# RECURRING FISH MORTALITY EPISODES IN BANGALORE LAKES: SIGN OF IRRESPONSIBLE AND FRAGMENTED GOVERNANCE


| Ramachandra T.V. | Sincy V. | Asulabha K. S. |
| --- | --- | --- |
| Sudarshan P Bhat | Rahaman M. F. | |


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Energy & Wetlands Research Group, CES TE 15
Environmental Information System [ENVIS]
Centre for Ecological Sciences,
Indian Institute of Science,
Bangalore - 560012, INDIA
Web: http://ces.iisc.ernet.in/energy/, http://ces.iisc.ernet.in/biodiversity
Email: cestvr@ces.iisc.ernet.in, energy@ces.iisc.ernet.in

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**Centre for Ecological Sciences,**
**Indian Institute of Science**
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**Energy & Wetlands Research Group,**
**Centre for Ecological Sciences, TE 15**
**New Bioscience Building, Third Floor, E Wing**
**Indian Institute of Science**
**Bangalore 560012, India**
http://ces.iisc.ernet.in/energy, http://ces.iisc.ernet.in/biodiversity
**Email:** cestvr@ces.iisc.ernet.in, energy@ces.iisc.ernet.in

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# RECURRING FISH MORTALITY EPISODES IN BANGALORE LAKES: SIGN OF IRRESPONSIBLE AND FRAGMENTED GOVERNANCE

1995 (Sankey, Lalbagh), 2005 (Ulsoor, K R Puram), 2010 (Jakkur, Cubban park, Devarabisanahalli), 2013 (Sankey), 2015 (Dorekere, Jakkur), 2016 (Ulsoor, Devarabisanahalli, …….)

## EXECUTIVE SUMMARY


Wetlands (*lakes, ponds, tanks, areas of marsh, fen, peat land, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water*) in urban landscape aid in (i) moderating microclimate, (ii) recharge groundwater resources, (iii) remediation – kidneys of the landscape remove contaminants, (iv) sustaining food (fish, fodder etc.), (iv) recreation and habitat for array of diverse organism, (vi) infiltration and mitigate floods and loss to human life and properties, (vii) enhance the aesthetics of the landscape and support many significant recreational, social, and cultural activities, aside from being a part of region's cultural heritage. Despite these significant services, wetlands are being encroached, polluted and constantly abused by senseless and irresponsible urban decision makers of 21$^{st}$ century. Recurring episodes of fish mortality, algal bloom, profuse growth of invasive exotic weeds, introduction and rearing of exotic species of fish highlights mismanagement of fragile and ecologically vital wetlands.

Recent episodes of large-scale fish mortality in Ulsoor and Devarabisanahalli lakes of Bangalore city, Karnataka has necessitated field investigations to understand the causal factors. Analysis of water samples and fish samples reveal that the fish-kill in Ulsoor Lake and Devarabisanahalli lake were due to asphyxiation with a sudden and considerable fall in dissolved oxygen (DO) levels in some locations caused by the sustained inflow of untreated sewage. Sudden increase in temperature (>34 °C) has enhanced biochemical activities of the micro biota (algae, bacteria) as well as plant respiratory rate leading to depletion of dissolved oxygen. Higher temperature in sewage fed aquatic ecosystem increases the level of ammonia, BOD, etc.

Major agents of deteriorating lake ecology and biodiversity in any water body are due to the irresponsible act of

- sustained inflow of untreated sewage into the lake, which increase the organic content in the lakes enhancing biological activities (evident from higher BOD and ammonia);
- introduction of exotic fish species (such as African cat fish, Tilapia, etc.); and
- dumping solid waste in the lake bed. Major fraction (70-75%) of solid waste is organic, and the nutrients leaches to the water body.

| Causal Factors | |
|---|---|
| Fish Mortality | Asphyxiation due to **depletion of dissolved oxygen** |
| Low dissolved oxygen | The sustained inflow of untreated sewage and the quantum beyond the remediation capability of the lake.<br><br>Higher organic content and increase in temperature (> 34 °C in April) has **enhanced the biological activities** leading to higher ammonia, BOD and COD |
| Enhanced biological activities | Bacteria and algae population have increased with higher temperature and favourable conditions (organic content)<br><br>Bacteria and algal demand for oxygen (during day and night respectively) has lowered dissolved oxygen |
| Viral attack | With higher temperature and favourable organic content in the Lake, susceptible fish have died. Red spots on dead fish specimen indicate the possibility of Epizootic ulcerative syndrome (EUS), also known as red spot disease (RSD), which requires further analysis [Details at: http://www.thefishsite.com/diseaseinfo/21/epizootic-ulcerative-syndrome-red-spot-disease]. |
| **Solution** | |
| • Treat sewage and allow only treated sewage to the lake<br>• No diversion of sewage of one locality to downstream localities.<br>• Sewage generated in each locality to be treated locally.<br>• Pass the treated sewage (secondary treatment) through constructed wetlands (to remove nutrients). This model has been working satisfactorily at Jakkur Lake.<br>• Improve the aeration in the lake (which will enhance dissolved oxygen levels) through water fountains. Installation of music synchronized water fountains (animated fountain with three dimensional images) would enhance the aesthetics and also recreation value of the lake. This would help as distressing measures for the employees working in nearby industries and IT establishments.<br>• Introducing ducks also helps in aeration<br>• Ban plastic in the vicinity (hawkers, street vendors)<br>• Penalize polluters (dumping of solid waste / construction waste)<br>• Remove all encroachments of drains connecting the lake and route the drain to integrated treatment plant (STP with constructed wetlands)<br>• Ban introduction of exotic fish species | |
| Sewage treatment | Adopt integrated treatment system (constructed wetland and algae pond along with the conventional STP) to remove nutrients (N & P) similar to the functional model at Jakkur Lake. |
| Silt removal | Removal of accumulated contaminated sediments, through wet dredging with the help of MEG |
| Maintaining buffer zone | Maintain at least 30 m buffer with riparian vegetation (to enhance hydrologic regime and remediation) and recreation facilities |
| Stop senseless developmental activities | Plan to have floating restaurant (irrational plan of tourism department) should be abandoned as this will affect the ecological integrity and ultimately leads to the death of the lake (Ulsoor Lake) |
| Ban on exotic fish species introduction | Exotic species eliminates native biota and affects local biodiversity |

| | |
|---|---|
| and culture | |
| Regular water quality monitoring | Involving local educational institutions in regular water quality (physical, chemical and biological parameters) would help in capacity building and environmental awareness. |
| Constitution of functional lake protection and management committee | Lake protection and management committee involving all active local stakeholders, who regularly take part in monitoring while ensuring timely maintenance and management. |

**Eco-approach in the management of Lakes**

1. Regulate fish species such as- (i) *Oreochromis mossambica* and (ii) *Oreochromis nilotica*
    - Through introduction of BASS-Lates calcarifer- the seed is available in Chennai (TN) from CIBA (Central Institute of Brackishwater Aquaculture).
    - Stop total fishing activity for the next 3-4 years in order to eradicate complete Tilapia population.

    (iii) Eradicate ***Clarias gariepinus*****:** The African Catfish- attains a size of 59.5 Kg. highly predatory fish. Need to eradicate to conserve native species.

