to address the issues of pollution, encroachment, and urbanization to ensure the sustainable management and conservation of Bangalore's lakes for the benefit of present and future generations.

2.4. STAKEHOLDER LAKES

The lakes were selected to set the precedence of the methodology and to verify working principles of the application. The lakes were chosen based on the geographical location as well as the differences in lake surroundings, which were crucial in diversifying the data obtained. The lake group and stakeholders support played a major role with which the entire project, especially the collection of lake health data could function optimally.

Halasuru (Ulsoor) lake

One of Bangalore's largest lakes, Ulsoor or Halasuru Lake, is located on the city's eastern outskirts. It spans 50 hectares (123.6 acres) and includes multiple islets. Despite the fact that the lake dates back to Kempegowdas' period, the current lake was created by Lewin Bentham Bowring, the then-Commissioner of Bangalore. The Madras Engineer Group controls a portion of the lake, while the Bruhat Bengaluru Mahanagara Palike (BBMP) controls the remainder.

The water flowing into the lake is mostly municipal/residential.

Doddabommasandra lake

Doddabommasandra lake, which spans 124 acres along the Hebbal valley in northern Bengaluru, is unique as defense PSU Bharat Electronics Limited (BEL) has erected a 10 MLD sewage treatment facility (STP) to pump tertiary treated water into it since 2018.

The water coming into the lake is mostly municipal/residential and also from a few small-scale industries that generate waste water.

The lake in its current form is critical for preserving the region's groundwater table, which includes areas of Vidyaranyapura, Govindayyanapalya, Doddabommasandra, and Thindlu.

Shivapura lake

This lake, located in the Peenya Industrial Area, is plagued by regular waste dump issues, as well as untreated discharge of industrial effluent and sewage entry points from the slum. Local residents complain that small-scale enterprises routinely dump industrial trash and garbage.

The water coming into the lake is mostly from industries that surround the lake and also municipal/residential from the surrounding slum area.

Despite the rapid contamination, locals continue to use the lake's water for washing clothes and cattle, and some surrounding farms let their livestock to graze near the lake.

3. Objective of the study

- To understand the seasonal variation in lake health parameters.
- Understanding feasibility of aid from citizens and stakeholders for acquiring the necessary data for analysis of lake health.
- To develop a dynamic application to be used by citizens to have a holistic education on lake health and further the mitigation of pollution.

4. Scope

Knowledge about lake systems, lake water health and its mitigation measures can be obtained by citizens who do not have biology and chemistry background, leading to greater awareness about the surroundings which would lead to further changes and improvements to existing systems.

Diverse solutions, including sewage treatment facilities, floating islands, and aerators, are being implemented in various lakes to alleviate lake pollution. Although we lack evidence about the best ways to address the city's lakes, it can be resolved with the use of appropriate solutions if the geographical and temporal variations in lake health factor levels are known.

5. Methodology

5.1. SAMPLE COLLECTION

- Samples were collected and tested for two seasons, namely pre-monsoon and post-monsoon, along the periphery of three different lakes in Bangalore city, Karnataka, India.
- The lakes were chosen based on their surroundings (i.e, industries, layouts, agricultural fields etc.).
- The three lakes which are Ulsoor lake, Doddabommasandra lake and Shivapura lake were chosen as there are apartments, apartments and small-scale industries and heavy industries surrounding these lakes respectively.
- The samples were collected and tested on site between 8:00 am and 10:00 am by a group of volunteers in both seasons.
- Parameters selected for analysis were: Odour, Colour, pH, Temperature, Dissolved Oxygen, Total Dissolved Solids (TDS), Nitrate, Phosphate, Total Suspended Solids (TSS), Turbidity, Algal blooms, Floating garbage, Land use around the lake, Fishing activities as well as Flora and fauna in and around the lake.

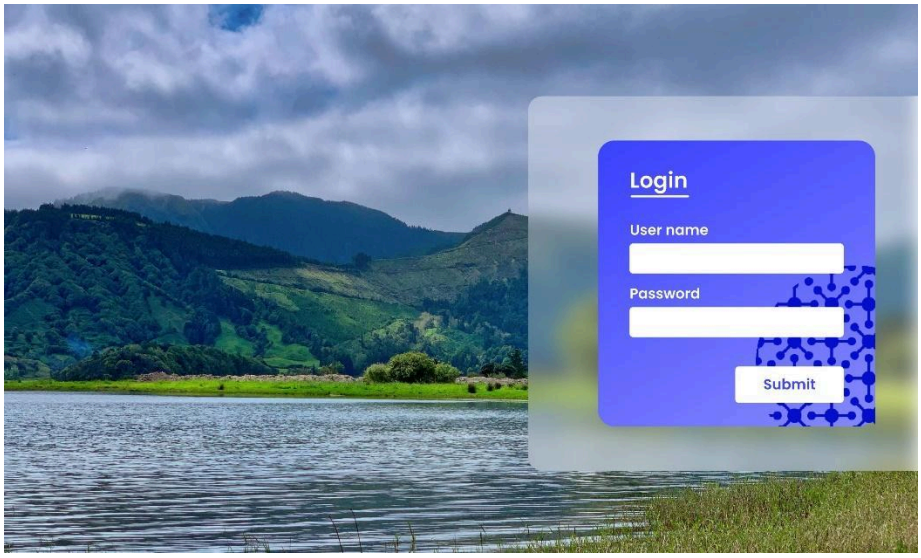
5.2. WATER ANALYSIS

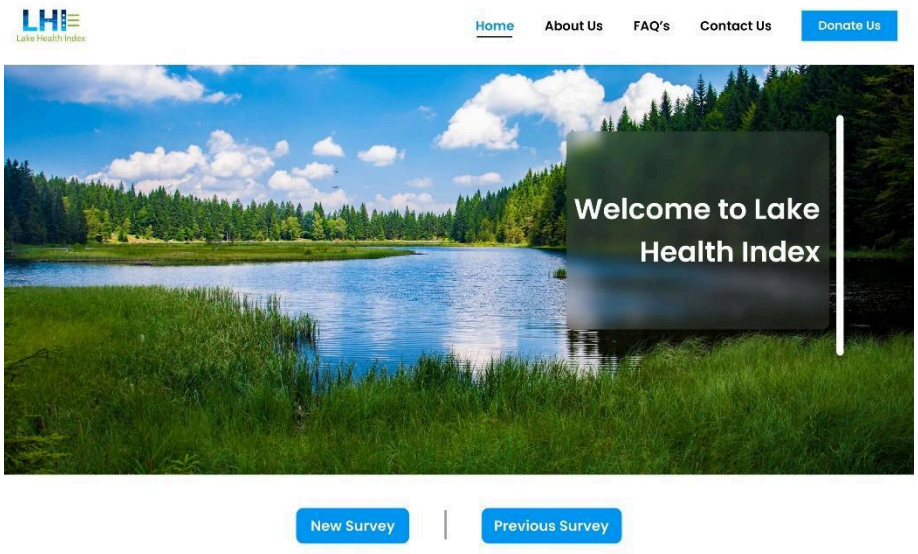
The water samples were tested in-situ. Physical and biological parameters i.e., odour, colour, floating garbage, floating plants, types of birds plants around the lake, fishes etc. were done through the senses of team. Chemical parameters like pH and TDS were tested using Hanna stick type probe and D.O was tested using Lutron D.O meter, the nutrient level [Nitrite and phosphate] and the turbidity was tested using water quality testing kits developed by ffem [Foundation for Environmental Monitoring] which allow the team to acquire the data on the field or on ground without the use of laboratory equipment.

5.3. APPLICATION DEVELOPMENT

The LHI application will be a dynamic people friendly device for civilians to understand the health of a lake [or waterbody], to spread awareness and holistic learning opportunity. The program shall be evolved by engaging stakeholders such as citizen lake groups, who would be the primary data analyzers and evaluators. The primary focus of this lake health index would be via citizen science engagement, simplified process of evaluating lakes health in terms of parameters such Physical (visual), biological, chemical.

