PHYSIOCHEMICAL COMPARISON OF LAKES TO ANALYSE LEVEL OF POLLUTION

Leanna Rose Joy & Hima P

Designation: Student
Organisation: Christ University
Place: Bangalore

ABSTRACT

Lakes constitute a considerable part of our ecosystem. Like every other water body on the surface of earth, lakes are also being polluted as a result of urbanization. In this study, we deal with the physiochemical aspects of 4 different lakes located in Bangalore city and one in Quilon district, Kerala. Out of the four lakes, Ulsoor, Hebbal and Sankey tank are recreational. Belandur lake supports a large population which results in a greater amount of sewage flowing into the lake. Sasthamkotta lake, which is situated in Kerala is a lake that meets drinking water purposes. Bangalore and Quilon are topographically different and vary in the extent of urbanization. In this study, we are going to analyse the length to which urbanization and characteristics of surroundings have affected lake water quality.

ACKNOWLEDGEMENT

I sincerely thank Dr. Antony PU for inspiring me to study lakes in Bangalore and giving me a chance to think more about conserving water. I also thank all my friends who have been helpful for the completion of this project. I would also like to express my gratitude towards Cauvery bhavan officials for their cooperation.
OBJECTIVES

The objective of this study is to assess the ecological status and make a comparative study of four lakes in Bangalore and one lake in Kerala. The study details the water quality aspects of Ulsoor lake, Belandur lake, Sankey tank and Madiwala lake in Bangalore and the Sasthamkotta Kayal in Kerala.
INTRODUCTION

Aquatic ecosystems are broadly categorised based on the differences in their salt content as:

♦ Freshwater ecosystems
♦ Marine ecosystems (includes the ocean and the sea) and
♦ Estuarine ecosystems (region where freshwater from a river mixes with the sea)

Familiar examples of Freshwater ecosystems include lakes, ponds, rivers and streams. They also include areas such as floodplains and wetlands, which are flooded with water for all or only parts of the year.

Freshwater ecosystems are characterised as

♦ Lotic (running waters) – streams, rivers, etc.
♦ Lentic (still waters) – wetlands, ponds, tanks, lakes, etc.

Lentic ecosystems generally include ponds, lakes, bogs, swamps, reservoirs, pools, etc. and they vary considerably in physical, chemical and biological characteristics.

A lake is a terrain feature (or physical feature), a body of liquid on the surface of that is localized to the bottom of basin (another type of landform or terrain feature; that is not global). Another definition is a lake is a sizable waterbody surrounded by land and fed by rivers, springs, or local precipitation. Natural processes of lake formation most commonly include glacial, volcanic, and tectonic forces while human constructed lakes are created by reservoirs or excavation of basins and terrestrial environments.

Aquatic ecosystems are connected to each other and provide essential migration routes for species. Aquatic ecosystems require sediment loads, chemical and nutrient inputs from the adjoining terrestrial ecosystems for sustenance. Even isolated lakes are linked to the land and water around them through the flow of freshwater. Many of the problems faced by freshwater ecosystems come from outside the lakes, rivers or wetlands themselves. Watershed is all the land and water area, which drains towards a river or a lake, river or a pond. A watershed is a catchment basin that is bound by topographic features, such as ridge tops and performs primary functions of the ecosystem.

Thus, the watershed can constitute slopes, agricultural lands, forests, streams, waterbodies, buildings, etc. People and animals are also a part of the watershed community and all depend on the watershed and they in turn influence what happens there. Accordingly, what happens in a small watershed also affects the larger watershed. The entry nutrients, sediments through the surface runoffs enter and remain in the system causing fluctuations in the physico-chemical characteristics of the ecosystem.
When pollutants enter lakes, streams, rivers, oceans, and other waterbodies, they get dissolved or lie suspended in water or get deposited on the bed. The system is able to withstand the pollutants up to a certain threshold, beyond which the quality of the water deteriorates, affecting aquatic ecosystems. The most common problems associated with various pollutants are discussed below:

• Oxygen demanding wastes are substances that oxidise in the receiving body of water, reducing the amount of dissolved oxygen (DO) available. As DO drops, fish and other aquatic life are threatened and, in the extreme case, get killed. In addition to the fall in DO levels, undesirable odours, tastes, and colours reduce the acceptability of the water as a domestic supply and its attractiveness for recreational purposes. Oxygen demanding wastes are usually biodegradable organic substances contained in municipal wastewaters or in effluents from industries such as food processing and paper production.

• Contaminated water is responsible for the spread of many contagious diseases. Pathogens associated with water include bacteria responsible for cholera, dysentery, typhoid, etc., viruses cause hepatitis and poliomyelitis, protozoa are responsible for amoebic dysentery and giardiasis, and helminthes or parasitic worms cause diseases like schistosomiasis, etc.

• Nutrients, when present in concentrations that can stimulate the growth of algae can be considered pollutants. The discharge of waste from industries, agriculture, and urban communities into waterbodies generally stretches the biological capacities of aquatic systems. Chemical run-off from fields also adds nutrients to water. Excess nutrients cause the waterbody to become choked with organic substances and organisms. When organic matter exceeds the capacity of the microorganisms in water that break down and recycle the organic matter, it encourages rapid growth, or blooms of algae. When they die, the remains of the algae add to the organic wastes already in the water; eventually, the water becomes deficient in oxygen. Anaerobic organism then attack the organic wastes, releasing gases such as methane and hydrogen sulphide, which are harmful to the aerobic forms of life. The result is a foul-smelling, waste-filled body of water. This artificial supplementation of nutrients, and consequent abnormal increase in the growth of water plants is often referred to as eutrophication. This is a growing problem in freshwater lakes all over India. Eutrophication can produce problems such as bad tastes and odours as well as green scum algae. Also, the growth of rooted plants increases, which decreases the amount of oxygen in the deepest waters of the lake. It also leads to the death of all
forms of life in the waterbodies.

- Organic inputs from the food industry, i.e., carbohydrates, lipids, and proteins, all impact lakes and rivers by increasing the biological oxygen demand. The worst-case scenario is the total loss of oxygen from the water as a result of microbial activity. Lipids create the greatest oxygen demand but carbohydrates (more easily biodegradable) also result in unsightly ‘sewage fungus’. Protein waste can be degraded to produce ammonia and sulphide, both of which produce toxicity problems.

- Acid precipitation is caused mainly by humans burning fossil fuels, which leads to increased sulphuric, and nitric acid in the atmosphere. Acidification of aquatic ecosystems impacts all aquatic organisms. Acid rain has major effects on biological systems ranging from altered microbial activity to the ability of fish to survive and reproduce.