    **Control:** prevent its access to get its oxygen (since it is an air-breathing fish) from the atmosphere by spreading a net of different mesh size, below 4"-6" from surface water area of any water body. This process prevents the fish to come to the surface to breath and gets chocked.
2. Introduce only 500 fingerlings/ha of Indian Major Carp – *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* are to be introduced in fingerling sizes of 75mm and above. Before that, ascertain the fish species present in a water body.
3. Assess the water quality, plankton, benthos/littoral to introduce the desirable fish germ plasam.
4. Introduce indigenous herbivorous carp- *Puntius pulchellus* or the exotic grass carp- *Ctenopharyngodon idella* to control aquatic weeds such as Vallisneria, Hydrilla, Potamogeton, Azolla, *Lemna* spp.
5. Instead of African Catfish, introduce Murrals- *Channa marulius*-12Kg; *Channa striatus*- 3Kg (Native to state/Country: the seed is available in tanks of Shimoga and Hassan).
6. Promote culture of the original native fish species such as: *Puntius sophore*; *Puntius ticto*; *Puntius vittata*; *Amblypharyngodon mola*; *Rasbora daniconius*; *Clarias batrachus* (Magur); *Heteropneustes fossilis* (Singhi) and *Mystus vittatus*.
7. Water quality is to be assessed regularly throughout the year through active particiapation of local education institutions (schools and colleges). Monitoring strategy shall be
    - Regular water sample analysis every month (before 8 am). Representative samples to be collected (inlet, centre and outlets)
    - Assessment of primary productivity- once in 3 months (between 10:00am to 1:00 pm)

 

- Diurnal observations (24 hrs observation –samples like surface water, bottom water, surface plankton and bottom plankton) every season.

The rapid urbanisation trend consequent to unplanned developmental activities with burgeoning population has posed serious challenges in the regional planning and management involving plethora of issues like wetland conservation, infrastructure development, traffic congestion, basic amenities, etc. The rapid urbanization has led to increased anthropogenic pressure on most of the water bodies in Bangalore. Irresponsible act of dumping of solid wastes and sustained discharge of untreated sewage has deteriorated the quality of lakes/wetlands, evident from algal bloom, profuse growth and spread of invasive exotic species of macrophytes, recurring episodes of fish mortality, etc. Untreated sewage enters directly the Ulsoor Lake which has altered the chemical integrity of the ecosystem affecting biological constituents. The physico-chemical characteristics of Ulsoor Lake reveals depletion of oxygen, high turbidity and organic contents, high biochemical oxygen demand (BOD) and ammonia toxicity. Fish usually require a minimum of 5 milligrams per liter (mg/l) of dissolved oxygen (DO) for optimum health and the maximum admissible ammonia concentration for fish is 0.05 mg/l. Fish in an aquatic ecosystem also helps in detecting the toxicity of different chemicals including heavy metals in an aquatic environment. Microbial communities present in the sewage water causes infectious diseases that infect aquatic life as well as terrestrial life through drinking water. Analysis of water samples and fish samples reveal that the fish-kill in Ulsoor Lake and Devarabisanahalli lake were due to asphyxiation with a sudden and considerable fall in dissolved oxygen (DO) levels in some locations caused by the sustained inflow of untreated sewage. Sudden increase in temperature (>34 °C) has enhanced biochemical activities of the micro biota (algae, bacteria) as well as plant respiratory rate leading to depletion of dissolved oxygen. Higher temperature in sewage fed aquatic ecosystem increases the level of ammonia, BOD, etc. Ammonia is toxic to fish at elevated pH and temperature. Fish become more susceptible to viral or bacterial infections during a low DO period and thermal stress. Red spots on dead fish specimen indicate the possibility of Epizootic Ulcerative Syndrome (EUS), also known as red spot disease (RSD), which however requires further investigations.

**Keywords**: Fish Mortality, Dissolved Oxygen (DO), untreated sewage, ammonia, Biochemical Oxygen Demand (BOD), Mismanagement

# 1.0 INTRODUCTION

Wetlands (*lakes, ponds, tanks, areas of marsh, fen, peat land, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water*) in urban landscape aid in (i) moderating microclimate, (ii) recharge groundwater resources, (iii) remediation – kidneys of the landscape remove contaminants, (iv) sustaining food (fish, fodder etc.), (iv) recreation and habitat for array of diverse organism, (vi) infiltration and mitigate floods and loss to human life s and properties, (vii) enhance the aesthetics of the landscape and support many significant recreational, social, and cultural activities, aside from being a part of region's cultural heritage.

Wetland ecosystems are the most productive ecosystems in the biosphere. Lakes provide the essential components for the sustenance of life on earth, such as water (agriculture, drinking, etc.), food (protein production, fodder, etc), biodiversity (diverse flora and fauna), energy (fuel wood, etc), recreation (tourism), transport, water purification, pollutant sink, flood control and climate stabilizers (Ramachandra, 2008). Lakes and ponds naturally support a healthy population of aquatic life. Lentic ecosystems (still waters that include wetlands, ponds, tanks, lakes, etc.) have three zones – littoral, limnetic and benthic. The littoral zone is near shore area where sunlight penetrates all the way to the sediment and extends from the shoreline to the innermost rooted plants. Littoral zone is populated with frogs, snakes, snails, clams, and a variety of adult and larval insects. The limnetic (pelagic) zone is the open water down to the depth of light penetrations. This zone contains phytoplankton (diatoms, green and blue green algae, etc.), zooplankton (protozoa, microcrustaceans, arthropods, etc.). It is also inhabited by a variety of larger swimming organisms including fish, amphibians and larger insects. The benthic zone (bottom of the lake) is covered by fine layers of mud consisting mostly of decomposers (Ramachandra and Solanki, 2007). Watershed based planning and resource management is a strategy for more effective protection and restoration of aquatic ecosystems and for protection of human health. The watershed approach emphasizes all aspects of water quality, including chemical water quality (e.g., toxins and pollutants), physical water quality (e.g., temperature, flow and circulation), habitat quality and biological health and biodiversity (e.g., species abundance, diversity etc.) (Ramachandra, 2005). Wetlands ensure water security evident from higher groundwater availability in the vicinity. Valuation of wetlands goods and services highlight its role in supporting the local livelihood to the extent of Rs 10500 per hectare per day. Water and food security provided by these ecosystem necessitate its conservation and sustainable management to maintain intergenerational equity.

Various threats faced by lakes include encroachment of lakebed, flood plains and lake itself; encroachment of rajakaluves/storm water drains and loss of interconnectivity; topography alterations in lake catchment; unauthorised dumping of municipal solid waste and building debris; sustained inflow of untreated or partially treated sewage and industrial effluents; removal of shoreline riparian vegetation and pollution due to enhanced vehicular traffic etc. (Ramachandra et al., 2013). The land use analyses of greater Bangalore showed 925% growth in built-up area during the last four decades (1973 to 2014) with the decline of vegetation by 78% and water bodies by 79%. The analyses of the temporal data of greater Bangalore revealed an increase in urban built up area of 342.83% (during 1973–1992), 129.56% (during 1992–1999), 106.7% (1999–2002), 114.51% (2002–2006) and 126.19% from 2006 to 2010 (Ramachandra et al., 2012). The elevated nutrient levels through sustained inflow of untreated sewage brings about undesirable changes in lakes like (a) unpleasant odor and taste, (b) excessive algae growth, (c) reduced water clarity, (d) release of toxins from blue-green algae, (e) low dissolved oxygen, (f) changes in fish population or large scale fish mortality (Ramachandra et al., 2015). Sustained inflow of untreated effluents waste from industries, domestic sewage into water bodies triggers stress in aquatic ecosystems. Enrichment of nutrients especially compounds of nitrogen and or phosphorus in water bodies referred as eutrophication, leads to an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance in trophic levels in the aquatic ecosystem and to the quality of the water concerned (EPA, 2001).

