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Ecological Assessment and Conservation Strategies of Yele Mallappa Shetty Lake in Bengaluru, India

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Abstract: ***At present the human race is staring at the threat from global warming and climate and at this point of time, the need for conservation of wetland ecosystem is a big necessity. Hence it is crucial to make the ecological assessment of water bodies in the urban areas to find out the solution. Water resources are important for urban areas as they provide for a wide range of uses. Yele Mallappa Shetty lake (YMSL) being one of the major lakes of Bengaluru city covering a large watershed spread over in an area of 287 km^2 needs urgent conservational efforts. Especially in the background of severe shortage water for domestic purposes in city. Ecological assessment of this iconic lake was carried out by studying the physico-chemical, topographical, and biological parameters. The results were analysed using specific standards. They clearly showed that there is high risk of contamination in this lake which is mainly because of domestic sewage and effluents released from industries. YMSL has shown sever depletion in aquatic flora. The number of plant species found to be very low. The lake was dominated by only a few species, which is highly disturbing. Despite of the fact the Government is announcing projects and schemes to rejuvenate the lakes the number of lakes is decreasing. Some of them are fast disappearing. All existing lakes need urgent attention and especially YMSL should be rejuvenated. Conservation strategies of the lakes are also discussed and presented in the paper.***

Keywords: Ecosystem, Yele Mallappa Shetty Lake (YMSL), Ecological assessment and Conservation Strategies

1. Introduction

Yele Mallappa Shetty Lake is an artificial water reservoir constructed around 19th century to solve the drinking water crisis. The lake is spread around 260 acres of land, it was considered to be a beautiful ecosystem. It is one of the largest lakes in Bengaluru. The lake is a biological hotspot for migratory birds, some usually spotted are Golden Oriole, Northern Shoveler, Green Bee-Eater, Bulbul, Pied Kingfisher, Egrets, and Eurasian Coot.

The water demand in 2001 was around 750 million litres per day and the actual supply is only 570 million litres per day, per capita usage is about 105 litres per day. The national standard is 150 litres per day while the international standard is 200 litres per capita per day (Suresh, 2001). At present (2016) BWSSB supplies 1,400 MLD (million litres per day) against the demand of 1,600 MLD in Bengaluru city.

The dependence on lakes, tanks, ponds, wells and other sources in the past for supply of raw water to the city was de–linked with treated supplies arranged from river based schemes. Priyadarshini and Ramachandra (1998) established the water quality of Ulsoor Lake; sewage runoff and waste discharge has influenced the water quality of the lake. The Fishy odour, hardness, high alkalinity, phosphates, coliform population and a very high co-dominant existence of *Microsystis*indicated high pollution in the lake. Ranjani and Ramachandra (1999) reported eutrophication in Hebbal Lake, Bengaluru due to sewage and industrial effluents. Rajinikanth and Ramachandra (2000) studies revealed had reached eutrophic conditions because of high organic waste discharge in Amruthahalli Lake, situated in north of Bengaluru city. Bacteriological analysis of groundwater from Vrishabhavathi and Arkavathi basins, Bengaluru conducted by Singh (2009) showed the level of contamination was beyond the acceptable range for signal organisms in groundwater during winter season, which renders the water unsafe from the health point. Similarly there have been many attempts to study the status of lakes in Bengaluru.

Topographically Bengaluru city has radial slopes towards east and west with a smooth ridge running north to south; rainfall over the ridge area gets divided and flows east or west into the three gentle slopes and valleys of Koramangala–Challagatta, Hebbal and Vrishabavathi. Doddabettahalli 1,062 m (3,484.3 ft) is the highest point on this ridge. Slopes and valleys have given rise to lakes and chain of reservoirs in Bengaluru. Cascading streams link the chain of water bodies all over the city. The naturally undulating terrain of hills and valleys, lends itself perfectly to the development of lakes that can capture and store rainwater. Small streams are formed by each valley starting with the ridge at the top. A series of shallow tanks varying in size are developed. The gentle topography of the city always had a good potential of ground water development. The link was already broken on the wetlands of Nagavaralake, where a tech park emerged to disrupt an ecosystem that had ensured a natural flow of water for centuries.