Metals and other inorganic pollutants act as toxic pollutants in aquatic ecosystems. Metals can bioaccumulate in many organisms and can be bioconcentrated in trophic food chains. Bioconcentration has led to problems such as excessive lead and mercury contamination in fish. Atmospheric deposition and industrial waste releases, particularly mining are common sources of metallic contamination. Such mining activities have had extensive negative impacts in aquatic habitats. The inorganic inputs, particularly of phosphorus, stimulate undesirable algal growths, some of which may produce particularly dangerous toxins. Arsenic can cause problems because it can be present in high concentrations naturally or as runoff form industrial uses. Historically arsenic was also used as pesticide and subsequently contaminated aquatic ecosystems. Radioactive compounds can be contaminants in water. They usually occur naturally in water. The primary contaminants are isotopes of radium, radon, and uranium. The effects of natural radioactive materials on aquatic habitats are difficult to gauge. More than 10,000 organic pollutants have been created and used by man. Several hundred new chemicals are created each year and discharged by humans into the aquatic habitats, including pesticides, oil, and materials in urban runoff. Only a few of them have been tested for toxicity. In some cases microbes can break down these compounds through bioremediation in a given time. The effects of unregulated release of pollutants into large
ecosystems are exemplified by the experiences in the Great Lakes of North America. Worldwide, where, about 2.3 million metric tons of pesticides are used yearly. Petroleum products are another source of aquatic contamination. Urban runoff is a significant source of oil contamination. Chlorinated hydrocarbons such as poly-chlorinated biphenyl (PCBs) have carcinogenic properties. In addition to this many sewage treatment plants treat their final effluents with chlorine to kill all pathogens and this forms chlorinated hydrocarbons.

Turbidity and suspended solids are natural parts of all freshwater environments. Some are naturally highly turbid but human activities have increased the levels of suspended solids in many habitats. Agricultural and urban runoff, watershed disturbance such as logging, construction of roads, etc., removal of vegetation, alteration of hydrodynamic regimes can all lead to increase in the total suspended solids.

Sediments can have different biological and physical effects depending on the type of suspended solids. High values of suspended solids can lower the primary productivity of systems by covering the algae and macrophytes, at times leading to almost their complete removal. Thermal pollution can cause shifts in the community structure of aquatic organisms. This may allow for the establishment of exotic species and local extinction of native species. As water temperature increases, it makes it more difficult for aquatic life to get sufficient oxygen to meet its needs.

**Water Quality**

Water pollution may be defined as the presence of impurities in such quantity and of such nature as to impair the use of water for a stated purpose. Thus, the definition of water quality is predicted on the intended use of the water. Many parameters have evolved that qualitatively reflect the impact that various impurities have on selected water uses.

Many methods and criteria are available to assess aquatic ecosystems. A physico-chemical approach to monitor water pollution is most common and plenty of information is available on these aspects. Such data is valuable and necessary in the assessment of water quality of the waterbody.

**Physico Chemical Assessment**
Physical character of lakes such as size, depth, number and the size of inflowing and outflowing streams and shoreline configuration influence the character of the lake. They also influence decisions about sampling locations, water quality parameters and how to interpret data collected. Shallow lakes are more likely homogenous and water is well mixed by wind. Physical characters like the temperature and oxygen vary little with depth. Sunlight reaches all the way to the lake bottom, photosynthesis and growth occurs throughout the water column and thus the growth rate or productivity is higher.

Physical parameters define those characteristics of water that respond to the sense of sight, touch, taste or smell. Suspended solids, turbidity, colour, taste, odour and temperature fall under this category. Chemical parameters are related to the solvent capabilities of water. Total dissolved solids, alkalinity, hardness, fluorides, metals, organics, and nutrients are chemical parameters of concern in water-quality management. Some of the important physical and chemical parameters, few of which are estimated in this study are discussed below:

- **Temperature:**
  
  Temperature exerts a major influence on the biological activities and growth. To a certain point the increase in temperature leads to greater biological productivity, above and below which it falls and it also governs the species composition. At elevated temperatures metabolic activity of the organisms’ increases, requiring more oxygen but at the same time the solubility of oxygen decreases, thus accentuating the stress. Temperature influences water chemistry, e.g. DO, solubility, density, pH, conductivity etc. Water holds lesser oxygen at higher temperatures. Some compounds are more toxic to aquatic organisms at higher temperatures. Additionally temperature of drinking water has an influence on its taste. Temperature is expressed in Celsius and a thermometer- 0.1°C division is used to measure temperature.

- **pH:**
  
  pH – potential of hydrogen, is the measure of the concentration of hydrogen ions. It provides the measure of the acidity or alkalinity of a solution and is measured on a scale of 0 – 14. The pH of water is 7, which is neutral, and lower than 7 is acidic, while higher than 7 is termed as alkaline. The pH of water determines the solubility and biological availability of certain chemical nutrients.
such as phosphorus, nitrogen, carbon and heavy metals like lead, copper, cadmium, etc. pH determines how much and what form of phosphorus is most abundant in water. It also determines whether aquatic life can use the form available. In the case of heavy metals the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble in acidic waters. pH is measured on a scale of 0 – 14. pH of natural waters would be around 7, but mostly basic. pH of seawater is around 8.5. pH of natural water usually lies in the range of 4.4 to 8.5. BDH Indicator (Universal Indicator) and test tubes or a pH meter can be used to measure pH.

- **Dissolved oxygen:**

Sources of oxygen in water are by diffusion of oxygen from the air into the water, photosynthetic activity of aquatic autotrophs and inflowing streams. DO is a very important parameter for the survival of fishes and other aquatic organisms. Diffusion of oxygen or transfer of oxygen in these organisms is efficient only above certain concentrations of oxygen. Too low concentrations of oxygen may not be enough to sustain life. Oxygen is also needed for many chemical reactions that are important to lake functioning (oxidation of metals, decomposition of dead and decaying matter, etc.). Measurement of DO can be used to indicate the degree of pollution by organic matter. DO is expressed as mg/L. DO concentrations of below 5 mg/L may adversely affect the functioning and survival of biological communities. Below 2 mg/L may lead to fish mortality.