**1.1 Ulsoor lake or Halasuru Lake** derives its name from the locality it is situated, namely, Ulsoor, close to MG Road. It is located on the eastern side of the city with the spatial extent of over 50 ha (123.6 acres) with an average depth of 5.8 m; 3 km of shore length and located at 900 m of elevation. This lake is built by the family of Kempe Gowda-II in 17$^{th}$ and 18$^{th}$ centuries for drinking and irrigational purposes and is located in the middle of the city. During the early 19$^{th}$ century, this lake was the major source of drinking water for the cantonment area and troops. The catchment area of Ulsoor Lake is 1.5 km$^2$. The lake has a recreational complex with a swimming pool. There is also a garden at one end of the lake and there are many islands that are spread across the Ulsoor lake and tourists reach these islands via boating.

**1.2 Fish mortality in lakes:** Fish kill is an indicator of environmental stress, declining of aquatic ecosystems health and water quality problems. Furthermore, investigations of fish kill will indicate the spatial and temporal distributions of pollutants (e.g. nutrients, pesticides, trace metals, oils) and problems (e.g. hypoxia, anoxia) in aquatic environment (Kibria, 2015). Weather patterns, water temperature, salinity, pH, ammonia, nitrite, carbon dioxide, turbidity, dissolved oxygen, pesticides, stress, thermal shock, toxic algae, toxins, fish community structure and disease outbreak (due to the presence of viruses and bacteria in the water) are the factors that triggers fish kill/mortalities. Fish also become stressed during a low DO period and become more susceptible to viral or bacterial infections (Njiru, 2015). Fish can suffer from various types of protozoan (Ichthyophthiriasis, Costiasis, Trichodiniasis, Epistylis and Myxosporidians infestation), fungal (Saprolegniasis, Branchiomycosis and Icthyophonus disease), bacterial (Fin and tail rot fin diseases, Ulcer/Columnaris disease, Dropsy and Eye disease), viral (Spring viremia and Fish pox), crustacean (Argulus infestation and Learnaea disease) and helminth diseases (Sharma et al., 2012).

## 2.0 FACTORS RESPONSIBLE FOR FISH MORTALITY

Role of various factors responsible for fish kill are discussed next.

**2.1 Temperature:** Higher temperature increases the oxygen demand and rate of biochemical activity of the micro biota as well as plant respiratory rate. Higher temperature decreases solubility of oxygen and also increases level of ammonia in water that can build up to dangerously high levels affecting fish health (Bhatnagar and Devi, 2013). Fish affected by thermal stress (cold or warm temperatures shock) reduces its resistance to diseases thereby could be susceptible to bacterial and fungal infections that eventually kill them. Weather related disturbances or turnovers could bring anoxic (lack of oxygen) bottom water and decaying materials of lakes into the water column and release large quantities of hydrogen sulphide ($H_2S$).

**2.2 Untreated waste:** Sewage brings in large quantities of carbon (C), nitrogen (N) and phosphorus (P) that are trapped within the lake ecosystem (Mahapatra et al., 2011). The discharge of untreated industrial effluents and sewage into lakes and rivers causes oxygen depletion, increases the level of chlorophyll ‘a’, and alkalinity (pH 9.2) which in turn causes large scale mortality of fishes (Zutshi and Prasad, 2008). The suspended particles reduce the amount of sunlight penetrating the water, disrupting the growth of photosynthetic algae/plants and micro-organisms, thus hampering the normal functioning of aquatic ecosystems. Organic waste entering lakes may overload a natural system causing a serious depletion of oxygen supply in the water that in turn leads to fish kill (Murthy et al., 2014).

Microorganisms in water feed on biodegradable substances and their population depends on the quantity of organic matter/biodegradable material in water. When sewage enters a lake, micro-organisms begin to decompose the organic materials. The decomposition activities cause oxygen depletion and thus, aerobic microorganisms begin to die and anaerobic microorganisms begin to thrive. Some anaerobic microorganisms attack the organic matter and produces harmful toxins such as methane, ammonia and sulfides (Mahapatra et al., 2011). When organic compounds decompose in the absence of oxygen, it gives rise to the undesirable odours usually associated with foul-smelling, septic or putrid conditions. Heterotrophic bacteria consume oxygen and release carbon dioxide while oxidizing organic matter, whereas the autotrophic nitrifying and sulphur bacteria consume oxygen and carbon-dioxide while oxidising ammonium, nitrite or sulphide, respectively (Moriarty, 1997).

2.3 **Dissolved oxygen:** The major source of dissolved oxygen (DO) in the water is through photosynthesis by phytoplankton and aquatic plants, but some also enters the water directly from the atmosphere by diffusion. At the same time, however, oxygen is being removed from the water by the respiration (breathing) of fish, plants, and other underwater inhabitants. Decomposition of plant and animal matter in the water also consumes oxygen. During night, the photosynthesis ceases, and the algae, sediment and fish consume oxygen (respiration), producing fluctuating patterns of dissolved oxygen concentration. The competition between plants, bacteria and animals particularly at night and in dull weather can lead to lack of oxygen, causing fish suffocation and subsequent mortality. A decline in DO has serious implications on the health of the aquatic system, as hypoxic and anoxic conditions reduce or eliminate sensitive native fish and invertebrate species (Mahapatra et al., 2011). Fish usually require a minimum of 5 milligrams per liter (mg/L) of DO for optimum health. Most fish can tolerate DO below 2 mg/L for short periods, but starts dying when DO drops below 1 mg/l. Under normal conditions, the DO in a water body is lowest in the morning just before the sunrise.

**Oxygen depletion** in water bodies can occur due to algae die-offs, weather related 'turnovers' of lakes water, surface run-off of organic materials into water bodies, disturbance of sediments containing large quantities of aquatic vegetation or with excess nutrient loads, low water levels, and high temperatures etc. During the summer, water holds less oxygen and warm temperatures make bacteria grow faster resulting in faster oxygen depletion. 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 (Ramachandra and Solanki, 2007). During cloudy days, the rate of photosynthesis as well as oxygen production by algae will decrease and enough oxygen will not be available for bacterial respiration. In addition, fish experience a faster metabolic rate as water temperature increases; therefore, their requirement for oxygen increases. The fish are therefore more likely to be stressed during the warmer months. The possible signs of fish kills due to oxygen depletion are fish gasping at the surface, sluggish movement, larger fish die earlier than smaller fish of the same species, kill occur at night or in the early morning.

2.4 **Carbondioxide:** Decomposition of the dead plants will also raise carbon dioxide and total ammonia concentrations. When carbon dioxide concentrations are high, the fish will have difficulty in reducing internal carbon dioxide concentrations, resulting in its accumulation in fish blood. This accumulation inhibits the ability of hemoglobin, the oxygen-carrying molecule in fish blood, to bind oxygen, and may cause the fish to feel stress similar to suffocation.

2.5 **Turbidity**: Lakes with higher silt transport in the catchment (due to removal of vegetation cover) will have more turbidity, restricting the penetration of sunlight and reducing the photosynthetic activity, which in turn influence the productivity of water (Chandrasekhar, 2002). The higher turbidity shows the presence of higher concentration of organic and non-biodegradable components in the lake water that require higher amount of oxygen for their decomposition (Poodari et al., 2014), which in turn affects fish population. Turbidity thus, affects the productivity of an aquatic ecosystem. In highly turbid waters, gill surfaces of fishes will be clogged with suspended matter.