The mobile application and website development was awarded to a startup company named 'Digitalpita' which will develop a dynamic application for citizens which can even be used by people with non-scientific background and further their understanding about lake health.





6. Results and discussion

A. Physical parameters

6.1. LAKE SURROUNDINGS

The water quality of lakes can be greatly influenced by their surrounding environments. For instance, Ulsoor Lake is surrounded by residential complexes and apartments, while Doddabommasandra Lake has a mix of residential areas and small-scale industries. On the other hand, Shivapura Lake is fully encompassed by large and small industries. Due to these varying surroundings, the chemical parameters of the lakes may differ significantly, as seen in the following report.

The surrounding land use of a water body can have a significant impact on its water quality. For instance, when a lake is bordered by apartments or farmlands, it is common for the water to receive an abundance of nutrients from household discharge and fertilizer runoff. Conversely, when surrounded by industrial areas, the levels of total dissolved solids tend to be higher due to effluent discharges and acidic pH as well. Finally, if the water body is surrounded by residential layouts, the impact on its water quality tends to be less significant compared to the other land use types.

The findings from Amin et. Al (2014) show that considerable changes in land use have occurred over the last three decades (1981-2011), resulting in lake contamination from the addition of fertilizers and pollutants emitted from stakeholders and citizens. The study reveals that land modification has significantly harmed the once-freshwater lake.

6.2. FLOATING GARBAGE

The presence of floating garbage in a lake can be indicative of the level of maintenance and care it receives. In the case of Shivapura Lake, a large amount of floating garbage was observed, whereas Ulsoor and Doddabommasandra Lakes had relatively little to no floating garbage, suggesting regular maintenance practices. It is worth noting that the majority of the garbage observed in all three lakes was pushed towards the bund regions due to wave action.

Floating garbage in lakes can have negative impacts on the water quality and ecosystem. The accumulation of debris can lead to the depletion of oxygen levels, promote the growth of harmful microorganisms, and harm aquatic organisms. In addition, the presence of litter can also diminish the aesthetic value and recreational use of the lake.

The results from Chen,. et al (2019), indicate that varying environmental factors such as temperature, nutrient levels, and suspended solids in lake water affect the growth rate and

composition of algae in biofilms. Notably, we observed faster biofilm development on smaller plastics in all seasons. This information emphasizes the urgent need for comprehensive strategies to mitigate plastic pollution and manage the health of aquatic ecosystems.

6.3. DEAD BIRDS AND FISHES IN THE LAKE WATER

The presence of dead fish and birds in a lake can be indicative of poor water quality and ecosystem health. Notably, Ulsoor and Doddabommasandra Lakes had a few such observations, whereas Shivapura Lake has a history of fish fatalities caused by low dissolved oxygen (DO) levels and high total dissolved solids (TDS) and nutrient concentrations. This highlights the importance of regular monitoring and management practices to maintain a healthy aquatic ecosystem.

The presence of dead birds and fishes in a lake suggests poor water quality. This could be due to low levels of dissolved oxygen and high levels of nutrients, which can lead to harmful algal blooms and fish kills. It may also be an indication of pollution from human activities, such as agricultural runoff or sewage discharge.

A study conducted by Du et al. (2018) investigated the impact of bird mortality on the water quality of a eutrophic lake in China. The study found that bird mortality caused a rapid increase in water turbidity, pH levels, and concentrations of total phosphorus, ammonia nitrogen, and organic matter. The increase in nutrients and organic matter in the water resulted in a harmful algal bloom, which further exacerbated the oxygen depletion in the lake. Similarly, a study by Ren et al. (2015) examined the impact of fish mortality on water quality in a shallow lake in China. The study found that the decomposition of fish carcasses led to an increase in nutrient concentrations, which resulted in a significant increase in algal biomass, as well as a decrease in dissolved oxygen levels in the water, Further research is needed to quantify the harm caused.

6.4. FISHING ACTIVITIES

Fishing activity was observed at Ulsoor and Doddabommasandra Lakes, with weekend angling being a common practice. In contrast, Shivapura Lake was deemed too polluted for fishing due to poor water quality. Despite this, the occasional sighting of catfish surfacing suggests that some fish species may still survive in the lake, albeit in compromised conditions. If people are regularly fishing in the lake, it is generally an indication that the water quality is good enough to support aquatic life. However, this is not always a reliable indicator, as some fish species may be able to survive in polluted or degraded conditions.

Fishing can help improve lake water quality in several ways. By reducing the number of fish in a lake, fishing can help control the growth of algae and other aquatic plants, which can improve water clarity and quality. Additionally, fishing can help reduce the spread of invasive species, which can outcompete native species and disrupt the balance of the lake ecosystem. Finally,

fishing can also support the local economy and encourage the conservation and management of natural resources. (Wells, M. L., & Heath, R. T. 2016).

6.5.COLOR

Ulsoor lake exhibited green colour at the inlet and brownish-green coloured water around the bank at the outlet. Doddabommasandra lake had clear water with hints of green observed near the center, attributable to the presence of a Sewage Treatment Plant. Shivapura lake had black water throughout, except for the northern side which was green during the pre-monsoon period. The observations imply a range of water quality issues, including high nutrient levels, pollution, and possible eutrophication.

In post-monsoon period, Ulsoor lake was green and, in some places, dark green. Doddabommasandra lake showed similar results with a lighter green colour. Shivapura lake showed the same black coloured water even in the post-monsoon period. Colour of the lake is mostly influenced by suspended and dissolved particles present in the water. Green colour of the lake indicates the presence of abundant growth of blue green algae while brown colour shows the presence of humus or decaying plant matter (Kumar, 2016). Water colour is also influenced by factors like iron, nitrate concentrations and pH differences (Johansson et AL., 2010).

6.6. ODOR

In the pre-monsoon odor of the Ulsoor wetland area was slightly fishy and smelled of sewage, and the rest of the lake had little to no odor. Doddabommasandra lake had a fishy and sewage-like odor throughout the lake, except for the south which only had a slight fishy odor. The odor of Shivapura lake was sewage-like and fishy throughout the lake inlet.

In the post-monsoon period, The Ulsoor inlet wetland predominantly had a fishy odor and only a few places in the southern side had no odor. The inlet of Doddabommasandra had a fishy and sewage-like smell throughout the lake. Shivapura lake had a sewage like smell throughout the lake and a rotten egg smell around the inlet.

Smell or odor of a lake is a physical parameter which helps in indicating the Health Index of a particular lake. It represents the presence of various contaminants in the lake. Odor can be due to microorganisms like Algae and bacteria. The fishy smell can be attributed to two major chemical compounds i.e. amine and fatty acid derivatives. Amines are compounds that contain nitrogen and are often associated with fishy odors, while fatty acid derivatives are substances derived from fats. (Watson, 2004).

6.7.ALGAL BLOOM

Ulsoor and Doddabamsandra lakes showed significant algal growth, primarily attributed to the inflow of nutrients from the surrounding residential areas. The water quality of Shivapura lake was highly compromised, and the presence of algal species in the water could not be determined due to its heavily contaminated state, resulting in black coloration.

Due to anthropogenic influence, agricultural practices, sewage wastes and industrial run-off water gets contaminated with nitrate and phosphates which leads to the growth of algae (Smith, 2003). Temperature can also increase the growth of algal blooms resulting in the death of fishes and other aquatic life. Having excess nutrients can trigger eutrophication in water bodies which promote the growth of blue green algae that can produce harmful chemical toxins that endanger the life of aquatic organisms (Ariyawansa, 2012).

B. Chemical parameters

6.8. SUSPENDED SOLIDS

Ulsoor and Doddabamsandra lakes exhibited higher levels of suspended solids in the pre-monsoon season than the post-monsoon season, likely due to increased runoff and sedimentation from surrounding areas. In Shivapura lake, the high total dissolved solids (TDS) and dark water color made it challenging to determine the suspended solids concentration, although elevated TDS could be an indicator of high suspended solids.