City administrators and land developers have no clue or inclination to sustain a system that acted as reservoirs to impound rainwater, store it for future use and recharge the ground water. This has severely depleted the underground water table (UGWT) of Bengaluru city. The city which mainly depends on a few reservoirs, Kaveririver and bore-wells for drinking water will definitely run into deep water crisis within a few years. The effect of urbanization has taken some heavy toll on the Beautiful lakes in Bengaluru. In the 1960s the number of tanks and lakes were 280 and less than 80 in 1993. Bengaluru possessed a large number of lakes, which have attributed to the high level of groundwater table. Today many of these lakes have been lost due to

urbanization and anthropogenic activities and remaining lakes are also disappearing gradually. The existing lakes are sewage and solid waste filled. Studies on Bengaluru wetlands indicate that 40% of lakes in Bengaluru are fed by sewage and 13 percent of the lakes are surrounded by slums (Ramchandra, et al, 2002).The pollutants and the pollution of lakes has been a question for the survival of lakes and have also posed a serious threat to flora and fauna in them (Benjamin et al, 1996). The lakes in the city have been largely encroached for urban infrastructure and as a result, in the heart of the city only 17 good lakes exist as against 51 healthy lakes in 1985. On account of the importance, several urban water bodies have been studied for physico-chemical characteristics (Srivatsava et al, 2009; Sulekh Chandra, et al 2012; Preeti Gupta, et al, 2011; ParameswaraNaik, et al, 2012;Trivedi and Kataria,2012; Ramesh and Krishnaiah,2013; Upadhyay and Chandrakala, 2015). For assessing water quality topographical, biological, physical and chemical characteristics of YMSL were analyzed.

2. Materials and Methods

Topographical, biological, physical and chemical characteristics of YMSL were studied as follows.

Collection of water samples
The water was assessed during the period from December 2015 to April 2016. The samples were collected routinely around 6 am in sterile plastic bottles (1L) from three different locations i.e., A, B and C.
Sample A- South-Western Part of the lake.
Sample B- North-Eastern Part of the lake.
Sample C- South-Eastern Part of the lake.

Physico-chemical studies: The parameters of the lake were categorized into topographical, biological, physical and chemical characteristics. The lake was visited on different seasons and all the relevant information was collected and documented regularly. Physical characters like the lake pH, electrical conductivity and temperature were determined by using standard procedures (Standard methods.1999). Chemical characteristics like Dissolved oxygen, Biological oxygen demand, Chemical oxygen demand, Nitrates, Sulphates, Hardness, alkalinity, Turbidity, Sodium, Phosphateand Potassium were analyzed.Standard analytical procedures were used in the determination of these parameters. The observations were made three times in a year representing three different seasons. The samples were collected from three different places of the lake. Each result given in this table is the average of five independent readings.

Phycological studies: The samples were studied for the presence of fresh water algae. The dominant species of algae were identified and documented

Study of the aquatic flora: Biological characteristics were made by only identifying plant species of the lake. The dominant plant species growing in the lake were collected and identified.

Statistical analysis: SAS programming was used for the statistical analysis.

3. Results and Discussion

YMSL watershed:
YMSLwatershed is spread over in an area of 287 km^2 in the North taluk of Bengaluru and lies between the Latitude13°0', 13°15' and Longitude 77°30', 77°45'. It is a part of Bengaluru North taluk and comprises of Hebbal and Rachenahalli valley. The urbanized area covers the town places like satellite town Yalahanka in the North; Hebbal in the south-east and Krishna Rajapuram in the west within the BBMP (Bhruhat Bengaluru MahanagaraPalike) boundary. The altitude of this area varies from 860-954m covering in topographical map of 57 G/12 NE-NW and SE-SW of 1:25000 scale. The outlet of YMSL joins river Pinakini and reaches finally river Cauvery (Chandan and Renuka Prasad, 2014).