<table>
<thead>
<tr>
<th>D.O (mg/L)</th>
<th>Water quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 8.0</td>
<td>Good</td>
</tr>
<tr>
<td>6.5-8.0</td>
<td>Slightly polluted</td>
</tr>
<tr>
<td>4.5-6.5</td>
<td>Moderately polluted</td>
</tr>
<tr>
<td>4.0-4.5</td>
<td>Heavily polluted</td>
</tr>
<tr>
<td>Below 4.0</td>
<td>Severely polluted</td>
</tr>
</tbody>
</table>
Table 1- Dissolved oxygen level and water quality

- **BOD:**
  BOD is defined as the amount of oxygen required by the microbes while stabilizing the biologically decomposable organic matter in the water by aerobic condition. Since the decomposition is aerobic it is necessary to provide standard conditions of nutrient supply, pH, temperature etc.,

- **COD:**
  COD is the oxygen required by the organic substances in water to oxidise them by a strong chemical oxidant. The determination of COD values are of great importance where the BOD values cannot be determined accurately due to the presence of toxins and other such unfavourable conditions for growth of microorganisms. COD usually refers to the laboratory dichromate oxidation procedure. COD test has an advantage over BOD determination in that the result can be obtained in about 5 hours as compared to 5 days required for BOD test.

Impact of pollution on DO – BOD and COD: Pollution like sewage contributes oxygen demanding organic matter or nutrients that stimulate growth of organic matter, which causes a decrease in the average DO concentrations. The decomposition process takes up the DO and results in the decrease in average DO. If the organic matter is formed in the lake by algal growth, at least some oxygen is produced during growth to offset the loss of oxygen during decomposition. It is expressed as mg/L and the analysis is done in the laboratory

- **MPN**
  Coli form bacteria are indicators of faecal contamination. Hence the water is not potable.
STUDY AREA

1. Ulsoor lake

Halasuru Lake or Ulsoor Lake is one of the biggest lakes in Bengaluru, is located on the eastern side of the city, on the northeastern fringe of the city center, near the busy M. G. Road. It derives its name from the name of the locality it is situated, namely, Ulsoor, close to M G Road, Bangalore. It is spread over 50 ha (123.6 acres) and has several islands.

The present study area, Ulsoor lake is situated in Bangalore city, located at latitude 12° 8' N and longitude 77° 37' E. The mean temperature in the warmest month, April is 27° C and coldest month, January is 20° C, and seldom falls below 15° C (December, January, and February are winter months). The mean value of the relative humidity is 63%. Bangalore benefits from both the Southwest and Northeast monsoons. The average annual rainfall is 87 centimeters. Monsoon is from October to November and dry months are from December to March.

Ulsoor Lake is lavishly spread across an area of 50 hectares. Initially the lake was known by a separate name, the 'Halsur' or the 'Alasur'. Situated in the northeastern fringes of the city, the lake can be easily accessed from all parts of Bangalore. Various activities can be enjoyed in the Ulsoor Lake. The lake has a recreational complex that has a swimming pool. There is also a garden at one end of the lake known as 'Kensington Park'. The most fascinating part of the Ulsoor Lake of Bangalore is that there are many islands that are spread across the lake. Tourists can reach these islands via boating. The Boat Club at the lake offers wonderful boating facilities to the visitors.

This waterbody of 50 hectares was built by the family of Kempegowda II in 17th and 18th centuries, for drinking and irrigation, and is located in the middle of the city. In early 19th century, the lake was the major source of drinking water for the cantonment area and troops. The Ulsoor lake drain enters the lake in the north and excess water overflows from the southeast canal. It is estimated that around 4 to 6 feet of sediment has accumulated over a period in the lake. The current depth ranges from approximately 6 to 7 feet in the middle and 3 to 4 feet in the periphery. The catchment area of Ulsoor lake is 1.5 km².

The lake has been subject to severe pollution and efforts were made in the recent years to rejuvenate this lake. Some of the recent efforts to this end were:

- On Thursday, Feb 11, 2010, as part of a cleanup drive by the Global Academy of Technology and Bale Com Tech and Biotechnology, 3,000 litres of an activated microbe solution were sprayed to cleanse it of the odour and slime.
• On Sunday 19 September 2010 to reduce pollution level in Ulsoor Lake, Bale Com Tech and Biotechnology and Global Academy of Technology sprayed at least 7,500 litres of Maple em.1, an organic effective micro-organisms solvent

Lake Profile

Location: Bangalore District, Karnataka
Coordinates: 12°58′53.3″N 77°37′9.17″E / 12.981472°N 77.6192139°E / 12.981472; 77.6192139
Lake type: Freshwater
Primary inflows: Rainfall and city drainage
Primary outflows: Nala
Catchment area: 1.5 km2 (0.6 sq mi)
Basin countries: India
Surface area: 50 ha (123.6 acres)
Average depth: 19 ft (5.8 m)
Max. depth: 58 ft (18 m)
Shore length1: 3 km (1.9 mi)
Surface elevation: 931 m (3,054.5 ft)
Islands: several islands
Settlements: Bengaluru
Three sampling spots were selected for the study along the perimeter of the lake:

1. Near the Bangalore tamil sangam
2. Near bobby’s dhaba
3. Ulsoor cooperation swimming pool
Map 2- Site1. Near the Bangalore tamil sangam

Map 3- Site2. Near bobby’s dhaba
Geographically, the study area is located between 77° 35´ west and 77° 45´ east and latitude 12° 50´ south and 13° 00´ north (toposheet 57 H/9, scale: 1:50,000). The over all catchment area is about 287.33 sq. km with a water spread area of 361 ha (Water Resources Department, 2003). The terrain of the region is relatively flat and sloping towards south of Bangalore city. Relative slope of the region is found to be very gentle to gentle slope. The relative contour height is 930 m above mean sea level and the lowest is 880 m. The height is found to be 870 m above mean sea level near the tank. Three main streams join the tank, which form the entire watershed. One of the streams originates at the northern part of the region, Jayamahal and covers the eastern portion and is referred to as the eastern stream. Another stream originates from the central part of the city, Krishna Raja Market and covers the central part of the region before joining the tank and is called the central stream. Another stream commands southwestern part of the region called the western stream. Further, before the confluence with Bellandur Tank, all the streams come across two to three tanks (Sreekantha and Narayana, 2000). The rainfall data is available for the last 100 to 110 years.
Rainfall varies from 725.5 mm to 844.8 mm. The district receives 51% of the total annual rainfall in the southwest monsoon period, i.e. June to September. The average annual rainfall in the catchment was 859 mm in 1999. April is usually the hottest month with the mean daily maximum and minimum temperature of 33.4°C and 21.2°C respectively. December is generally the coolest month with the mean daily maximum and minimum temperature of 25°C and 15.3°C respectively. The temperature drops down to 8°C during January nights. Relative humidity is high from June to October (80 to 85%). Thereafter, it decreases and from February to April becomes 25 to 35%. The relative humidity in the morning is higher than in the evening, giving rise to the formation of fog.