The suspended solids observed with the naked eye were significantly higher in the pre monsoon rather than the monsoon season which can be interpreted as a result of dilution due to the monsoon rains. the lakes were high Suspended Solids [SS] are an extremely important physical parameter that causes water quality deterioration, that leads to a decline in fishery resources, high cost water treatment, and degradation of aquatic ecosystems (Billota and Brazier, 2008).

Suspended solids are carriers of pollutants like phosphorus in water bodies (Villa et. al., 2019). They reduce light penetration affecting photosynthetic systems. As a result, phytoplankton and vascular plants are negatively affected. They also affect zooplankton, micro vertebrates, fishes and other aquatic life (Sorensen et al .,1977). Suspended solids also influence the levels of dissolved oxygen present in the water, increasing the water temperature. (Shah et al., 2014).

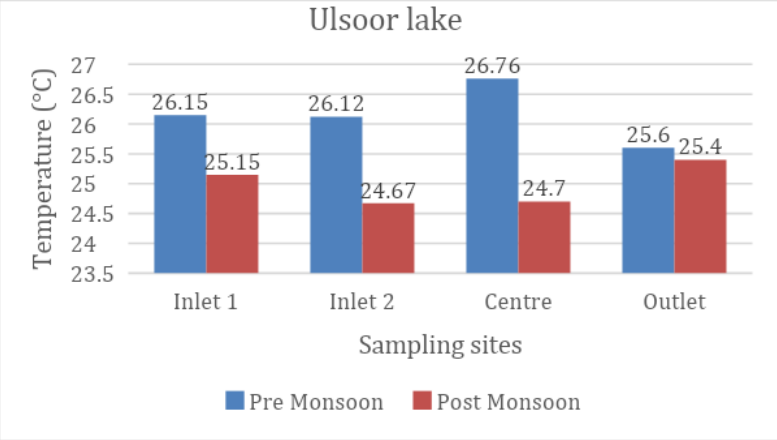
6.9. TEMPERATURE

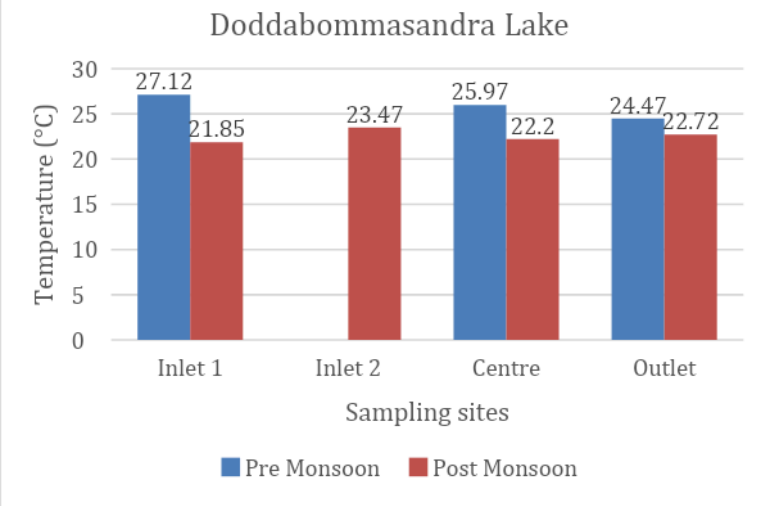
The temperature of water bodies plays a major role in influencing the growth and activities of aquatic life. Temperature also affects parameters like DO, pH, and other parameters of the water (Ramachandra and Solanki, 2007). As the temperature increases, the oxygen levels in the water decrease.

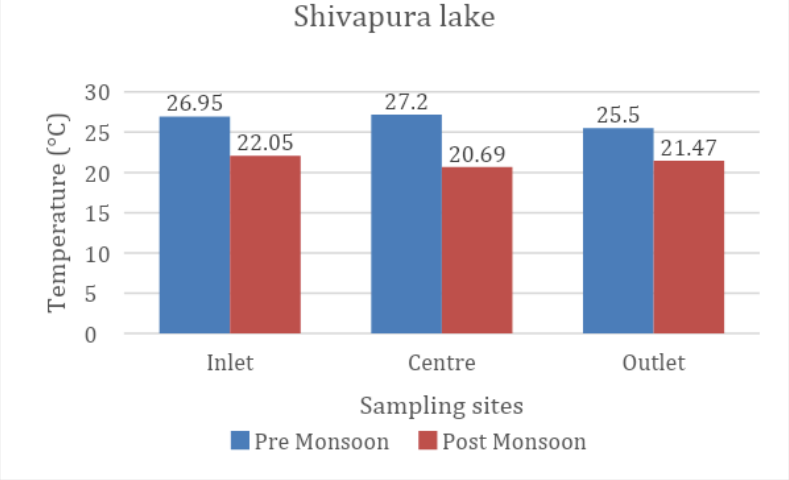
Water temperature in lakes varied spatially and temporally, with post-monsoon showing a lower temperature than pre-monsoon due to seasonal variation and water volume. Temperature affects the rate of photosynthesis, metabolism, and sensitivity of aquatic organisms to toxic wastes, parasites, and diseases, which in turn affects the water quality and ecosystem health of the lake. Change in temperature can be a result of climatic changes (Bhateria and Jain, 2016), inlets and outlets of the water, sunlight and radiation, atmosphere, turbidity. Shallow and surface waters are more easily affected than the deep waters.

Ulsoor Lake			**Doddabommasandra Lake**			**Shivapura Lake**		
Temperature (°C)								
Sampling site	Pre-Monsoon	Post Monsoon	Sampling site	Pre-Monsoon	Post Monsoon	Sampling site	Pre-Monsoon	Post Monsoon
Inlet 1	26.15	25.15	Inlet 1	27.12	21.85	Inlet	26.95	22.05
Inlet 2	26.12	24.67	Inlet 2	-	23.47	Centre	27.2	20.69
Centre	26.76	24.7	Centre	25.97	22.2	Outlet	25.5	21.47
Outlet	25.6	25.4	Outlet	24.47	22.72			