YMSL is located in northern part of Bengaluru city (Fig-2). It is surrounded by Medahalli on the east, Avalahalli and Veeranahalli in the west, Old Madras road on south and Doddabanahalli on the eastern side. YMSL is sliced into two by the Old Madras Road and eventually the so called Raja Kaluve system of this region is severed. Satellite imagery clearly shows this water body's organic connection to the distant Hebballake. From Hebbal to Nagavara to Kalkere to Maragondanahalli, the link runs into the YMSL, only to be disrupted by a highway.Cipla Ltd. a drug manufacturing company situated on the south west of the lake is releasing the effluents into the lake. The domestic sewage is also being directly released into the lake from all the directions.

Depletion of Biodiversity:
YMSL has shown sever depletion in aquatic flora. The number of plant species found to be very low. The lake was dominated by only a few species (see table- 2). Human activity is the driving force behind the current biodiversity crisis, which is causing great species loss in a short time period. Freshwater biodiversity is exposed to a range of natural disturbances varying in strength, frequency, predictability, duration, and spatial scale. Such disturbances can deplete the biota, disrupt ecological processes, and redistribute resources (Giller 1996; Lake,2000). This aspect needs a more serious attention and a more elaborate study. With the increasing levels of anthropogenic disturbance, it can be expected there will be changes in the linkages between above-sediment and sediment biota.