It is the largest lake in east Bangalore. Bellandur Lake is 130 years old and spreads across an area of 892 acres. Bellandur tank is part of the Bellandur drainage system that drains the southern and the southeastern parts of the city. The tank is a receptor from three chains of tanks. One chain, originates in the north, from Jayamahal, covers the eastern portion and has been referred to as the eastern stream. Another chain originates from the central part of the city, from around the K.R. Market area and covers the central portion and is called the central stream. The other chain, that reaches the tank is through the southwestern region and is called the western stream. The catchment area of Bellandur tank is an area of about 148 sq kms. Water from this tank flows further east to the Varthur tank, from where it flows down the plateau and eventually into the Pinakani river basin.

In 1970s people from as many as 18 villages depended on the waters of Bellandur tank to lead their lives. Due to urbanization in 1980s, there was breakage of chains of tanks feeding the lake. The breakage in chains, unchecked industrial, residential as well as commercial development, resulted in insufficient rainwater reaching the tank and excess untreated sewerage and effluents laden water flow to the tank. This further led to a decrease in aquatic life.

Presently a large part of the Bellandur tank is covered by weeds. The colour of the water is dark and opaque in appearance. There is also a foul stench coming from it. There are hardly any birds visible near the tank. At the outlets, downstream of the lake, heavy foaming is visible, indicative of the presence of effluents.

In 1996, PIL was filed by the Bellandur gram panchayat approached the High court to prevent the pollution of the lake. The sewage treatment plant at the inflow of the lake was upgraded as a result.

In 1997, fishermen groups from Yemlur, Kempapura and nearby places petitioned against the then Chief Minister of the state as the polluted lake affected the fish population. The petition passed on to the fisheries department who released baby fish into lake for increasing their numbers, these fishlings did not survive due to heavy pollution. In 1999, the High Court ordered the BWSSB to supply potable water to residents in Bellandur and proper treatment of the sewage in the STP. Following the authorities’ lack of
compliance to the HC directives, another petition on contempt of court was filed. The case is still pending before the Lok Adalat. In 2006, Right To Information (RTI) activist C.H. Ram placed application to the Tashilder East and Minor Irrigation department for cleaning of the lakes. He even applied to the Deputy Commissioner (Urban) of Bangalore district and Karnataka Information Commission (KIC). Till date he did not receive any response.

This Lake has been subjected to more than one-third of the domestic sewage (about 400+ MLD) generated in Bangalore city is on the verge of an imminent ecological disaster. The Bellandur Lake has to bear the natural drainage that flows into the lake from all these wards including both storm water and sewerage water. The urbanisation in Bellandur Lake catchment has been evident from the population prevalent in the region. It is observed that the population in the lake catchment under the municipal limits is about 1721779 persons as per the 2001 census. This is almost one-third of the Bangalore city’s population for which the lake catchment is catering to. With the natural topography of the catchment sloping towards the lake in the entire catchment, any storm water run off eventually makes its way into the lake. Further, with the increased presence of urban areas in the catchment, the lake is also receiving wastewater generated in these areas that flow along the natural drainage.

Wastewater Treatment Scenario in the Catchment

Bangalore Water Supply and Sewerage Board (BWSSB) is the nodal agency for Bangalore city to manage the water supply and wastewater collection, treatment and disposal. The wastewater is collected according to the three important drainage basins, Hebbal valley, Vrishabhavathi and Koramangala and Challaghatta valley (K&C valley). The K&C valley essentially comprises the northern and eastern part of the Bellandur Lake catchment.

Lake Profile

Location Southeast of Bengaluru city
Coordinates: 12°58′N 77°35′E / 12.967°N 77.583°E / 12.967; 77.583
Coordinates: 12°58′N 77°35′E / 12.967°N 77.583°E / 12.967; 77.583
Primary inflows Sewage from Bengaluru city
Primary outflows Varthur Lake
Catchment area 148 km²
Max. length 3.6 km
Max. width 1.4 km
Surface area 3.61 km²
Surface elevation 921 m
Frozen Never
Settlements Bangalore

Three sampling spots have been considered:

1. National Aerospace Laboratories
2. Eidgah and masjith E Bilal
3. Sobha dahlia
The Madivala Lake is located in Bangalore south between Bannerghatta road and Hosur road covering an extent of 272 acres (110.07 ha) (table 3.2). The water-spread area is about 200 acres (80.93 ha) and the wetland area is about 72 acres (29.13 ha). Earlier the lake formed an important landmark of the city and had a wide catchment area, which filled to the maximum water level every monsoon. (Figure 3.3). Madiwala Lake receives water
from two lakes Hulimavu and Jaraganahallikere on the upstream. With a large catchment area spread into the Hulimavu valley and Jaraganahallikere, Madiwala Lake has the capacity to fill up to the maximum during a good monsoon season and helps with the important wetland functions of recharging of the sub-soil ground water table around the area. Lately the holding capacity of the lake is considerably reduced due to the blockage of the inflowing channels, illegal encroachments in the catchment area, etc.

Sewage water has become the only major source of inflow into the lake, which has led to a drastic change in the water quality. The lake has a STP (sewage treatment plant) of 4 million litres per day (mld) capacity (total amount of sewage produced in the area is around 12 mld) on the south west end, which treats a portion of the inflowing sewage and the remaining sewage is let into the sewage diversion channels untreated, which is on the eastern side of the lake. There is a storm water drain towards the north side near the bund region. The lake is fenced with barbed wires and on the western side of the lake is a walk path, which was developed during the restoration of the lake. During this study the fencing was incomplete on the northern side, which paves way for people to dump garbage and filth into the lake. The adjoining slum dwellers have converted this side of the shore into a major defecating zone. The lake also allows for fishing and the fisheries department undertakes this. The Karnataka State, Forest department and the Lake Development Authority, under the Indo-Norwegian Environment Programme had undertaken restoration of the lake in the year 2000 and today Madiwala Lake is a popular recreational spot, with boating facilities and bird watching.