Temperature







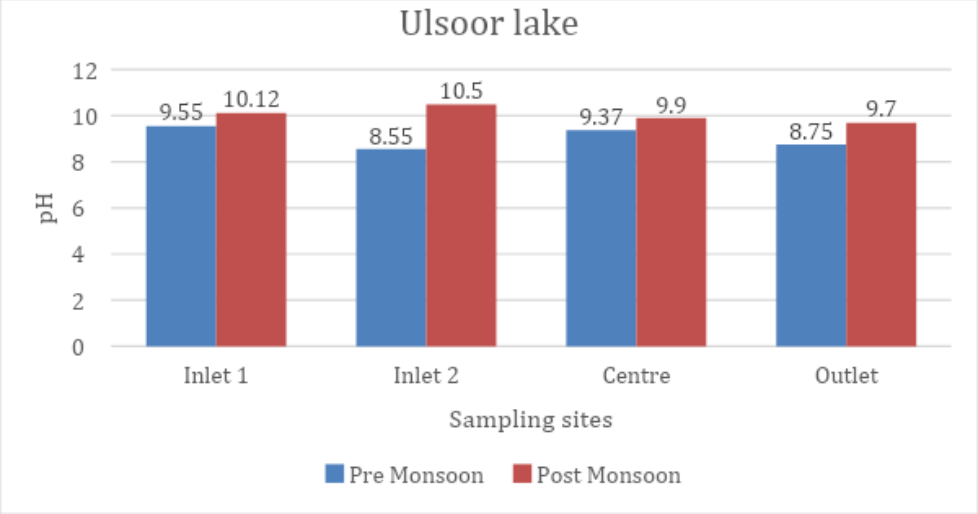
6.10. pH

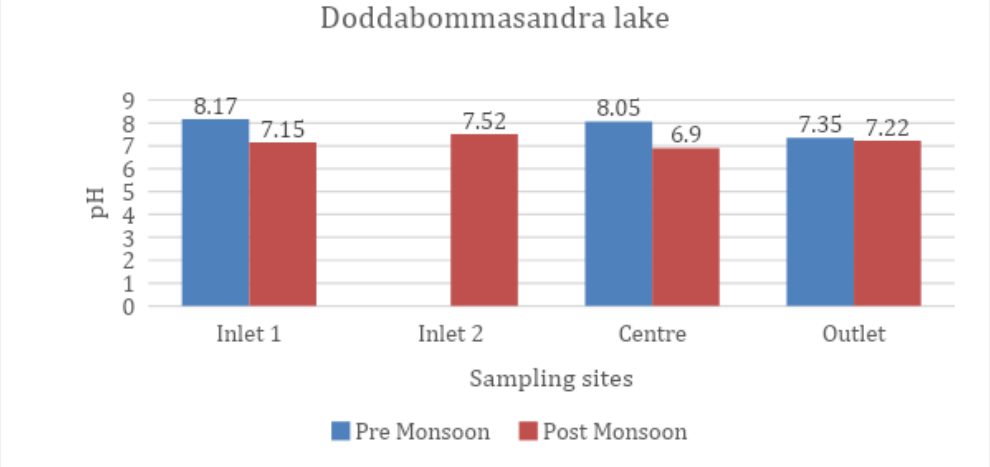
pH is the measure of hydrogen ions in a substance. Knowing the pH of the water in the lake allows us to judge whether the water is acidic, neutral or basic. pH levels of the water is very important as it affects the chemical and biological processes of the aquatic ecosystem. Different species adapt at different pH ranges. Most of them cannot survive if the water is too acidic or basic. Optimum pH for many species range between 6.5 to 9 (Baker et al.,1990).

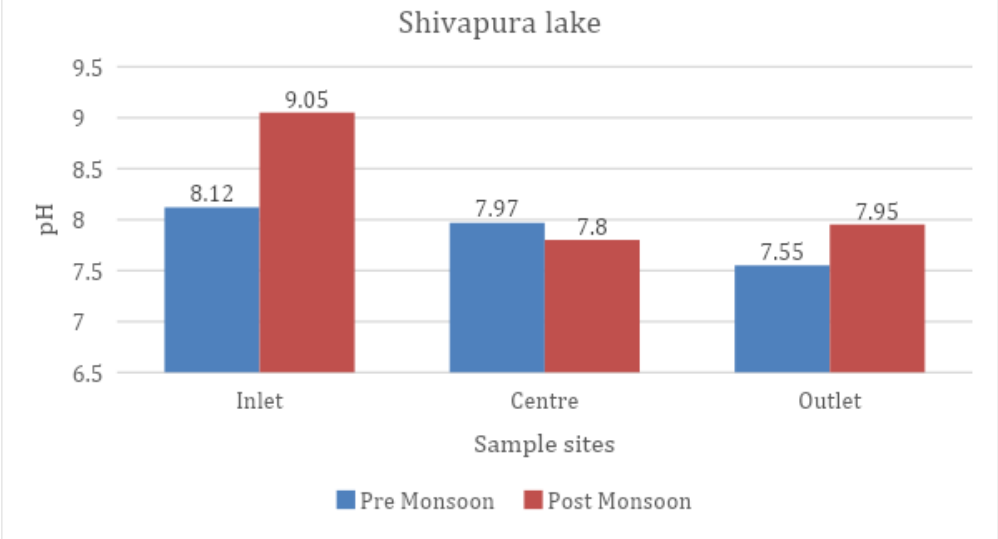
The pH varied throughout the lake mostly showing basic pH, but it largely turns neutral as the water passes through the lake, post monsoon had higher pH than the pre monsoon due to seasonal variation and influx of nutrients. Anthropogenic activities have affected aquatic habitats globally. The change in pH of the water can be a result of the water inlets (can be sewage), increased pollution, chemicals from the surrounding factories (Spyra, 2017). pH also determines the corrosive nature if the water The reduction of photosynthesis activity and increase in carbon dioxide are due to the increase in pH levels (Bhateria and jain, 2016).

Ulsoor Lake			**Doddabommasandra Lake**			**Shivapura Lake**		
pH								
Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon
Inlet 1	9.55	10.12	Inlet 1	8.17	7.15	Inlet	8.12	9.05
Inlet 2	8.55	10.5	Inlet 2	-	7.52	Centre	7.97	7.8
Centre	9.37	9.9	Centre	8.05	6.9	Outlet	7.55	7.95
Outlet	8.75	9.7	Outlet	7.35	7.22			

pH


Ulsoor lake
12
10
8
6
4
2
0
pH
9.55
10.12
8.55
10.5
9.37
9.9
8.75
9.7
Inlet 1
Inlet 2
Centre
Outlet
Sampling sites
Pre Monsoon
Post Monsoon


Doddabommasandra lake
9
8
7
6
5
4
3
2
1
0
pH
8.17
7.15
7.52
8.05
6.9
7.35
7.22
Inlet 1
Inlet 2
Centre
Outlet
Sampling sites
Pre Monsoon
Post Monsoon


Shivapura lake
9.5
9
8.5
8
7.5
7
6.5
pH
8.12
9.05
7.97
7.8
7.55
7.95
Inlet
Centre
Outlet
Sample sites
Pre Monsoon
Post Monsoon