2.6 **Nitrates, Phosphates and Biochemical Oxygen Demand (BOD):** Nitrates are the end product of the aerobic decomposition of organic nitrogenous matter (Sincy et al., 2012). The significant sources of nitrates are chemical fertilizers from cultivated lands, drainage from livestock feeds, as well as domestic and industrial effluents (Ramachandra and Ahalya, 2001). Phosphates occur in natural or wastewaters as orthophosphates, condensed phosphates and naturally found phosphates. Their presence in water is due to detergents, used boiler waters, fertilizers, biological processes and occurs in detritus. They are essential for the growth of organisms and is a nutrient that limits the primary productivity of the water body (Ramachandra and Ahalya, 2001). Nitrates and phosphates in water can contribute to high BOD levels. Nitrates and phosphates allow algae to grow rapidly. The death of algae contributes to organic waste in the water, which is then decomposed by bacteria contributing to high BOD levels. When BOD levels increases, dissolved oxygen (DO) level decreases as the oxygen available in the water will be consumed by different bacteria.

2.7 **Phytoplankton bloom:** Algae tend to grow very quickly under high nutrient availability but are short-lived. The high nutrient levels in lakes can even produce dense “blooms” of phytoplankton. The entire algae population dies, sinks and becomes food for the bacteria. The available oxygen will be rapidly consumed by the bacteria, but oxygen cannot be replenished soon as a result of the decreased algal population and minimal photosynthetic activity. Thus, a sudden phytoplankton die-off and the decomposition of dead plankton can reduce DO to levels lethal to fish. Also, the blooms can reduce or block sunlight penetrating the water, stressing or killing aquatic plants.

2.8 **Ammonia:** Ammonia poisoning is another primary cause of the fish kills. The various forms of nitrogen influent in sewage are organic N (protein N), urea, ammonia, nitrites and nitrates through processes like nitrification, denitrification and ammonification. Autotrophic nitrification consists of two consecutive aerobic reactions (figure 1), the conversion of ammonia to nitrite by *Nitrosomonas* and then from nitrite to nitrate by *Nitrobacter* (Mahapatra et al., 2011).

Nitrogen such as un-ionised ammonia ($NH_3$) is highly toxic to fish. Potential sources of ammonia are organic pollution, fertilizers, overcrowding of fish and industrial effluents. A higher level of ammonia exposes fish to higher incidences of bacterial gill disease. Ammonia enters the aquatic ecosystem via anthropogenic sources such as sewage entry, agricultural runoff, nitrogen fixation and the excretion of nitrogenous wastes from animals (USEPA, 2013). One of the main sources of ammonia in lake water is through fish excretion. The excrement rate is directly related to the feeding rate and the protein level in the feed being used. Fish digest the protein in their feed and excrete ammonia through their gills and in their feces. Another main source of ammonia is the diffusion from the lake sediments itself. Large amounts of organic matter are produced by algae or added to lakes as feed. Fecal solids and dead algae settle to the lake bottom and begin the process of decomposition and produces ammonia that diffuses from the sediment bottom into the water column. In water, ammonia is present in a molecular form ($NH_3$) and in the form of ammonium ions ($NH_4^+$). The ratio between these two forms depends on the pH and temperature of the water. The cell walls of the organisms are comparatively impermeable to the ammonia ion ($NH_4^+$), but molecular ammonia ($NH_3$) can readily diffuse across the tissue barriers where a concentration gradient exists and is therefore the potentially toxic form to fish (Patil et al., 2015).

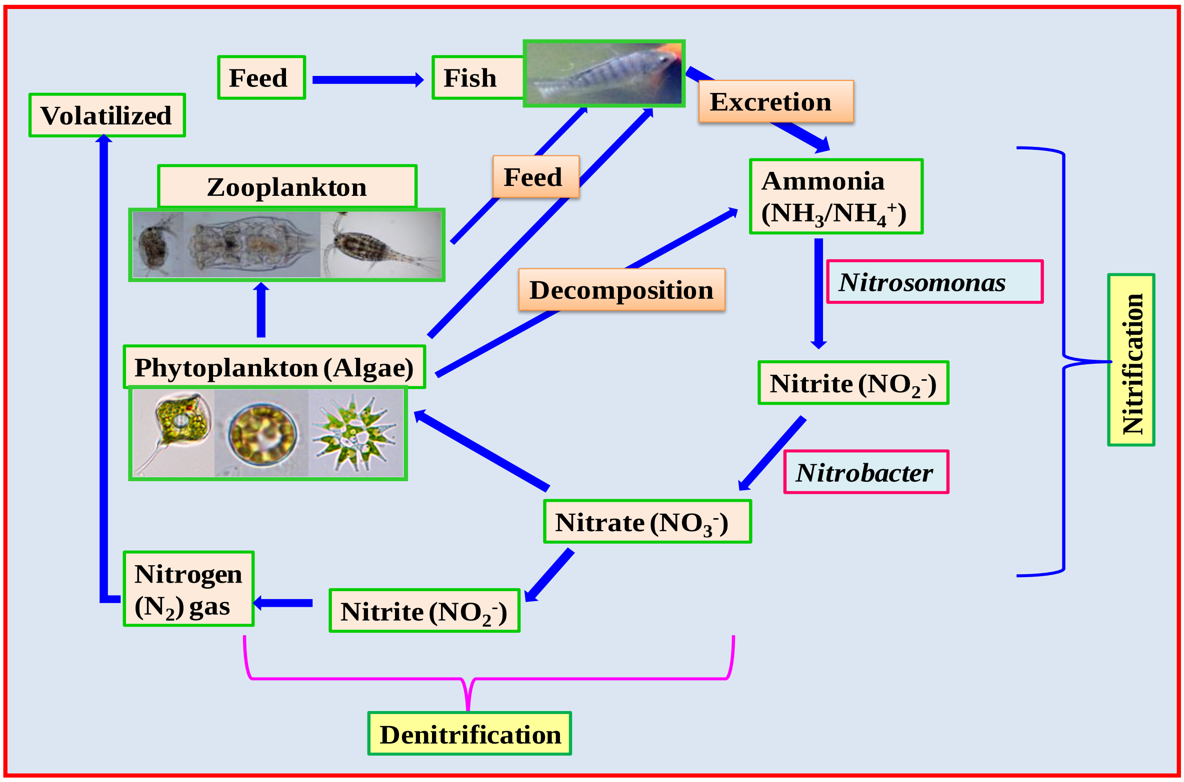


**Figure 1:** Role of ammonia in aquatic ecosystem

## 3) CASE STUDIES OF FISH KILLS

**3.1 Oxygen depletion:** The fish kill in 1996 at Sankey lake (*Eutroplus suratensis*, *Chanda ranga*, *Puntius* sp., *Nandus nandus* and *Amblypharyngodon mola*) was due to sudden fall in DO levels in some locations (at sewage inlet) resulting in asphyxiation and not due to any infection (Benjamin et al., 1996). Fish death was reported in Ulsoor Lake due to chemicals that flushed into the lake after cleaning of swimming pool, introduction of different varieties of fishes and due to phosphorus loading in the lake (Maheshwari, 2005). The insufficient oxygen levels in water affects fish population as oxygen has a low solubility in water (0.5%) than in air (21%) and also diffusion of oxygen is slower in water than air. Fish death is correlated with a stinking odour resembling rotten eggs, characteristics of hydrogen sulphide ($H_2S$). $H_2S$ (odour is perceptible in a dilution of 0.002 mg/L) is a colour-less gas produced by respiration of certain bacteria and is highly toxic to most respiratory organisms with the ability to kill animals, plants and microorganisms in micromolar range by coming into contact with the respiratory enzyme, cytochrome c oxidase (Maheshwari, 2005). The disastrous mass mortality of Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) in Lake Hashenge, Tigray occurred in June, 12 to 15$^{th}$, 2014. The physico-chemical characteristics of Hashenge lake water revealed the presence of abnormal water color, low level of DO (2.39 mg/L), low Secchi disk reading, and slightly alkaline pH. The turnover of the lake due to the mixing of the thermally layered water was the reason for the low DO, which caused mass kills of the fishes. The mass mortality was more severe in Nile tilapia as compared to mortality of common carp (Teame et al., 2016).