Construction activities in the catchment area have increased dramatically over the last few decades due the pressure of urbanisation and pressure on land. The area has been converted into huge residential and commercial properties without providing for the basic amenities and infrastructure. With this, Madiwala Lake perhaps became the most convenient site to dump the construction debris and sewage. During the monsoons, the excess storm waters choke the drains and the weir at the outlet is blocked leading to the mixing of the sewage with the storm water, which eventually finds its way into the lake. The depth of the lake has also decreased due to the increased sedimentation, thus reducing the capacity of the lake. As a result of the increased pollutants there is proliferation of rooted aquatic plants and water hyacinth. The weed growth prevents surface aeration and penetration of sunlight, which in turn affects the dissolved oxygen content in the lake and consequently influencing the biodiversity of the lakes’ flora and fauna. The proliferating growth of weeds also contributes to the spread of mosquitoes and water borne diseases.
The Lake Development Authority's (Karnataka) website states that “Madivala Lake was subjected to intense pollution, with the blockage of inflow channels, encroachments into the catchment area and inflow of sewage water. All these had transformed the lake into a very large sewage pool. Madiwala Lake, which was once, a fresh water tank, was fully covered with thick growth water hyacinth, thus preventing aeration and affecting the bio-diversity of flora and fauna. Presently the lake is restored under Indo-Norwegian Environment Programme (INEP) and is in good condition. The sewage treatment plant near the lake is not fully functional. The BWSSB has made a canal to let sewage water into the lake.

Lake Profile

Location Begur hobli, Bangalore south
Extent
272 acres (110.07 ha)
Water spread area
200 acres (80.93 ha)
Wetland area
72 acres (29.13 ha)
STP capacity
4 mld
Total sewage inflow
Approx 12 mld
Main inflows (south and southwestern sides)
Hulimavu, Sarakki and Jarganahalli
Outflows (north and north eastern side)
Agaram lake and Bellandur lake
Catchment areas
Rupena agrahara, bommanahalli, J.P.Nagar, Jayanagar, bilakahalli, hulimavu, madiwala, kodi chikkanahalli, devarchikkannahalli, dorasamipalya
Lake surrounds
♦ Rupena agrahara slum on the south eastern side
♦ BDA layout on the northeastern side
♦ STP of 4-5 mld capacity near south west end
♦ Mud walk path & entrance to the lake on the western side

Map7- Madivala Lake

3 Sampling sites were chosen for the study:
1. Childrens park
2. Corporation bank branch
3. Presidency school Bangalore south
Map8 Site 1 Childrens play area
4. Sankey Tank

Sankey tank, a manmade lake or tank, is situated in the western part of Bangalore in the middle of the suburbs of Malleshwaram, Vyalikaval and Sadashiva Nagar. The lake covers an area of about 15 ha (37.1 acres). At its widest, the tank has a width of 800 m (2,624.7 ft).

Sankey tank was constructed by Col. Richard Hieram Sankey (RE) of the Madras Sappers Regiment, in 1882, to meet the water needs as Gandhadhakotikere, as the Government Sandalwood Depot used to be located near the lake.
Sankey reservoir was constructed in 1882 and the works cost Rupees 575000. It was linked to the Miller's tank and Dharmambudhi tank and was built as a safeguard against water shortages, such as that experienced in the Great Famine of 1875-77.

The tank was converted into a park by the Bangalore Water Supply and Sewerage Board (BWSSB) and the Bangalore Mahanagara Palike (BMP) with funds provided by the Government of Karnataka.

Lake Profile

Location Bangalore District, Karnataka
Coordinates 13°01′N 77°34′E / 13.01°N 77.57°E / 13.01; 77.57
Lake type Freshwater
Primary inflows Rainfall and city drainage
Catchment area 1.254 km (0.8 mi)
Basin countries India
Surface area 15 ha (37.1 acres)
Max. depth 9.26 m (30.4 ft)
Shore length 1.7 km (1.1 mi)
Surface elevation 929.8 m (3,050.5 ft)
Islands 1 Settlements
Bengaluru

5. Shasthamcotta kayal

Sasathamkotta Lake, also categorized as a wetland, is the largest fresh water lake in Kerala, a state of India on the south of the West Coast. The lake is named after the ancient Sastha temple (a pilgrimage centre) located on its bank. It meets the drinking water needs of half million people of the Quilon district and also provides fishing resources. The purity of the lake water for drinking use is attributed to the presence of large population of larva called cavaborus that consumes bacteria in the lake water. The lake is a designated wetland of international importance under the Ramsar Convention since November 2002.
The Lake is located at a distance of 29 km from Quilon city, which is on the left bank of Ashtamudi Lake. Thiruvananthapuram International Airport, at 105 km, is the nearest airport to Kollam. Karunagapally, at a distance of 2 km, is the closest town to the lake. A ferry service across the lake transports people between West Kallada and Sasthamkotta.

Except for an earthen embankment of 1.5 km length which separates the lake from the paddy fields on its southern side, bordering the alluvial plains of the Kallada River, all other sides of the lake are surrounded by hills which are steep and form narrow valleys. In the south and southwestern parts of the Lake there are a number of smaller water bodies and waterlogged areas. The present area of the lake is 375 ha since large part of the lake is reported to have been occupied for agriculture. Rock formation of mainly archaean origin are recorded with intrusions of charnockite, biotite gneiss and dolerite dyke rocks. The Tertiary Varkala formations are observed along the coastal beds. In the valley portion, sand and silt deposits are recorded. Geomorphological divisions of the basin area of the lake comprise a) the undulating uplands which have fairly thick vegetation of mixed crops and plantations, b) the valley fills of laterite alluvium and colluvial deposits with low level areas which are intensely cultivated and thickly populated and c) the Flood Plains/Alluvial plains of the Kallada River on the south that are mostly cultivated.

There are no visible tributaries feeding the lake but springs at the bottom of the lake are stated to be one of the source which supply water throughout the year; volume of water in the lake is estimated to be of the order of 22.4 million cum. A thick 10–20 m mantle of Kaolinite rich (derivative of laterite) soil around the lake is stated to check flow into the lake and the theory is now that the Lake is also rain fed; the lake water level is recorded to be higher at the end of the monsoon season. The average annual rainfall in the area is 2398 mm and mean annual temperature varies between 26.70 C and 29.160 C. Ground Water table in the area is reported at depth of 3.89 m. After accounting for estimated evaporation loss of 5 Mm3 and water utilized for domestic use of 8 Mm3 (at a pumpage rate of 22 MLD), the two together account for about two-thirds of the inflow.