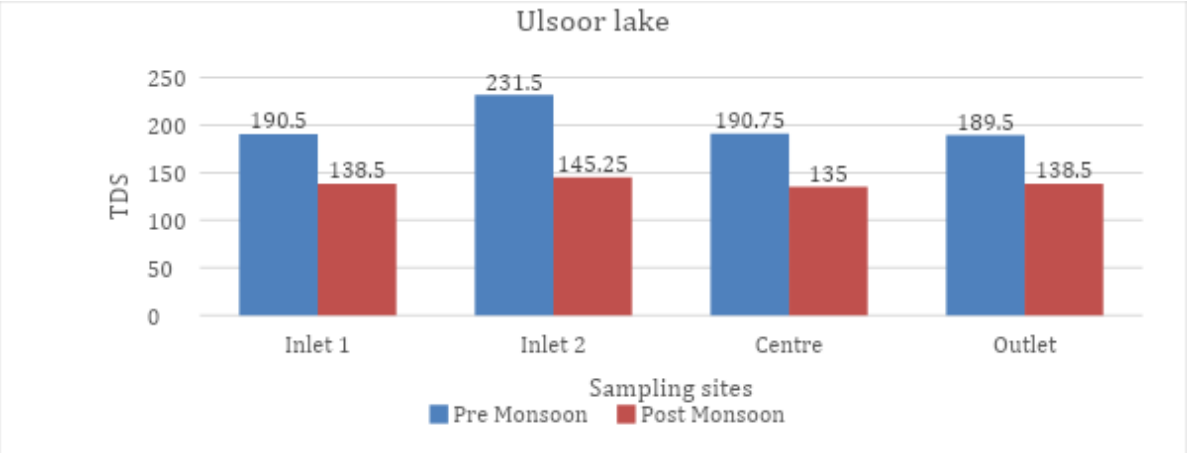
6.11. TOTAL DISSOLVED SOLIDS

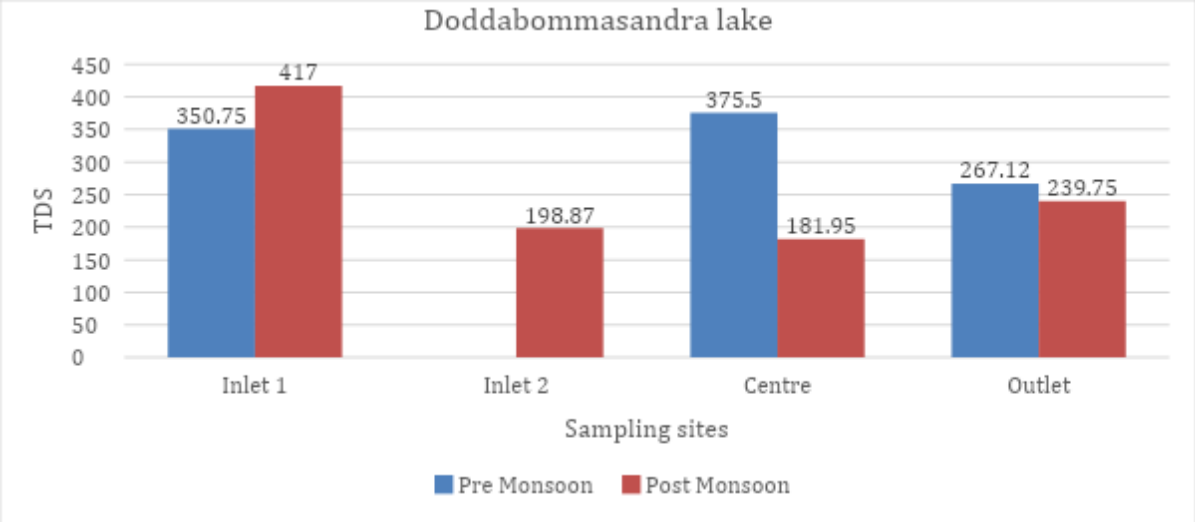
Total Dissolved Solids (TDS) is the measure of all the organic and inorganic matter or salts present in the water. These salts can be cations of calcium, magnesium and potassium and anions of carbonates, bicarbonates, nitrate, chloride, sulphates etc., (Islam et al., 2016).

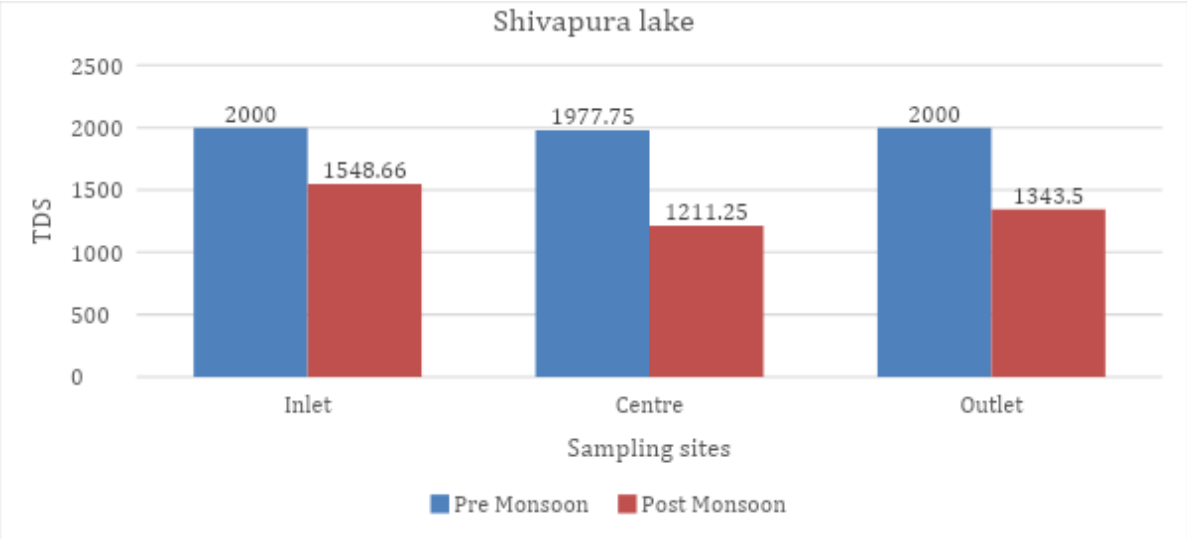
Shivapura lake had the most TDS due to its vicinity to industries while water at ulsoor and Doddabommasandra had low and relatively similar in both pre and post monsoon seasons. TDS concentration affects aquatic life. Generally, in lakes and rivers the TDS value is found to be in between 50 to 250 mg/L (Bhateria and Jain 2016). It also determines the salinity of water.

Ulsoor Lake			**Doddabommasandra Lake**			**Shivapura Lake**		
Total DIssolved Solids (mg/L)								
Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon
Inlet 1	190.5	138.5	Inlet 1	350.75	417	Inlet	2000	1548.66
Inlet 2	231.5	145.25	Inlet 2	-	198.87	Centre	1977.75	1211.25
Centre	190.75	135	Centre	375.5	181.95	Outlet	2000	1343.5
Outlet	189.5	138.5	Outlet	267.12	239.75			

Total Dissolved Solids







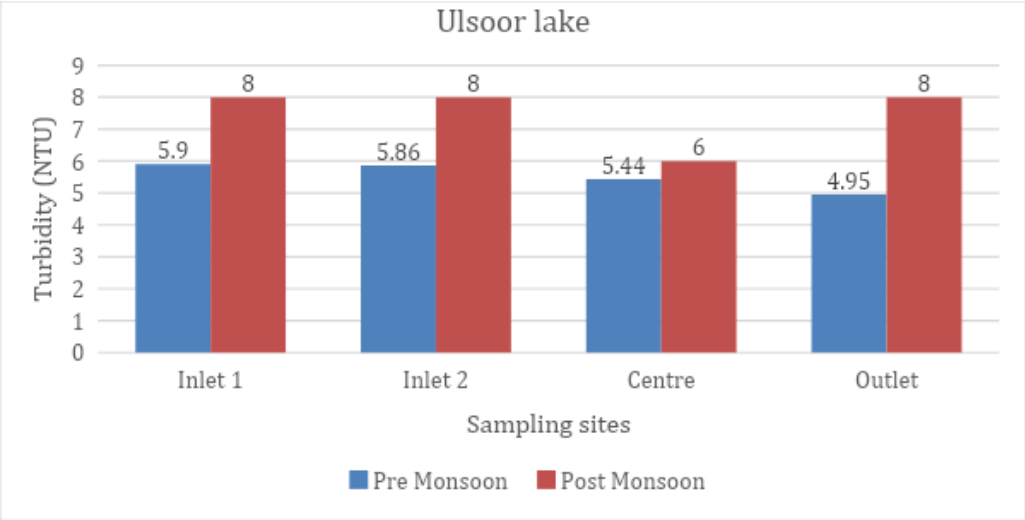
6.12. TURBIDITY

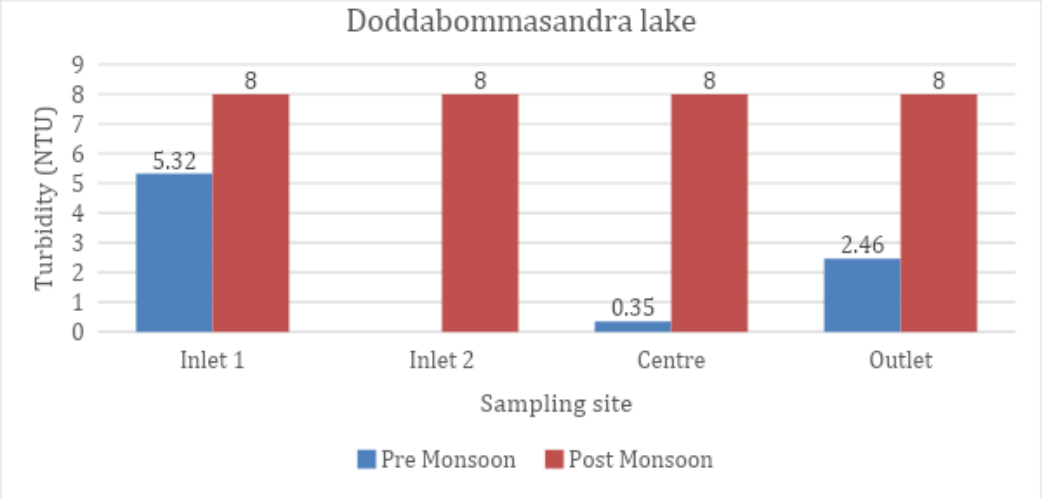
Turbidity is the light scattering property of the water sample. It also tells us the if the reduced water quality is due to the presence of suspended materials (inorganic) which reduce and aggregate dissolved substances, bacteria and algae.