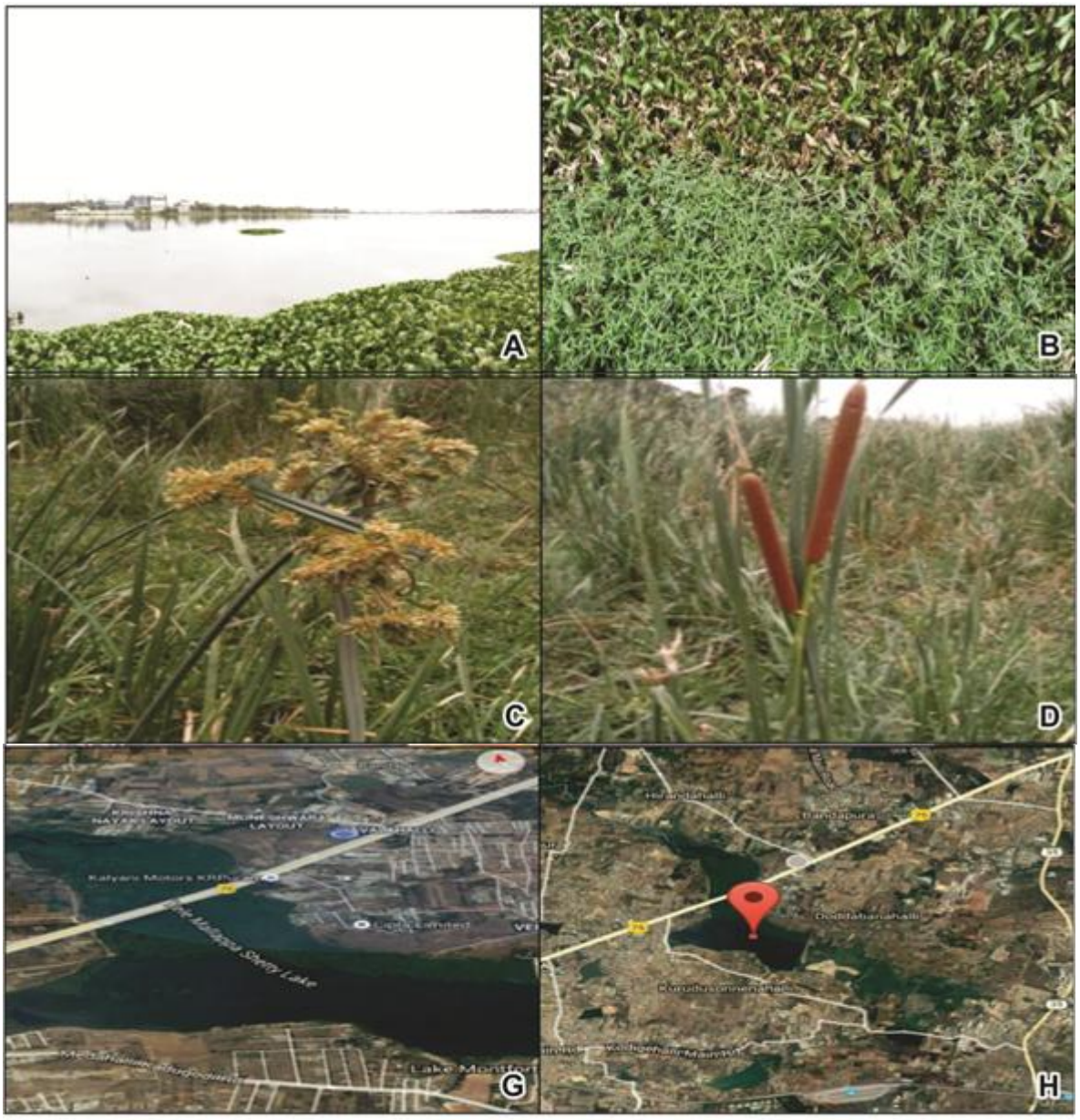

Fig-1. Images of YMSL: 1a-Image of the lake showing peripheral regions contaminated by the growth of *Eicchornia*; 1b- *Eicchornia* and *Alternanthera*; 1c-*Cyperus*; 1d-*Typha*; 1e-outflow of water showing froth formation; 1f-Drug company, Cipla Ltd which releases effluents in to the lake 1g and 1h-Satellite images of YMSL

Table 1: Details about the location of YeleMallappaShetty Lake

Name of the lake	YeleMallappaShetty Lake
City	Bengaluru
State	Karnataka
PIN Code	560049
Country	India
YeleMallappaShetty Lake Latitude	13.0231
YeleMallappaShetty Lake Longitude	77.7295

Table 2: Biological assessment: List of dominant plant species with relative densities

Sl. No.	Algal species	Relative density %Biomass	Eukaryotes	Relative density(%)
1	*Oscillatoria aeruginosa*	32	*Eichhornia crassipes*	78
2	*Zygnema mucigenum*	28	*Alternanthera sessilis*	09
3	Diatoms (pinnate type)	14	*Typha latifolia*	03
4	*Mycrocystis* species	09	*Cyperus rotundus*	02
5	Other species	17	Other species	08

Table 3: Physico-chemical characteristics of YMSL. The observations were made three times in a year representing three different seasons. The samples were collected from three different places of the lake. Each result given in this table is the average of five independent readings.

Parameters	Standard	Months during which the samples were collected											
		Samples in December				Samples in August				Samples in April			
		A	B	C	Mean	A	B	C	Mean	A	B	C	Mean
Temp- °C		21	21	21	21.0	24	24	24	24.0	29	29	29	29.0
pH	6.5-8.5	8.1	7.8	7.6	7.8	7.5	7.3	7.4	7.4	7.6	7.4	7.4	7.5
Conductivity,	300 πS/cm	840	750	743	777.7	460	398	402	420.0	611	553	467	543.7
Turbidity	0.5 NTU	21	39	41	33.7	18	21	21	20.0	11.83	13.5	14.1	13.1
DO	5.0 mg/l	4.2	4.3	5.1	4.5	4.9	4.3	5.1	4.8	2.3	3.1	3.3	2.9
BOD	30 mg/l	109	99	112	106.7	158	98	78	111.3	289	99	99	162.3
COD	250 mg/l	325	313	127	255.0	478	312	318	369.3	878	312	313	501.0
Alkalinity	200 mg/l	340	280	265	295.0	212	234	331	259.0	250	270	180	233.3
Hardness	300 mg/l	789	652	623	688.0	512	552	512	525.3	613	662	551	608.7
Sodium	200 mg/l	148	122	137	135.7	270	222	231	241.0	192	132	120	148.0
Potassium	-	5	4	3.8	4.3	9	5	6	6.7	9	4.1	3.9	5.7
Phosphate	0.1 mg/l	1.6	7.3	7.2	5.4	2.3	5.3	4	3.9	3.1	7.2	6.8	5.7
Nitrate	45 mg/l	3	2.3	3.1	2.8	4.5	2.3	2.6	3.1	3.9	2.3	2.2	2.8