Location Kerala
Coordinates  9°02′N 7°38′E / 9.03°N 76.63°E / 9.03; 76.63
Coordinates:  9°02′N 7°38′E / 9.03°N 76.63°E / 9.03; 76.63
Catchment area 12.69 km2
Basin countries India
Surface area 373 ha
Average depth 6.53m
Max. Depth 15.2m
Water volume 22.4 M.m3
Surface elevation 33m

Settlements Karunagapally and Sasthamkotta
3 sampling spots were taken:
1. Sasthamcotta temple
2. Brooke international school
3. Chavara Pattakadavu road

Map11- Sathamkotta Kayal

Map12- Site 1 Sasthamcotta temple
Map 13- Showing Site 2. Brook International school and Site 3. Chavara Pattakadavu Road

Lake profile of the five selected lakes

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Ulsoor Lake</th>
<th>Bellandur Lake</th>
<th>Madiwala Lake</th>
<th>Sankey Tank Lake</th>
<th>Sasthamkotta Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Bangalore District, Karnataka</td>
<td>Southeast of Bengaluru city</td>
<td>Begur hobli, Bangalore south</td>
<td>Bangalore District, Karnataka</td>
<td>Kerala</td>
</tr>
<tr>
<td>Coordinates</td>
<td>12°58'53.3&quot;N 77°35'E / 12.967°N 77.583°E / 12.967; 77.583</td>
<td>12°58'N 77°35'E / 12.967°N 77.583°E / 12.967; 77.583</td>
<td>12.92°N</td>
<td>13.01°N</td>
<td>9°02'N 7°38'E / 9.03°N 76.63°E / 9.03; 76.63</td>
</tr>
<tr>
<td>Coordinates</td>
<td>77°37'9.17&quot;E</td>
<td>12°58'N</td>
<td>77.62°E</td>
<td>77.57°E</td>
<td>9°02'N 7°38'E /</td>
</tr>
<tr>
<td>Lake type</td>
<td>Freshwater</td>
<td>Freshwater</td>
<td>Freshwater</td>
<td>Freshwater</td>
<td>Freshwater</td>
</tr>
<tr>
<td>----------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>Primary inflows</td>
<td>Rainfall and city drainage</td>
<td>Sewage from Bengaluru city</td>
<td>(south and southwestern sides) Hulimavu, Sarakki and Jarganahalli</td>
<td>Rainfall and city drainage</td>
<td>-</td>
</tr>
<tr>
<td>Primary outflows</td>
<td>Nala</td>
<td>Varthur Lake</td>
<td>(north and north eastern side) Agaram lake and Bellandur lake</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Catchment area</td>
<td>1.5 km² (0.6 sq mi)</td>
<td>148 km²</td>
<td>72 acres (29.13 ha)</td>
<td>1.254 km (0.8 mi)</td>
<td>12.69 km²</td>
</tr>
<tr>
<td>Basin countries</td>
<td>India</td>
<td>India</td>
<td>India</td>
<td>India</td>
<td>India</td>
</tr>
<tr>
<td>Surface area</td>
<td>50 ha (123.6 acres)</td>
<td>3.61 km²</td>
<td>200 acres (80.93 ha)</td>
<td>15 ha (37.1 acres)</td>
<td>373 ha</td>
</tr>
<tr>
<td>Average depth</td>
<td>19 ft (5.8 m)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6.53 m</td>
</tr>
<tr>
<td>Max. depth</td>
<td>58 ft (18 m)</td>
<td>-</td>
<td>-</td>
<td>9.26 m (30.4 ft)</td>
<td>15.2m</td>
</tr>
<tr>
<td>Shore length</td>
<td>3 km (1.9 mi)</td>
<td>3.6 km</td>
<td>-</td>
<td>1.7 km (1.1 mi)</td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>931 m (3,054.5 ft)</td>
<td>921 m</td>
<td>-</td>
<td>929.8 m</td>
<td>33 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>elevation</td>
<td>(ft)</td>
<td></td>
<td>(3,050.5 ft)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Islands</td>
<td>several islands</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Settlements</td>
<td>Bengaluru</td>
<td>Bengaluru</td>
<td>Bengaluru</td>
<td>Bengaluru</td>
<td>Karunagapally and Sasthamkotta</td>
</tr>
</tbody>
</table>
METHODOLOGY

Physico Chemical analysis of samples collected at the five Study areas selected were conducted. The following parameters were considered:

1. Temperature
2. pH
3. DO
4. BOD
5. COD
6. Feecal colliform

The following were the experiments conducted to determine the selected parameters:

1. Temperature

Temperature is one of the most important parameters that influence almost all the physical, chemical and biological properties and thus the water chemistry.

Apparatus required: The temperature is measured in the field using a thermometer with 0.1°C division on a Celsius scale. For measuring the temperature of open waterbody, the thermometer is dipped directly into the water and the reading is taken while it is in the waterbody.

Procedure: Thermometer is immersed directly in the waterbody for a period of time sufficient to permit constant reading. While collecting the sample, care was taken that it is not exposed to heat or direct solar radiation.

2. pH – potential of hydrogen, is the measure of the concentration of hydrogen ions. It provides the measure of the acidity or alkalinity of a solution.

Apparatus required: An electronic probe or a pH meter, which also measures, TDS and conductivity, and is used to measure pH at a scale of 0 – 14.

Procedure: Immerse the probe directly in the water collected in a wide mouthed sampling bottle at the sampling site immediately after collection for a period of time sufficient to permit constant reading.
3. Dissolved oxygen

DO content indicates the health and ability of the waterbody to purify itself through biochemical processes. DO is a very important parameter for the survival of fishes and other aquatic organisms.

Sampling: Samples from surface waters is collected in narrow mouthed bottles with glass-stopper. It is important not to let the sample remain in contact with air, air bubbles to be formed or to be agitated, because either condition can cause a change in its gaseous content. The bottles should be filled to overflow and stoppered. Entraining or dissolving atmospheric oxygen should be avoided. DO should be determined immediately on the sampling site.

Method: Winkler’s method. Titration.

Principle: Oxygen present in the sample oxidises the dispersed divalent manganous hydroxide to the higher valency to precipitate as a brown hydrated oxide after addition of potassium iodide and sodium hydroxide. Upon acidification, manganese reverts to its divalent state and liberates iodine from potassium iodide, equivalent to the original dissolved oxygen content of the sample. The liberated iodine is titrated against 0.025N sodium thiosulphate using fresh starch as an indicator.

Apparatus required: BOD bottles-125 ml capacity, lab glassware - measuring cylinder, conical flasks, analytical balance, glass rods and Bunsen burner.

Reagents:
- Manganese sulphate: 480 g of manganous sulphate tetra hydrate is dissolved and made up to 1000 ml with distilled water
- Conc. sulphuric acid
- Starch indicator: 0.5 g of starch is dissolved in glycerine and boiled for few minutes. Once cooled 2 drops of formaldehyde is added as a preservative.
- Stock sodium thiosulphate: 24.82 g of sodium thiosulphate pentahydrate (Na2S2O2. 5H2O) is dissolved in distilled water and made up to 1000 ml.
- Standard sodium thiosulphate (0.025N): 250 ml of the stock sodium thiosulphate pentahydrate is made up to 1000 ml with distilled water to give 0.025N.