**3.2 Ammonia toxicity**: Ammonia causes negative effects on fish like reduced growth rates, poor feed conversion and reduced disease resistance. Excess ammonia ($NH_4$) levels accumulate in organisms and cause alteration of metabolic activities or increases in body pH harming the aquatic life. At extreme ammonia levels, fish may experience convulsions, coma and death. A short-term exposure to toxic un-ionized ammonia at about 0.6 mg/L (ppm) is capable of killing fish over a few days. But, chronic exposure to toxic un-ionized ammonia as low as 0.06 mg/L (ppm) can cause gill and kidney damage, growth reduction, brain malfunctioning and reduction in the oxygen-carrying capacity of the fish (Durborow et al., 1997; Hargreaves and Tucker, 2004; Waqar K et al., 2013). Ammonia in the range >0.1 mg/L tends to cause gill damage, destroy mucous producing membranes, "sub-lethal" effects like reduced growth, poor feed conversion and reduced disease resistance at concentrations that are lower than lethal concentrations, osmoregulatory imbalance, kidney failure. Fish suffering from ammonia poisoning generally appear sluggish or often at the surface gasping for air (Bhatnagar and Devi, 2013). The maximum admissible ammonia concentration is 0.05 mg/L, where as the ammonia level in the Taj boudi (of Bijapur) water was 2.71 mg/L, which is lethal to fish (Patil et al., 2015).

**3.3 Detergents:** Detergents are commonly used for cleaning purposes in households. The extensive use of the detergents pollutes the aquatic ecosystem as they are made up of surface-active agents, builders and fillers. In addition, they contain additives such as anti re-deposition agents, optical fibre brighteners (whitening agents), bluing agents, bleaching agents, foam regulators, organic sequestering agents, enzymes, perfumes and substances that regulate density and assure the crispness of the material they are used on. Phosphates act as a builder in laundry detergents and automatic dishwasher detergents. They make the water soft and slightly alkaline and dissolve dirt and keep it in suspension during washing and thus, increase the performance of the detergent. The presence of detergent in water accelerates the corrosive action, impedes the filtering, sedimentation and coagulation processes, increases the saturation of water with oxygen and also deteriorates the taste properties of water (Vasanthi et al., 2013; Ramachandra et al., 2015).

The ‘after wash’ of detergents is either drained into the aquatic environment such as ponds, lakes, rivers, streams etc. or they find their way into the aquatic environment through sewage line connected to lakes. Fish has been used as model organism to detect the level of toxicity of different chemicals drained/contaminated in aquatic environment. Linear Alkyl Benzene Sulphonate (LABS) detergent was found to have acute toxic and severe histopathological effects on the gill of *Puntius ticto* fish. When fishes were exposed to LABS (**Henko**) in graded concentrations (20 - 28 mg/L, except 22 mg/L) for 24, 48, 72 and 96 hr duration, it was found that all the 30 fishes (100%) died in Henko concentration of 28 mg/L at 24 hr, indicating that the acute toxicity of LABS is dose dependent. The $LC_{50}$ of Henko was found to be 25.5 mg/L. The histopathological examination of fishes exposed to 2 mg/L Henko for one month revealed severe changes in the epithelial lining of gill arch, gill rakers and gill filaments, suggesting that LABS may induce abnormal cellular structure in gills. As the dose/concentration of LABS increases, the mortality percentage of *Puntius ticto* fingerlings also increases. Thus, the drainage of ‘after wash’ of this detergent besides other chemicals into the aquatic environment should be strictly prohibited (Varsha et al., 2011). A significant decrease in protein, carbohydrate and cholesterol content in the tissues of fish species *Cirrhinus mrigala* was observed when the fishes were exposed to sub-lethal concentration of detergent **Tide** i.e., 3.6 mg/L for 24, 48 and 72 hrs respectively. The kidney showed the highest percent decrease in carbohydrate (77.27%), in protein (76.42%) and in cholesterol (80.03%) content (Vasanthi et al., 2013). The fishes belonging to species *Cirrhinus mrigala* of mean body weight (1.25g±0.12) were exposed to three concentrations of detergent, **Surf excel easy wash** i.e, 0.5 mg/L, 1 mg/L, 3 mg/L respectively. Eventhough the test fish exhibited no signs of deformity; the fishes showed marked increase in protease activity with increasing concentration of Surf excel easy wash than the control group (Rani and Kaushik, 2014). The oxygen consumption in the freshwater fish, *Mystus montanus* increased with 1/3$^{rd}$ sublethal concentration of detergents like **Surf** and **Nirma** powder with increase in time (Chandanshive, 2014).

**3.4 Fish Diseases/Infections:** Disease is a prime agent affecting fish mortality. Fishes are exposed to different environmental pollutants, including drugs and chemicals. They carry pathogens and parasites and get infected by different pathogens, microorganisms or parasites. Some commonly found fish diseases, listed in Table 1 are gill disease, water quality induced diseases, constipation, anorexia, columnaris, ick, dropsy, tail and fin-rot, fungal infections, white spot disease, pop-eye, cloudy eye, swim bladder disease, lice and nematode worms infection, tuberculosis, lymphocytosis etc. (Sharma et al., 2012). Most fish pathogenic bacteria can reside in the environment or on/in normal fish. Thus, infections induced by some stress (e.g. overcrowding, low DO, high ammonia) upsets the natural defense of organisms (Khatun et al., 2011).

**Table 1:** Common fish diseases/infections

| Disease | Causes | Symptoms | Reason |
|---|---|---|---|
| **Dropsy** | Bacterial infection. Viral infection, nutritional, metabolic and osmoregulatory problems can also be responsible. | Accumulation of fluid inside the body cavity, scale protrusion, exophthalmic condition and inflammation of intestine and haemorrhagic ulcers occur on skin and fins. Bulging eyes, pale gills, the fish may stop eating and hang near the bottom or gasp for air at the top of the tanks and show signs of unbalanced swimming. | Usually triggered by poor water quality, especially the presence of ammonia and nitrite, also drastic temperature changes and improper nutrition. Often confined to individual fish. |
| **Ulcers** | *Pseudomonas* and *Aeromonas* bacteria | Pinky-white open wounds, often with a white edge and sometimes secondarily infected by fungi and other bacteria. | Very poor water quality or an excessively high pH level. Minor scratches can become infected if conditions are poor. |
| **Cloudy eye** | Poor water quality, poor diet, eye flukes, corneal damage, bacterial infection. | Entire surface or lens of eye takes on a cloudy, opaque appearance. There may be a build-up of mucus on the | Most commonly caused by poor water conditions. A lack of vitamins in the diet may also cause |