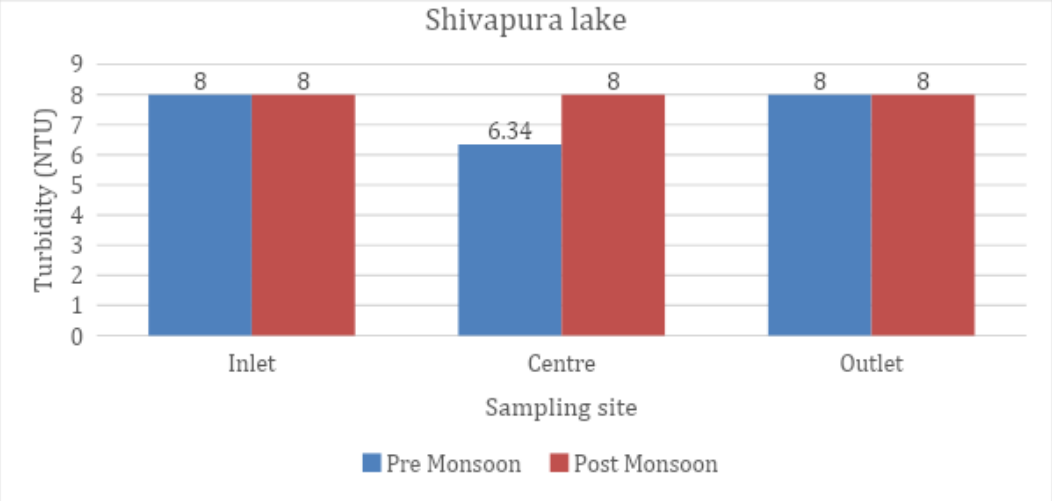
Doddabommasandra and shivapura lakes had turbidity value of more than 8 NTU in post monsoon indicating the surplus inflow of salts and silt. Only ulsoor lake had relatively low turbidity. It affects zooplankton, Phytoplankton and also fish growth rate (Grobbelaar, 2009) and is a widely used parameter used for describing water quality (Gauthier et AL.,2003). Turbidity is measured in Nephelometric Turbidity Units (NTU). A Turbidity value above 5 NTU is visible to eye in the form of precipitate. It can be a source of chemical disinfectant demand with organic particles (Allen et al.,2009).

Ulsoor Lake			**Doddabommasandra Lake**			**Shivapura Lake**		
Turbidity (NTU)								
Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon
Inlet 1	5.9	8	Inlet 1	5.32	> 8.00	Inlet	> 8.00	> 8.00
Inlet 2	5.86	> 8.00	Inlet 2	No data	> 8.00	Centre	6.34	> 8.00
Centre	5.44	6	Centre	0.35	> 8.00	Outlet	> 8.00	> 8.00
Outlet	4.95	> 8.00	Outlet	2.46	> 8.00			

Turbidity


Ulsoor lake
Turbidity (NTU)
9
8
7
6
5
4
3
2
1
0
5.9
8
5.86
8
5.44
6
4.95
8
Inlet 1
Inlet 2
Centre
Outlet
Sampling sites
Pre Monsoon
Post Monsoon


Doddabommasandra lake
Turbidity (NTU)
9
8
7
6
5
4
3
2
1
0
5.32
8
8
0.35
8
2.46
8
Inlet 1
Inlet 2
Centre
Outlet
Sampling site
Pre Monsoon
Post Monsoon



6.13. DISSOLVED OXYGEN

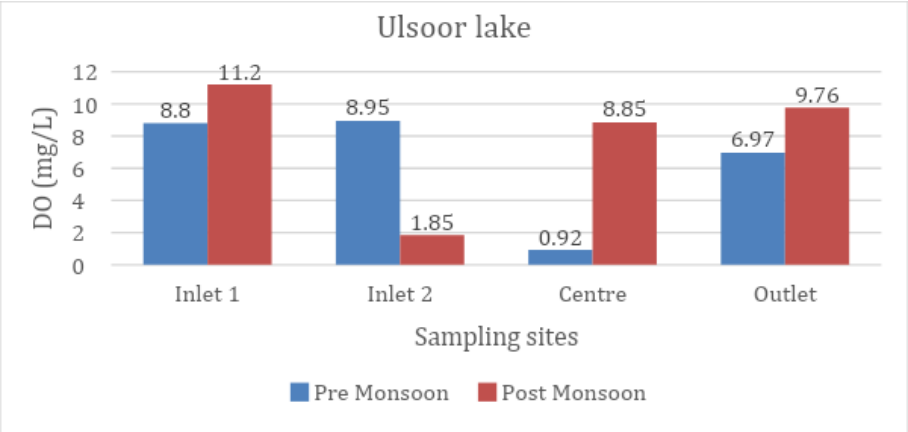
The amount of oxygen present in the water is called Dissolved oxygen. Water bodies receive oxygen from the atmosphere and aquatic plants. It is also one of the most important parameters that tell us about the quality of the water.

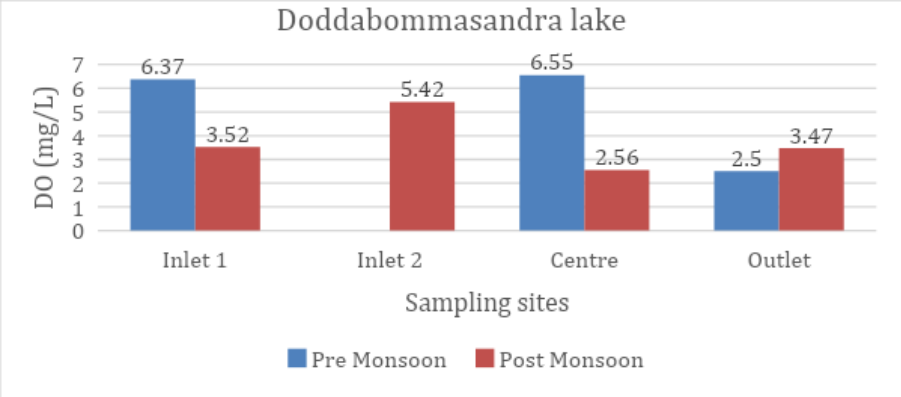
The bare minimum of DO required for aquatic organisms to exist is 4. Outlet of shivapura lake is shown to have less DO compared to inlet, which can be attributed to the high oxygen demand and lower holding capacity due to industrial effluents, DO is varied at different points at ulsoor and Doddabommasandra due to the excess algae and excess nutrients/sewage present in the water which causes high COD and BOD. The measuring of DO helps in determining whether the water is predominantly aerobic or anaerobic (Ibanez et al., 2008). The fluctuations of DO near its saturation determines the health of aquatic ecosystems (Prasad B.S.V.R, 2014).

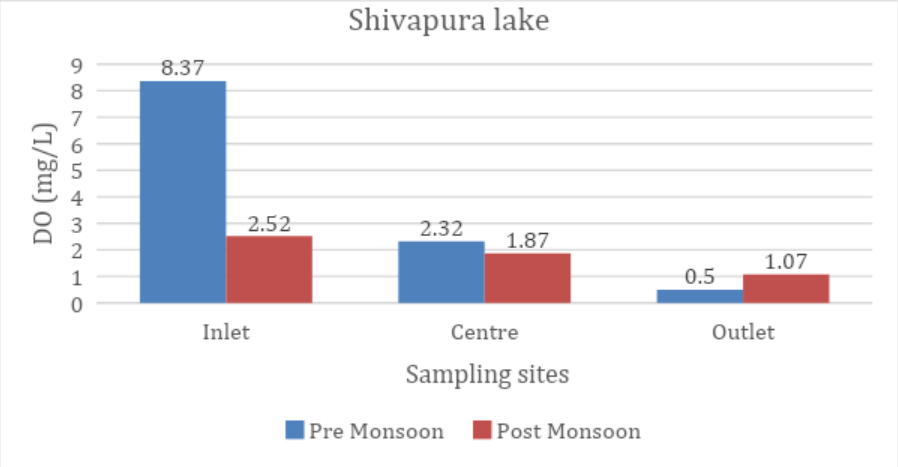
Ulsoor Lake			**Doddabommasandra Lake**			**Shivapura Lake**		
Dissolved Oxygen (mg/L)								
Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon
Inlet 1	8.8	11.2	Inlet 1	6.37	3.52	Inlet	8.37	2.52
Inlet 2	8.95	1.85	Inlet 2	No data	5.42	Centre	2.32	1.87
Centre	0.92	8.85	Centre	6.55	2.56	Outlet	0.5	1.07