Procedure: The sample is collected in BOD bottles (125 ml), to which 2ml of manganous sulphate and 2ml of potassium iodide are added and sealed. This is mixed well and the precipitate allowed to settle down. At this stage 2ml of conc. sulphuric acid is added, and
mixed well until all the precipitate dissolves. 25 ml of the sample is measured into the conical flask and titrated against 0.025N sodium thiosulphate using starch as an indicator. The end point is the change of colour from blue to colourless. The amount of titrant consumed gives the direct reading for DO in ppm. DO is calculated using the following formula.

Estimation:

\[
\text{DO (mg/L)} = (\text{ml} \times \text{N}) \times 8 \times 1000 / \left( \frac{\text{V2}}{\text{V1}} \right) - \frac{\text{v}}{\text{V1}}
\]

Where, 
- \( V2 \) = volume of the part of contents from the sample bottle titrated 
- \( V1 \) = volume of the sample bottle 
- \( v \) = volume of added 
- \( N \) = normalcy of sodium thiosulphate

4. **BOD**

BOD is defined as the amount of oxygen required by the microbes while stabilizing the biologically decomposable organic matter in the water by aerobic condition. Since the decomposition is aerobic it is necessary to provide standard conditions of nutrient supply, pH, temperature etc., Water should be collected in BOD bottle without bubbling and is incubated for 3 days. After incubation, 0.7ml of H2SO4 is added into the sample. 2ml of MnSO4 is added and shaken upside down. 2ml of azide solution is added and is again shaken upside down. The precipitate is allowed to settle down. 0.7ml of H2SO4 is again added to dissolve the precipitate formed.

30ml of this sample is taken in a conical flask and is titrated against 0.025N Na2SO3 taken in a burette until a straw yellow precipitate appears. Few drops of starch indicator are added and titration is continued until the deep blue color disappears. Initial and final burette readings were noted down. The dissolved oxygen was calculated using the standard formula,

\[
\text{DO in Mg/ml} = \frac{8 \times 1000 \times \text{N} \times \text{v}^2}{\text{V1}}
\]

BOD=DO of immediate collected water sample-DO of incubated distilled water sample.

5. **COD**

COD is the oxygen required by the organic substances in water to oxidise them by a strong chemical oxidant. This shows the oxygen equivalent of the organic substances in water that can be oxidised by a strong chemical oxidant such as potassium dichromate in acidic solution. The determination of COD values are of great importance where the BOD values
cannot be determined accurately due to the presence of toxins and other such unfavourable conditions for growth of microorganisms the COD usually refers to the laboratory dichromate oxidation procedure.

Method: Open reflux method using potassium dichromate.

Principle: COD is the measure of oxygen consumed during the oxidation of the oxidisable organic matter by a strong oxidising agent. Potassium dichromate (K2Cr2O7) in the presence of sulphuric acid is generally used as an oxidising agent in the determination of COD. The sample is treated with potassium dichromate and sulphuric acid and titrated against ferrous ammonium sulphate (FAS) using ferroin as an indicator. The amount of K2Cr2O7 used is proportional to the oxidisable organic matter present in the sample.

Apparatus: Conical flasks, measuring cylinder, Nessler's tubes, standard flasks, pipette, micropipette, titration burette, glass rods and analytical balance.

Reagents:

♦ FAS (ferrous ammonium sulphate or Mohr's salt) 0.1 N: 8.07 g of ammonium ferrous sulphate is dissolved in a little distilled water, to which 5 ml conc. H2SO4 is added. This is allowed to cool and then diluted and made it up to 250 ml in a standard flask

♦ (K2Cr2O7) Potassium dichromate 1 N (stock): 4.90 g of potassium dichromate, is dissolved in distilled water and made up to 100 ml in a standard flask

♦ Potassium dichromate 0.025 N: 25 ml of Potassium dichromate 1 N is taken and made up to 1000 ml with distilled water

♦ Ferroin indicator: 0.69 g of Ferrous sulphate and 1.4 g of phenanthroline monohydriate is dissolved in distilled water and made up to 100 ml.

Procedure:

♦ 0.1 N FAS is standardised and the normality value of the prepared reagent is calculated using the formula N (FAS) = V (K2Cr2O7) * N (K2Cr2O7) / V (FAS). The value thus got will be the normality of the FAS prepared and it is supposed to be closer to the normality required for the COD analyses, i.e. 0.1

♦ 10 ml of each sample and a blank is taken in conical flasks

♦ 10 ml K2Cr2O7 is added to this

♦ 15 ml of conc. H2SO4 is added carefully from the sides of the flask, allowed to cool, digested for about 30 minutes.

♦ To this 50 ml distilled water and 5 drops of ferroin indicator is added

♦ This is titrated with FAS in a burette carefully till the orange turns bluish green
to wine red (deeper wine red indicates high COD) and the amount of titrant consumed is noted.

Estimation: COD value is calculated using the formula:

\[(\text{Volume of titrant used in blank} - \text{volume of titrant used in sample}) \times N \times 8 \times 1000 / \text{volume of sample taken}.\]

6. MPN

Coliform bacteria are indicators of faecal contamination. Hence the water is not potable. The estimation of coliform bacteria is carried out sequentially in 3 steps.

1. Presumptive test: This test is used to detect and estimate coliform bacterial population in water sample. The test is known as positive presumptive test because of the development of a positive result in Mac Conkey broth which is a selective media for E-coli.

In this test known volume of sample is taken and the change in the color in the broth due to the production of acid indicates a positive result. A statistical method is used to estimate the presence of population of coliform bacteria expressed as the Most probable Number.

2. Confirmed test: This test is used to confirm the presence of coliform bacteria in water sample showing positive or doubtful presumptive test. In the confirmed test sample from the Mac Conkey broth are introduced into brilliant green like broth or streaked on Eosin Methylene Blue plates. The positive result is seen by the change in brilliant color of the brilliant green like both and production of gas. While on EMB media, the growth of only lactose fermenting bacteria is seen, i.e., it is specific for coliforms. E coli form a characteristic metallic sheen on the surface of colonies.