| | | | |
|---|---|---|---|
| | | outer surface. | clouding. On rare occasions digenetic flukes, such as *Diplostomum*, can cause problems. |
| **White spot** | *Ichthyophthirius multifilis* parasite | Whitish cysts on the skin, fins and gills. | Stress related, poor water conditions, fluctuating temperature. |
| **Bacterial infection** | *Aeromonas* and *Pseudomonas* bacteria | Reddening of the skin or fins; ragged fins with signs of infection, open sores. Often accompanied by other diseases, including fungi. | Poor water conditions, especially the presence of ammonia and nitrite. Bacteria infect the wounds on fish if the conditions are poor. |
| **Fungus** | *Saprolegnia* and *Achlya* | Cotton like growth on the skin and fins of freshwater fishes. It begins as small, local infections and then, spreads over the body. | It is a secondary infection seen after damage to fish integument. Water pollution and overcrowding are the other main factors. |
| **Finrot** | *Aeromonas*, *Pseudomonas* or *Flexibacter* bacteria | Frayed fins often with a pale pinkish-white edge and some blood in the fin tissue. | The bacteria are present on most fish. Stress from poor water conditions usually triggers an infection. Nipped fins become secondarily infected if water is polluted. |
| **Swimbladder disorder** | Bacterial infection, improper diet, trapped gas, physical deformities. | Fish have difficulty in swimming to the surface or to the lower levels of the tank. | Sometimes caused by poor water quality and due to genetic problems. |
| **Lymphocystis** | An iridovirus | The virus causes crusty grey-white lumps to develop on the skin and fins. | The disease is viral, but may be triggered by stress, poor handling or poor water. Some fish may carry the virus without showing any symptoms. |
| **Sources:** Benjamin et al., 1996; Sharma et al., 2012; Verma, 2008; Maheshwari, 2005. http://www.himachal.gov.in/WriteReadData/l892s/4_l892s/1402134883.pdf; http://homeaquaria.com/common-aquarium-fish-diseases/#4_Dropsy | | | |

Table 2 lists fish mortality cases reported from various aquatic ecosystems in India. More than 80% fishes were infected by fungi, *Saprolegnia parasitica* (which had cotton like appearance) in Naini Tal Lake, Uttaranchal, India. The infected parts of the body mainly included pectoral, pelvic and caudal fins, gills and skin. The symptoms include bleeding from the infected parts of the body; the fishes had ragged and tattered body appearance, peeling of skin, bulging eyes, and were sluggish (Nagdali and Gupta, 2002).

Similar large scale mass mortality of *Tilapia mossambicus* due to fungal infection was reported in culture pond of University campus, Bhopal. The fungal infection was observed on body of fishes in form of cottony mycelium. Anterior region of body was the most affected area and fishes suffered from severe infection followed by death. Isolation and culture of fungi revealed the presence of six different species of zoosporic fungi viz. *Achlya americana*, *Achlya proliferoids*, *Aphanomyces laevis*, *Pythiopsis* sp., *Saprolegnia diclina* and *Saprolegnia parasitica*. Most of the fungi appeared as mixed infections. Among these, *S. parasitica* was found as the most virulent and pathogenic fungi (Chauhan, 2014).

A total of 17 isolates of fungi were isolated from diseased fishes (of six different species viz. *Channa stratius*, *Channa punctatus*, *Clarius batrachus*, *Labeo rohita*, *Heteropneuste fossilis* and *Mystus cavasius*) which belong to 5 species namely *Saprolegnia diclina*, *Saprolegnia ferax*, *Saprolegnia hypogyana*, *Saprolegnia parasitica* and *Achlya americana* (Mastan, 2015).

**Table 2:** Fish Mortality cases in India

| Sl. No. | Name of water bodies | State | Reasons | Month and Year | Reference |
|---|---|---|---|---|---|
| **Research papers** | | | | | |
| 1 | Nanak Sagar reservoir in Nainital district | U.P. | Fungal diseases in fishes | February 1991 | Khulbe et al., 1995 |
| 2 | Sankey lake and Lalbagh lake, Bangalore | Karnataka | Depletion of DO levels in some locations caused by sewage let into the lake resulting in asphyxiation | June-July 1995 | Benjamin et al., 1996 |
| 3 | Lake Naini Tal, India | Uttaranchal | Fungal infection | 28th March - 4th April, 2000 | Nagdali and Gupta, 2002 |
| 4 | Ulsoor Lake, Bangalore | Karnataka | Increased oxygen demand and chemicals flushed into lake. | Jan 26, 2005 | Maheshwari, R., 2005 |
| 5 | Peddacheruvu lake and Sambaiah cheruvu lake, Medak District | Andhra Pradesh | Low levels of water (in dry season), low DO and high dissolved solids. | February 2012 | Poodari et al., 2014 |

 

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|---|---|---|---|---|---|
| **6** | Barkatullah University pond, Bhopal | Madhya Pradesh | Fungal infection on body of fishes in form of cottony mycelium, followed by fish death. | December, 2012 | Chauhan, 2014 |
| **7** | Jakkur lake, Bangalore | Karnataka | Oxygen depletion in some locations caused by sustained inflow of sewage into the lake, resulting in asphyxiation. | January 2015 | Ramachandra et al.,2015a |
| **8** | Sankey lake, Bangalore | Karnataka | Oxygen depletion, toxic algal blooms and sudden changes in temperature and increased ammonia levels | August 2013 | Ramachandra et al.,2015b |
| **9** | Taj Boudi of Bijapur | Karnataka | Depletion of DO, elevated BOD, high level of molecular ammonia and eutrophication due to the enrichment of water with Phosphorous and Nitrogen in the form of $PO_4$ and $NO_3$. | 20th to 23rd December 2010 | Patil et al., 2015 |
| **10** | Deverabisanahalli Lake near Marathalli Ring road, Bangalore | Karnataka | Organic pollutants discharged into the aquatic ecosystem | 24th November 2010 | Patil et al., 2015 |
| **Newspaper reports** | | | | | |
| **1** | Periyar river in Pathalam | Kerala | Sudden drop in the dissolved oxygen level which led to the fish kill | 10 February 2013 | The Hindu |
| **2** | Periyar river near Eloor | Kerala | Lack of dissolved oxygen is the cause of the large-scale fish death | 03rd July 2012 | The New Indian Express |
| **3** | Srisailam reservoir | Andhra Pradesh | Depleting oxygen levels in the water and steep variation | 28 September 2012 | The Hindu |

| | | | | | |
|---|---|---|---|---|---|
| | | | in day and night temperatures. | | |
| **4** | Tank in Atmakur Mandal in Warangal district | Andhra Pradesh | Lakhs of fish died as the tank went dry. | 8 May 2009 | The Hindu |
| **5** | Akiveedu in West Godavari district | Andhra Pradesh | Deficiency in oxygen levels caused by sudden changes in the climate | 2 may 2012 | The Hindu |
| **6** | Akiveedu in West Godavari district. | Andhra Pradesh | Hundreds of fish died due to intense heat wave and sudden fluctuation in temperature in West Godavari district. | 13 June 2014 | The Hindu |
| **7** | Visakhapatnam | Andhra Pradesh | Discharge of industrial effluents | 1 July, 2014 | The Hindu |
| **8** | Kolong, Kopili and Kiling rivers in Morigaon district | Assam | Water pollution | 29 Jun 2014 | The Times of India |
| **9** | Lower lake near Khatlapura, Bhopal | Madhya Pradesh | Toxic chemicals | 1 Nov, 2015 | The Times of India |
| **10** | Dorekere, Bangalore | Karnataka | Sewage flooded into the lake after heavy rain | 25 April 2015; 30 May 2014 | The Hindu |
| **11** | Jakkur lake, Bangalore | Karnataka | Sewage entered the lake from a damaged storm water drain. The underground drain from Yelahanka and Allasandra is blocked because of which sewage water is overflowing into the lake | 08 Jan 2015 | Deccan Herald |
| **12** | Cubbon Park pond, Bangalore | Karnataka | The sewage water had triggered a severe depletion of oxygen level. | 15 April, 2010 | Deccan Herald |
| **13** | Puttenahalli lake, Bangalore | Karnataka | A major storm water drain that flowed along the | 16 Jun 2005 | The Hindu |