Outlet	6.97	9.76	Outlet	2.5	3.47			

Dissolved Oxygen







6.14. NITRATE

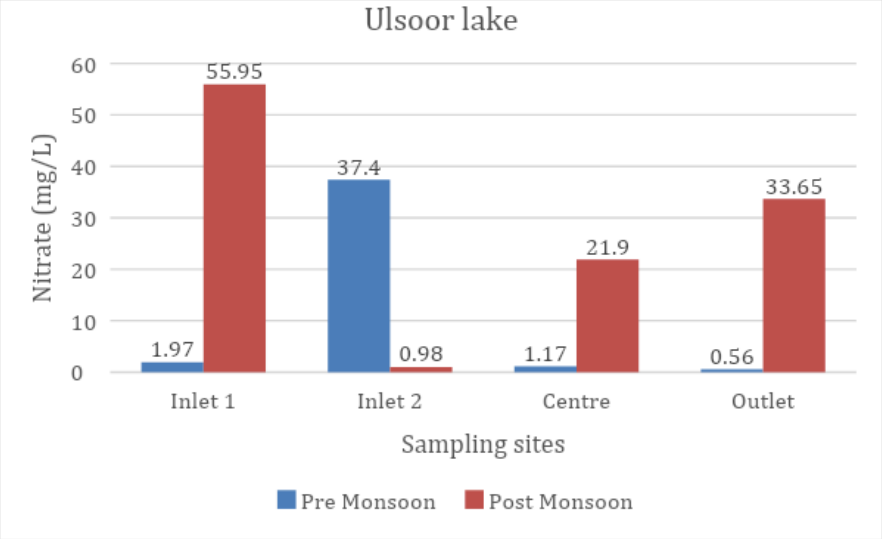
Nitrate can be found in water bodies as a result of sewage contamination, fertilizer deposits from runoff water, and deposited minerals from neighboring businesses.

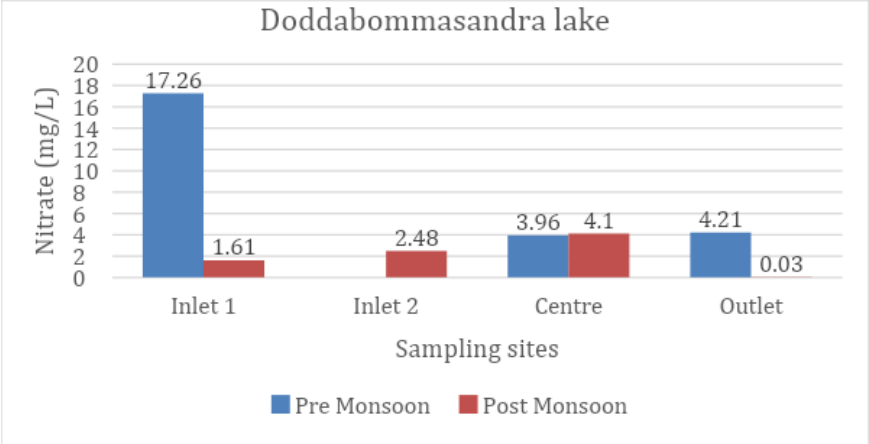
Ulsoor lake nitrate concentration increased in post monsoon as opposed to the effects seem at Doddabommasandra and shivapura. Which might be due to its surrounding residential buildings. The delusion observed in the other lakes is attributed to rainfall. Shivapura showed an unusual fall of nitrate concentration flow from inlet to the outlet, needing further research for better understanding. Nitrite concentrations in water bodies can be caused by bacterial contamination, nitrate reduction, or ammonia oxidation. (Mackerness and Keevil,1996). The C/N ratio was considered to be the cause of nitrite buildup. It can also have an impact on the aquatic ecosystem's living habitat (Hari et al., 2006).

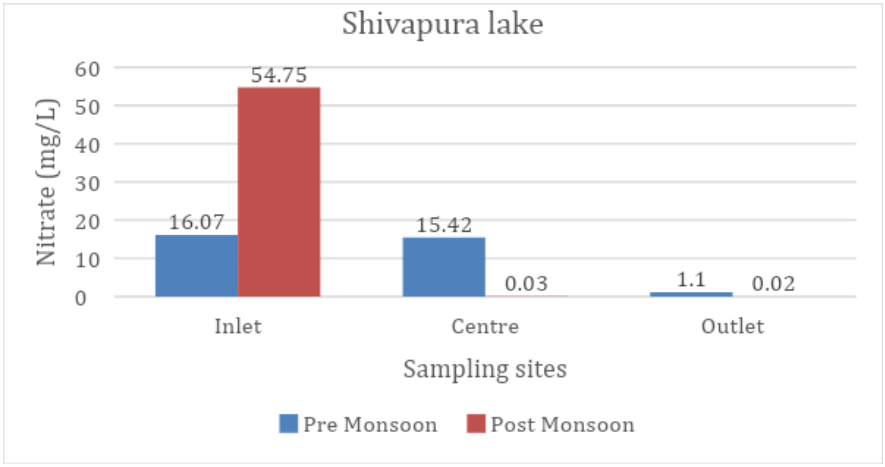
Ulsoor Lake	Doddabommasandra Lake	Shivapura Lake
Nitrate (mg/L)		

Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon
Inlet 1	1.97	55.95	Inlet 1	17.26	1.61	Inlet	16.07	54.75
Inlet 2	37.4	0.98	Inlet 2	No data	2.48	Centre	15.42	0.03
Centre	1.17	21.9	Centre	3.96	4.1	Outlet	1.1	0.02
Outlet	0.56	33.65	Outlet	4.21	0.03			

Nitrate







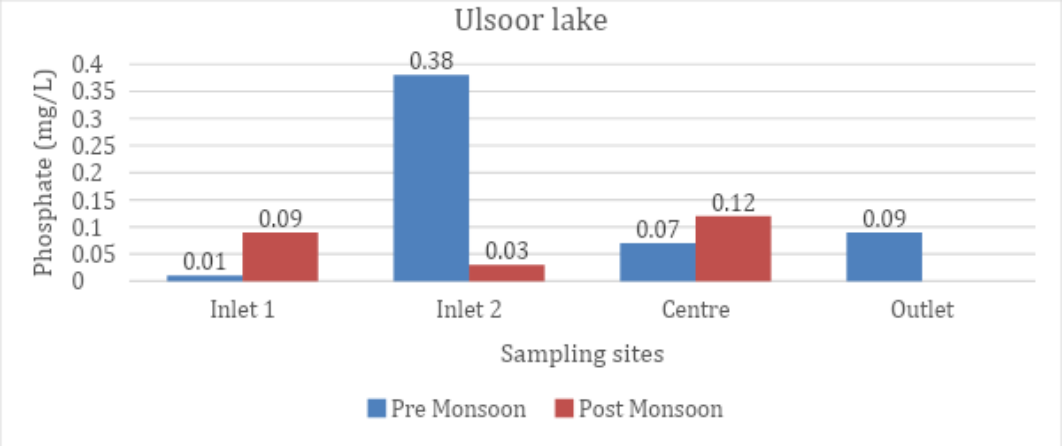
6.15. PHOSPHATE

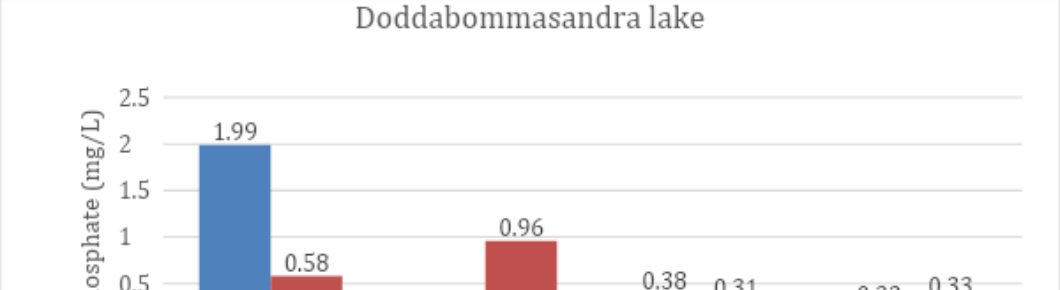
Phosphorus is commonly regarded as a limiting nutrient since it regulates the growth rate of algae and aquatic organisms. Phosphate is found in three different forms: organic phosphate, orthophosphate, and polyphosphates.