3. Completed test: Isolated coliforms from petriplates are transferred into lactose fermentation broth and streaked onto agar slant. The presence of gas in fermentation broth and presence of gram negative non spore forming bacilli on the slant gives evidence that coliform bacteria were present in original water sample.
OBSERVATIONS

Table 2: Physico chemical analysis of Ulsoor lake samples

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Sampling sites</th>
<th>Temperature</th>
<th>PH</th>
<th>DO</th>
<th>BOD</th>
<th>COD</th>
<th>Feacal Coliform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site 1</td>
<td>28</td>
<td>6.8</td>
<td>7.0</td>
<td>3.0</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Site 2</td>
<td>28</td>
<td>9.5</td>
<td>7.0</td>
<td>3.0</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Site 3</td>
<td>28</td>
<td>8.0</td>
<td>7.0</td>
<td>3.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3: Physico chemical analysis of Belandur lake samples

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Sampling sites</th>
<th>Temperature</th>
<th>PH</th>
<th>DO</th>
<th>BOD</th>
<th>COD</th>
<th>Feacal</th>
</tr>
</thead>
</table>

Table 4: Physico chemical analysis of Madiwala lake samples

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Sampling sites</th>
<th>Temperature</th>
<th>PH</th>
<th>DO</th>
<th>BOD</th>
<th>COD</th>
<th>Feacal Coliform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site 1</td>
<td>29</td>
<td>8.2</td>
<td>6.1</td>
<td>79</td>
<td>102</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Site 2</td>
<td>29</td>
<td>9.0</td>
<td>6.0</td>
<td>82</td>
<td>99</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Site 3</td>
<td>29</td>
<td>7.4</td>
<td>6.0</td>
<td>80</td>
<td>98</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 5: Physico chemical analysis of Sankey tank samples

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Sampling sites</th>
<th>Temperature</th>
<th>PH</th>
<th>DO</th>
<th>BOD</th>
<th>COD</th>
<th>Feacal Coliform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site 1</td>
<td>28</td>
<td>8.0</td>
<td>6.5</td>
<td>72</td>
<td>88</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Site 2</td>
<td>28</td>
<td>7.9</td>
<td>6.6</td>
<td>72</td>
<td>87</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Site 3</td>
<td>28</td>
<td>7.8</td>
<td>6.6</td>
<td>73</td>
<td>89</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 6: Physico chemical analysis of Sasthankotta lake samples

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Sampling sites</th>
<th>Temperature</th>
<th>PH</th>
<th>DO</th>
<th>BOD</th>
<th>COD</th>
<th>Fecal Coliform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site 1</td>
<td>24</td>
<td>6.4</td>
<td>6.2</td>
<td>0.8</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Site 2</td>
<td>25</td>
<td>6.8</td>
<td>7.6</td>
<td>1.2</td>
<td>12</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Site 3</td>
<td>25</td>
<td>6.7</td>
<td>6.9</td>
<td>0.9</td>
<td>12</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 7: Comparison of physico chemical analysis of different lakes

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Name of lake</th>
<th>Temperature</th>
<th>PH</th>
<th>DO</th>
<th>BOD</th>
<th>COD</th>
<th>Fecal</th>
</tr>
</thead>
</table>

22nd-24th December 2010
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Coliform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ulsoor lake</td>
<td>28</td>
<td>8.7</td>
<td>7.0</td>
<td>3.0</td>
</tr>
<tr>
<td>2</td>
<td>Belandur Lake</td>
<td>28</td>
<td>6.6</td>
<td>3.4</td>
<td>85.3</td>
</tr>
<tr>
<td>3</td>
<td>Madiwala Lake</td>
<td>29</td>
<td>8.2</td>
<td>6.0</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>Sankey tank</td>
<td>28</td>
<td>7.9</td>
<td>6.6</td>
<td>72</td>
</tr>
<tr>
<td>5</td>
<td>Sasthamkotta Lake</td>
<td>25</td>
<td>6.6</td>
<td>6.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Fecal coliform: (+) present, (-) absent

The physio chemical analysis of these lakes shows that

- Bellandur lake has the highest content of organic matter present which is followed by Madiwala and Sankey tank. Ulsoor lake has a comparatively lower organic matter content and Sasthamkotta lake had the least.

- Ulsoor lake, Madiwala and Sankey tank was found having a basic pH where as Bellander lake and Sasthamkotta lake were found having an acidic pH.

- The temperature for Ulsoor, Bellandur, Madiwala and Sankey tank were found to be almost the same but the temperature of Sasthamkotta lake was comparatively lower.

- The DO was found almost the same for all the lakes except for Bellandur lake which showed a marked reduction.

- Fecal coliform was noted in all five lakes.

CONCLUSION
Bellandur lake is part of the Bellandur drainage system that drains the southern and the Southeastern parts of the city.

Bellandur lake was found containing the highest organic matter content. This may be explained by the high population density in the catchment area and consequently the large quantity of sewage produced by the settlement. Also the topography of the land is such that the slope is towards the lake allowing the runoff to flow into the lake leading to further contamination. Further the sewage treatment plant situated in the area may not be functioning efficiently and much of the sewage is being released into the water after no or insufficient treatment. The sewage flowing in comprises mostly of domestic sewage. The DO is also very low. This may be because of the aquatic vegetation choking the lake or eutrophication. The inflow of urban runoff and the domestic sewage adds to the phenomenon of eutrophication in the lake. The acidic pH is also indicative of contamination. The presence of faecal coliform also confirms the presence of domestic sewage in the lake.

Ulsoor lake, Madiwala Lake and Sankey tank are lakes used for recreational purposes. Madiwala and Sankey Tank are of approximately the same levels of organic matter content while Ulsoor Lake has lower levels of contamination by organic matter this may be so because Ulsoor Lake was recently cleaned up as part of government initiatives. A similar trend was seen in the dissolved oxygen levels, while Madiwala and Sankey lakes showed a lower value of DO Ulsoor lake showed a higher level of DO which goes to show that the solvent treatment and activated microbe treatment have indeed proven effective.

Sasthamkotta Lake meets the drinking water needs of half million people of the Quilon district and also provides fishing resources. It showed a high DO and low BOD which shows that the contamination level in the waters is low. The purity of the lake water for drinking use is attributed to the presence of large population of larva called cavaborus that consumes bacteria in the lake water.
RECOMMENDATIONS

Bellandur Lake:
1. Upgrading of sewage treatment plant and proper monitoring of the process
2. Clearing up of the weeds and aquatic vegetation choking the Lake.
3. Employing methods like solvent treatment and activated microbe treatment as in the case of Ulsoor Lake to remove organic matter.
4. Applying techniques of bioremediation to rejuvenate the Lake.

Madivala and Sankey Lake:
1. Employing methods like solvent treatment and activated microbe treatment as in the case of Ulsoor Lake to remove organic matter.
2. Clearing up of the weeds and aquatic vegetation choking the Lake.

Ulsoor Lake and Sasthamkotta Lake:
1. Maintaining these Lakes without further pollution.