| | | | | | |
|---|---|---|---|---|---|
| | | | lake could have entered the lake resulting in the depletion of dissolved oxygen level. | | |
| **14** | Vengaiana lake, Bangalore | Karnataka | Drastic drop in oxygen level in the water, which in turn was caused by untreated sewage water | May 2005 | The Hindu |
| **15** | Ulsoor lake, Bangalore | Karnataka | Chemicals flushed into the lake, following a cleaning of the BCC-owned Ulsoor swimming pool; to a drastic drop in oxygen level in the water, which in turn was caused by untreated sewage water | January 2005 | The Hindu |
| **16** | Devarabeesanahalli lake, Bangalore | Karnataka | Inflow of sewage and industrial pollutants into the lake | 17 June 2015 | Deccan Herald |
| **17** | Karanji lake, Mysore | Karnataka | Oxygen levels in the water had dropped to zero at some points due to the discharge of effluents into the lake | 16 May 2014 | Bangalore Mirror |
| **18** | Kukkarahalli lake, Mysore | Karnataka | Sewage water flows into lake; attributed to blooming algae, which blocks sunrays into the water body, thus reducing photosynthesis and depleting oxygen levels | 5 Aug 2001 | The Times of India |
| **19** | Ulsoor Lake | Karnataka | Oxygen levels in | 7th March | The Hindu |

| | | | | | |
|---|---|---|---|---|---|
| | | | the water had dropped to zero at some points due to the discharge of untreated sewage | 2016 | |
| **20** | Devarabisanahalli | Karnataka | Oxygen levels in the water had dropped to zero at some points due to the discharge of untreated sewage | March 2016 | Times of India |

# 4.0 MATERIALS AND METHODS:

**4.1 STUDY AREA:** Greater Bangalore (77°37'19.54'' E and 12°59'09.76'' N) is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka with an area of 741 square kilometers and lies between the latitudes 12°39'00'' to 131°3'00''N and longitudes 77°22'00'' to 77°52'00''E. Bangalore is located at an altitude of 920 meters above mean sea level, delineating three watersheds: Hebbal, Koramangala - Challaghatta and Vrishabhavathi watersheds (Ramachandra and Kumar, 2008).

Ulsoor Lake is one of the well known historical lake in the city, located in the eastern part of Bangalore, in the Challaghatta Valley covering an area of 41.5 hectares (reduced from 50 hectares). Current depth of water is 1.5 m (earlier depth was 5.6 m) and is fed by Munireddy Palya drain and Doddakunte drain, the outlet is through Gurudwara Challghatta main SWD to Bellandur tank (Randhawa and Bharmal, 2010).


**Figure 2.1: Sampling points at Ulsoor Lake**

| | |
|---|---|
|  Ulsoor lake |  S1- Inlet to the lake |
|  S2 |  S3 |
|  S4 |  S5 |

**S6 – Outlet of the lake**

**Fishes at the outlet of Ulsoor lake**

**Plastic wastes and Organic waste floating at the surface of Ulsoor lake**

**Sewage water flowing into Ulsoor lake**

**Solid wastes at the outlet of Ulsoor lake**

Figure 2.2: Field conditions at various sampling locations

**Massive fish mortality at Ulsoor lake**

**Figure 2.3:** Dead fish in Ulsoor lake

**4.2 ANALYSIS OF PHYSICO-CHEMICAL PARAMETERS:** Water samples from six different sites were collected on 7th March, 2016 for water quality analysis of Ulsoor lake (sampling locations are marked in figure 2.1 and figure 2.2). The water temperature, pH, electrical conductivity, TDS and DO were determined on spot at the time of sampling. Other parameters like nitrate, orthophosphate, turbidity, total alkalinity, calcium and magnesium hardness, total hardness, chlorides, COD, BOD, sodium and potassium were analysed in the laboratory as per standard protocol (Trivedi and Goel,1986 and APHA, 1998). Table 3 lists the methods adopted for estimating various water quality parameters. Figure 2.3 depicts large scale fish mortality, which highlights the gravity of the contamination.

**Table 3:** Standard methods followed for water quality analysis

| Parameters | Methods (with Reference) |
|---|---|
| **Onsite Measurements** | |
| Water temperature ($^0$C) | Eutech: PCSTestr 35 |
| pH | Eutech: PCSTestr 35 |
| Total Dissolved Solids (TDS, mg/l) | Eutech: PCSTestr 35 |
| Electrical conductivity (µS/cm) | Eutech: PCSTestr 35 |
| Dissolved Oxygen (DO) (mg/l) | Winkler's Method (APHA, 1998: 4500-O) |
| **Laboratory Measurements** | |
| Turbidity (NTU) | Nephlometer/Turbidometer (HACH) |
| Hardness (mg/l) | EDTA titrimetric method (APHA, 1998: 2340-C) |
| Calcium hardness (mg/l) | EDTA titrimetric method (APHA, 1998: 3500-Ca B) |
| Magnesium hardness (mg/l) | Magnesium by calculation (APHA, 1998:3500-Mg) |
| Sodium (mg/l) | Flame emission photometric method (APHA, 1998:3500-Na B) |
| Potassium (mg/l) | Flame emission photometric method (APHA, 1998: 3500-K B) |
| Alkalinity (mg/l) | Titrimetric method (APHA, 1998: 2320 B) |
| Chloride (mg/l) | Argentometric method (APHA, 1998:4500-$Cl^-$ B) |
| Biochemical Oxygen Demand (BOD) (mg/l) | 5-Day BOD test (APHA, 5210 B, Trivedi&Goel, 1986, pp.53-55) |
| Chemical Oxygen Demand (COD) (mg/l) | Closed reflux, titrimetric method (APHA, 5220 C, Trivedi&Goel, 1986, pp.55-57) |
| Nitrates | Phenol Disulphonic acid method (Trivedy and Goel, 1986: pp 61) |
| Orthophosphates (mg/l) | Stannous chloride method (APHA, 4500-P) |

### 4.3 PHYTOPLANKTON AND ZOOPLANKTON ANALYSIS:

**Plankton collection and Identification: P**lankton samples were collected by filtering 50 litres of lake water through the standard plankton net (No. 25 bolting silk cloth net of mesh size 63 mm and 30 cm diameter). The final volume of the filtered sample was made to 20 ml and then transferred to another 125 ml plastic bottle and labeled, mentioning the time, date and place of sampling. The samples collected were preserved by adding 2ml of 5% formalin. Samples of phytoplankton and zooplankton were identified through microscope using the standard keys and interaction with experts.