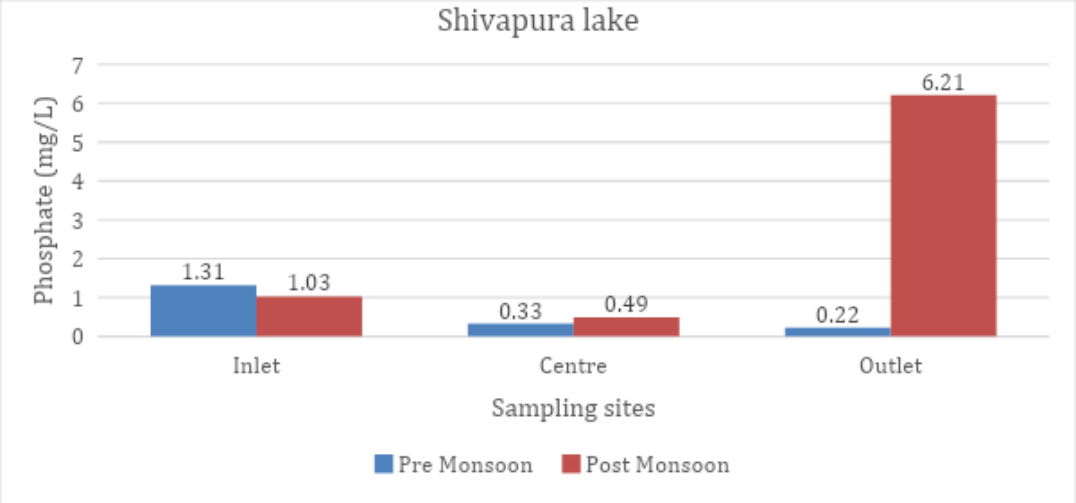
Phosphate concentration decreased in post monsoon as opposed to the pre monsoon in ulsoor and Doddabommasandra lakes but in shivapura it increases radically at the outlet in post monsoon which could be due to the industrial effluents and the variability as observed in the flow of nutrients in each lake is due to excess nutrients locked in the sediments. Phosphate contamination occurs as a result of sewage and industrial discharges, mineral breakdown, and agricultural run-off (Singh, 2013). Excess phosphate produces Eutrophication, which alters dissolved oxygen levels in the water, causing stress and killing sensitive aquatic organisms (Domagalski and Johnson, 2012).

Ulsoor Lake			Doddabommasandra Lake			Shivapura Lake		
Phosphate (mg/L)								
Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon	Sampling site	Pre Monsoon	Post Monsoon
Inlet 1	0.01	0.09	Inlet 1	1.99	0.58	Inlet	1.31	1.03
Inlet 2	0.38	0.03	Inlet 2	No data	0.96	Centre	0.33	0.49
Centre	0.07	0.12	Centre	0.38	0.31	Outlet	0.22	6.21
Outlet	0.09	0	Outlet	0.22	0.33			

Phosphate







C. Biological parameters

6.16. FLORA AND FAUNA

Ducks, Cormorants, kingfishers, herons, kites were the common bird species observed at ulsoor and doddabamsandra lakes but the shivapura lake had mostly ducks and purple herons due to high pollution load. Water hyssops, cattails, alligator weeds, common water hyacinth were observed at ulsoor and doddabamsandra lakes but the shivapura lake had mostly alligator weeds and duckweeds at the inlet.

The plants, birds and animals found in and around the lake determines the health index of the lake ecosystem. Macrophytes are aquatic plants that can be seen by naked eyes. They include plants that float to other surfaces such as water hyacinth, water lettuce and also submerged plants such as pond weed. These plants produce essential oxygen and food for the rest of the aquatic ecosystem. The presence of these plants indicates positive lake health. However, In some cases, macrophytes are considered as an indication for eutrophication (Penning et AL., 2008b), which

can lead to ecologically detrimental algal blooms. Various fish, amphibians, reptiles and bird species are found in and around the lakes. Presence of fish indicates the health of the lake. Eutrophication affects fish depending upon habitat requirements and physiological conditions (Müller and Standelmann 2004)

7. CONCLUSION AND SUMMARY

The pollution levels of all parameters were observed to be higher during the post-monsoon season. This may be due to high rainfall which pumped higher nutrients and pollutants that could have otherwise been stored or stuck due to the flat lands and rapid urbanization of Bangalore city.

The alkalinity of the pH levels observed in the lake is primarily attributed to the inflow of nutrients, which has a significant impact on the lake's color, odor, dissolved oxygen levels, as well as the aquatic flora and fauna. Therefore, it is imperative to consider the entire ecosystem to accurately identify and address environmental concerns. The Total Dissolved Solids (TDS) in Shivapura lake, which surpasses 2000 mg/L, along with the phosphate levels of 6.21 mg/L during the post-monsoon season, indicate the necessity for a proficiently designed effluent treatment plant to treat the water.

The high levels of nitrate [33 mg/l] and phosphate [>2mg/l] in the water samples analyzed indicate a concerning issue that requires immediate attention. These elevated levels can have detrimental effects on aquatic ecosystems, leading to eutrophication, oxygen depletion, and harm to fish and other aquatic organisms. Additionally, high nitrate and phosphate levels in water can pose health risks to human populations, particularly infants and pregnant women. Therefore, effective strategies must be implemented to mitigate nutrient pollution, such as improved agricultural practices, better wastewater treatment, and public awareness campaigns. Collaborative efforts between government agencies, communities, and stakeholders are crucial to safeguarding water quality and preserving the health and wellbeing of both aquatic ecosystems and human populations.

The findings of this report suggest that educational apps can be effective in increasing knowledge and awareness about lake water quality, providing a convenient and accessible way to disseminate information. By equipping individuals with knowledge and awareness, educational apps have the potential to contribute to the conservation and protection of lakes, ultimately leading to better water quality and a more sustainable future for our freshwater resources.

8. RECOMMENDATION

Ulsoor lake although the healthiest of the three studied, needs a functioning STP with tertiary treatments to combat high nutrient inflow. Doddavamsandra is recommended to have a constructed wetland to remove nitrate and phosphate from the inlets and STP. Shivapura needs an Effluent Treatment Plant/ETP for removing the industrial effluents. All three lakes are recommended to have an efficient constructed wetland in tandem with the functioning STP/ETP.

The usage of an educational software to raise knowledge and awareness regarding lake water quality has proven to be a helpful tool. The app offered users with accessible and entertaining content that helped them comprehend the relevance of lake water quality and the importance of conservation actions. Users have learned about many aspects of lake water quality, such as water testing methods, the impact of pollution, and the role of human activities.

Furthermore, the app has enhanced public knowledge of the problems and dangers to lake water quality, resulting in increased concern and action to safeguard lakes and their ecosystems. The app and website's interactive features, such as interactive questions have increased user engagement and allowed for a deeper comprehension of the subject.

The educational app has demonstrated its potential in increasing knowledge and awareness about lake water quality, further development is needed to improve its functionality and enhance user experience. By continuously refining and expanding the app's features, the app can become an even more valuable tool in promoting lake conservation and protecting our freshwater resources.

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