Physico-chemical analysis:

Lake water contains different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Physico-chemical analysis is crucial for the study of any water body. Physical analyses such as temperature, color, odour, pH, turbidity etc, were analysed frequently. Besides this chemical tests were also performed for the study of BOD, COD, dissolved oxygen, alkalinity, hardness and other characters. For obtaining more and more quality and purity water, it should be tested for its trace metal, heavy metal contents and organic i.e. pesticide residue. Some of the important physic-chemical parameters are discussed below with results obtained at YMSL. The results are presented in the table (see, Table-3).

Temperature:

In an established system the water temperature controls the rate of all chemical reactions, and affects the growth, reproduction of flora and fauna. Drastic temperature changes can be fatal. The YMSL temperature ranged between 21-29°C, which neither too high nor too low. It is an ideal situation for a lake (see, Table-3). This is due to fact that the lake is located at an ideal altitude. There is less chance for any major fluctuation in the temperature of the lake water as there is no inflow of heated water.

pH:

It is most important in determining the corrosive nature of water. Lower the pH value higher is the corrosive nature of water. pH is positively correlated with electrical conductance and total alkalinity(Gupta, 2009). The reduced rate of photosynthetic activity, the assimilation of carbon dioxide and bicarbonates are ultimately responsible for increase in pH, the low oxygen values coincid with high temperature during the summer month. Various factors bring about changes the pH of water. The higher pH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected. This is further due to change in physico-chemical condition (Karanth, 1987).pH of YMSL ranged between 7.3 to 8.1 as against the standard of 6.5-8.5 (see,Table-3)

Electrical Conductivity (EC):

EC shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand , chloride and iron concentration of water. NavneetKumar et al (2010) suggested that the water quality can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas. It is measured with the help of EC meter which measures the resistance offered by the water between two platinized electrodes. 300 πS/cm is the standard EC expected. However in YMSL it ranged between 398 to 840. Hence it was found to be on the higher side; indicating higher levels of alkalinity (see,Table-3)

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Dissolved oxygen (DO):

The high DO is due to increase in temperature and duration of bright sunlight which have an influence on the percentage of soluble gases such as oxygen and carbon dioxide. During summer the long days and intense sunlight seem to accelerate photosynthesis by phytoplankton, utilizing CO_2 and giving off oxygen. This possibly accounts for the greater qualities of O_2 recorded during summer (Krishnamurthy, 1990). DO gives direct or indirect indication of bacterial activity, photosynthesis, availability of nutrients, stratification etc. (Vikal, 2009). As the temperature increased dissolved oxygen decreased due to increase in temperature and also due to increased microbial activity (Kataria, 1996). Do in YMSL was found to lower than the standard. Especially it was too low during the month of April. It was probably due to increased concentration of sewage released in to the lake. During the rainy season the concentration decreased due to more amount of water flowing in to the lake. The decomposition of organic matter might be an important factor in consumption of DO, as more vigorous deposition could be likely during warm weather (see, Table-3).

Bio-chemical Oxygen Demand (BOD):

Biochemical oxygen demand (BOD) is an important parameter of water quality which measures the quantity of oxygen consumption by microorganisms during decomposition of organic matter. BOD is usually used for

determining the oxygen demand of municipal or industrial discharge. High BOD indicates high scale contamination of organic matter in the water. BOD is a measure of organic material contamination in water. BOD is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials. Water can only hold a limited supply of dissolve oxygen in a water body and it fluctuates with diurnal cycle of the aquatic ecosystem. The probable reasons for high BOD as well as normal DO in the studied lakes suggested that there is high nitrogenous oxygen demand (NOD) than carbonaceous biochemical oxygen demand (CBOD). NOD is the result of the breakdown of proteins into ammonia, which is readily converted to nitrate in the environment. The conversion of ammonia to nitrate requires more than four times the amount of oxygen as the conversion of an equal amount of hydrocarbons to carbon dioxide and water (BIS; Thakor et al, 2011). The BOD levels in YMSL ranges between 99 to 289. Moderate levels of DO despite high BOD is acceptable in the lakes where sewage runoff and agricultural run-off as well as domestic waste contamination are the main problems (see, Table-3).

Chemical Oxygen Demand (COD):
COD is the oxygen required for theoxidation of all the substance present in water, included those are not biologically decomposable. COD is a reliable parameter for judging the extent of pollution in water. The COD of water increases with increasing concentration of organic matter. The maximum permissible value of COD is 10 mg/lfor drinking water and it is 250 mg/l for lake water. Chemical oxygen demand of almost all the water samples collected YMSL exceeded the limit in most of the samples. A maximum of 878 was recorded in one of the samples (see,Table-3). It clearly indicates the presence of high levels of dissolved contaminants.

Hardness:
It is caused due to presence of cations like Ca+2, Mg+2, Fe+3 etc. This is the property of water to precipitate soap by formation of complex with calcium, magnesium present on water. As against the standard of 300 mg/l, the hardness at YMSL was very high. A maximum of 688 mg/l was recorded (see, Table-3). Formation of froth was observed in the lake water (see-fig-1E). Continued inflow of sewage in to YMSL comprises of many natural and synthetic dissolved organic compounds, such as soaps and detergents. These are surface-active agents or surfactants that reduce the surface tension of water, allowing air bubbles to persist at the surface of water. These detergents essentially consisted of phosphates, and a portion of which is used-up by aquatic plants while the balance gets trapped in the sediments. Continuous sewage fed in Bellandur and Varthur lakes of Bengaluru has been witnessing foam at downstream in chocked channels or discharge point since one decade (Mahapatra et al., 2013).

Alkalinity:
It is caused primarily due to the presence of carbonates and bicarbonates; alkalinity acts as a stabilizer for pH. Alkalinity, pH and hardness affect the toxicity of many substances in the water. Alkalinity of YMSL was also on the higher side (see, Table-3). A maximum of 789 mg/l was recorded as against the standard 300 mg/l.

Sodium:
The higher concentration of sodium limits the biological diversity due to osmotic stress. High sodium contents in the form of chloride and sulfates make the water salty and unfit for human consumption. High sodium content in irrigation water brings aboutpuddling of soil. As a result the water infiltration in the soils is reduced and the soil becomes hard making the germination of seed difficult (Trivedi and Gurdeep, 1992). Interestingly the concentration of sodium was found to be lower in YMSL as compared to the standard (see, Table-3).

Potassium:
Potassium plays the same role in water as sodium. It occurs in small amounts but is regarded as an important agro-nutrient in the metabolism of freshwater environments (Trivedi and Gurdeep, 1992). The concentration of potassium was higher in YMSL (see, Table-3).

Phosphate:
Phosphate has a limited source in nature and also acts as a limiting factor for productivity of water body. Phosphate may occur in lake as result of domestic waste, detergent and agricultural run-off containing fertilizer (Gopalkrushna, 2011). The average value of phosphate recorded in YMSL ranges between 1.6 to 7.2 mg/l. comparatively high amount of phosphate is recorded could be due to the discharge of municipality sewage and dumping of domestic waste into the lakes (Benjamin et al, 1996).

Nitrate:
Inorganic nitrogen that present in water is available as nitrate It is the main nutrient that accelerates the growth of hydrophytes and algae. Nitrate occurs in water from various natural sources and due to human activities like food waste, agriculture and manure disposal of domestic and industrial sewage. High level of nitrates is found in rural areas because of extensive application of nitrogenous fertilizers in agriculture. In urban areas sewage water rich in nitrates contaminate surface water thus increases the nitrate amount. (Tank, 2013; Gopalkrushna, 2011). A small amount of nitrate is common in all kinds of surface water. In this study relatively larger amount of nitrate was found. However the obtained levels are within range prescribed by BIS. Nitrate stimulates the growth of hydrophytes and phytoplankton that consequently increase the nutrient in water body leading to eutrophication. The average nitrate value at YMSL was between 2.2 to 4.5 mg/l.

4. Conclusions and Conservation Strategies

Water bodies like lakes are a part of wetland ecosystem and wetlands are vital parts of the hydrological cycle. They highly productive by supporting exceptionally large biological diversity. They provide a wide range of ecosystem services, such as food and fibre; waste assimilation; water purification; flood mitigation; erosion control; groundwater recharge; microclimate regulation. In addition to all these they also enhance aesthetics of the landscape bysupporting many significant recreational, social

and cultural activities, besides being a part of our cultural heritage(Envis Technical Report, 2009). The physical, chemical and biological processes occurring permanently in an aquatic environment should be considered to explain the inorganic elements and heavy metals concentrations (Nguyen et al. 2005). External processes like discharging of pollutants and anthropogenic activities also affect the concentration and behavior of inorganic elements and heavy metals concentrations (Baeyens et al. 1998). Dissolved metal ions create turbidity anddiscoloration of lake water. They can precipitate and form bottom sludge. Sustained inflow of untreated sewage released by BWSSB and effluents from the drug company Cipla Ltd and due to delinquency of duties by regulatory agencies such as Karnataka State Pollution Control Board and Central Pollution Control Board have resulted in contamination of lake as the inflow of pollutants has surpassed the lake's assimilative capacity. The pathetic situation of all the lakes including that of YMSL is caused as a result of unscrupulous attitude of citizens, officials, politicians.Froth formation at downstream, higher levels of pollutants, profuse growth and spread of eukaryotes and eutrophication are all the indicators of nutrient enrichment. Nutrients in the form of N (nitrogen), carbon (C) and P (phosphorous) enter the lake through untreated sewage. Major part of N is up-taken by plants and algae while phosphorous and carbon gets trapped in sediments. Given the fact that Kaveri river water is limited the only hope for the needs of drinking water is bore wells that arebeing dug all over the city indiscriminately. The water table is rapidly going deeper and deeper and hence the only way to solve this problem is to replenish the UGWT.This is possible by making water stand in the existing water bodies of the city. Despite the fact the Government is announcing projects and schemes to rejuvenate the lakes the number of lakes is decreasing. Some of them are fast disappearing. All existing lakes need urgent attention and especially. We must at least rejuvenate and conserve the remaining few lakes of city.YMSL is being one of the largest lakes needs to be rejuvenated and conserved.

Conservation Strategies

The following are some of the important points with respect to the conservation of all the fresh water bodies, especially near and around the human habitations;

- Delineation and clear cut demarcation of the boundary and mapping of all the water-bodies.
- Studying the carrying capacity of all major cities and towns.
- Integration of the activities with the common jurisdiction boundaries of Government agencies for proper management of water-bodies.
- Institution of Water-bodies' Conservation, Rejuvenation and Management Authority.
- Surveying and scientific documentation of flora and fauna.
- Formulation of management plans for individual water bodies.
- Construction and maintenance of sanitation facilities near the water bodies.
- Bringing water bodies under Central Government's **"SwacchaBharath"** scheme.
- Restoration, conservation, rejuvenation and management of polluted water-bodies.
- Ecological evaluation of lands and water within the catchment or watershed regions of each and every lake and rainwater harvesting near and around the water bodies.
- Regulation of recreational activities like boating and converting water-bodies into tourist attractions.
- Physical linking of all the water bodies to the extent possible.
- Conservation of riparian and buffer zone vegetation around the water bodies.
- Surveying, restoration and monitoring of linkages between water bodies.
- Providing environmental education and creation of awareness about the importance of water bodies, especially among the youth and children.
- Stringent implementation of Wetland Protection Laws and Acts.

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