## 5.0 RESULTS AND DISCUSSION:

The sustained inflow of untreated sewage into the Ulsoor Lake has enriched the aquatic ecosystem with nutrients. Water temperature at the time of sampling ranged from 25.7° – 29.7°C. All metabolic and physiological activities and life processes such as feeding, reproduction, movement and distribution of aquatic organisms are greatly influenced by temperature (Trivedy and Goel, 1986). An increase in the temperature, enhances the metabolic activities and reduces the solubility of gases like dissolved oxygen and carbon dioxide in the water. pH of the water samples ranges from 7.88 – 9.29 indicating alkaline conditions. The pH of aquatic ecosystems fluctuates during photosynthesis, respiration and nitrogen assimilation. pH is also governed by the equilibrium between carbon dioxide or bicarbonate or carbonate ions. pH increase due to increased photosynthetic processes (uptake of carbon dioxide with the release of oxygen) and decreases during high rate of respiration/ decomposition (consumption of oxygen with the release of carbon dioxide) (Ramachandra and Ahalya, 2001).

Sustained inflow of untreated sewage at the inlet has impacted the integrity of water evident from higher amount of TDS, EC, turbidity, BOD, COD, alkalinity, hardness, nutrients, sodium and potassium. The increase or decrease in TDS and EC are attributed to the ions concentration - calcium, magnesium, sodium, and potassium (cations) and carbonate, bicarbonate, chloride, sulfate, and nitrate (anions). High values of TDS are well correlated with the EC of lake waters and can have negative influence on the biological production efficiencies of lake ecosystems (Kiran and Ramachandra, 1999). Higher turbidity in lake water indicates the presence of higher concentrations of organic and also non-biodegradable components. Turbidity of the lake water, along with its warm temperature, alkaline pH and low oxygen levels, could lead to prolonged survival of pathogenic bacteria for up to several days. Since, there is a high demand of oxygen (as indicated by higher values of BOD and COD) in sewage as well as lake water. Lower values of dissolved oxygen indicate of organic contamination. Higher values of chloride and total hardness (also calcium and magnesium hardness) in lakes are attributed to the regular addition of sewage and detergents. Nitrogen and phosphate are limiting factors for primary production. Phosphorus occurs mainly as orthophosphate. Nitrogen occurs mainly as nitrate, nitrite, ammonia and as ammonium ions. The major sources of ortho-phosphate and nitrate are domestic sewage, detergents, agricultural runoff and industrial wastewater. The high nutrient contents (nitrate and orthophosphate) had supported algal growth in the Ulsoor Lake. The presence of higher amount of different physico-chemical parameters like total dissolved solids (217 – 454 mg/l); electrical conductivity (436 - 815 µS); chemical oxygen demand (14 - 278 mg/l); biochemical oxygen demand (8.13 – 93.5 mg/l); alkalinity (189.33 – 510.67 mg/l); chloride (73.37 – 109.81 mg/l); total hardness (95.33 – 214 mg/l); calcium hardness (18.7 – 50.5 mg/l); magnesium hardness (18.3 – 39.73 mg/l); nitrate (0.302 – 1.664 mg/l); phosphate (0.27 – 2.24 mg/l) sodium (89.6 – 125.2 mg/l) and potassium (24.4 -29.6 mg/l) and lower values of dissolved oxygen (0 – 5.69 mg/l), indicate pollution due to untreated sewage entry (table 4) and Table 5 lists CPCB standards and Ulsoor lake falls under Class E of Inland Surface Water.

**Table 4:** Physico-chemical characteristics of Ulsoor lake

| Parameters | Ulsoor Lake | | | | | | Water quality Standard IS 10500, 1991-2011 | |
|---|---|---|---|---|---|---|---|---|
| | **S1** | **S2** | **S3** | **S4** | **S5** | **S6** | **Desirable** | **Permissible** |
| Water Temperature ($^0$C) | 25.7 | 29.3 | 29.7 | 29.6 | 27.1 | 27.8 | - | - |
| TDS (mg/l) | 454 | 260 | 229 | 217 | 222 | 222 | 500 | 2000 |
| EC (µS) | 815 | 511 | 446 | 436 | 450 | 458 | - | - |
| pH | 7.88 | 8.73 | 8.6 | 9.29 | 8.65 | 8.45 | 6.5-8.5 | No relaxation |
| Turbidity(NTU) | 472.25 | 32.43 | 31.48 | 27.9 | 24.95 | 19.7 | 5 | 10 |
| DO (mg/l) | 0 | 4.88 | 5.69 | 4.72 | 2.36 | 2.6 | - | - |
| BOD (mg/l) | 93.5 | 24.39 | 8.13 | 28.46 | 28.46 | 8.13 | - | - |
| COD (mg/l) | 278 | 34 | 14 | 38 | 42 | 14 | - | - |
| Alkalinity (mg/l) | 510.67 | 233.33 | 208 | 205.33 | 189.33 | 217.33 | 200 | 600 |
| Chloride (mg/l) | 109.81 | 76.21 | 75.73 | 75.73 | 73.37 | 76.21 | 250 | 1000 |
| Total Hardness (mg/l) | 214 | 116 | 96.67 | 95.33 | 100 | 95.33 | 300 | 600 |
| Ca Hardness (mg/l) | 50.5 | 28.06 | 18.7 | 20.04 | 22.18 | 20.57 | 75 | 200 |
| Mg Hardness (mg/l) | 39.73 | 21.37 | 18.95 | 18.3 | 18.91 | 18.17 | 30 | 100 |
| Phosphate (mg/l) | 2.24 | 0.406 | 0.27 | 0.27 | 0.249 | 0.273 | - | - |
| Nitrate (mg/l) | 1.664 | 0.368 | 0.381 | 0.302 | 0.311 | 0.318 | 45 | 100 |
| Sodium (mg/l) | 125.2 | 106 | 102.4 | 89.6 | 95.6 | 94.8 | - | - |
| Potassium (mg/l) | 29.6 | 28 | 26.4 | 24.4 | 25.2 | 26.8 | - | - |
| Ammonia (mg/l) | 7.99 | 3.63 | 2.43 | 2.19 | 2.36 | 1.74 | 0.5 | No relaxation |

**Table 5:** Classification of Inland Surface Water (CPCB)

| As per ISI-IS: 2296-1982 | |
|---|---|
| **Classification** | **Type of use** |
| **Class A** | **Drinking water source without conventional treatment but after disinfection** |
| **Class B** | **Outdoor bathing** |
| **Class C** | **Drinking water source with conventional treatment followed by disinfection.** |
| **Class D** | **Fish culture and wild life propagation** |
| **Class E** | **Irrigation, industrial cooling or controlled waste disposal** |

| Characteristic | A | B | C | D | E |
|---|---|---|---|---|---|
| **pH** | **6.5 - 8.5** | **6.5 - 8.5** | **6.5 - 8.5** | **6.5 - 8.5** | **6.0 - 8.5** |
| **DO (mg/L)** | **6** | **5** | **4** | **4** | **-** |
| **BOD (mg/L)** | **2** | **3** | **3** | **-** | **-** |
| **TDS, mg/l, Max** | **500** | **-** | **1500** | **-** | **2100** |
| **Electrical Conductance at 25 °C, µS, Max** | **-** | **-** | **-** | **1000** | **2250** |
| **Total Hardness (as $CaCO_3$), mg/l, Max** | **300** | **-** | **-** | **-** | **-** |
| **Calcium Hardness (as $CaCO_3$), mg/l, Max** | **200** | **-** | **-** | **-** | **-** |
| **Magnesium Hardness (as $CaCO_3$), mg/l, Max** | **100** | **-** | **-** | **-** | **-** |
| **Chlorides (as Cl), mg/l, Max** | **250** | **-** | **600** | **-** | **600** |
| **Nitrates (as $NO_2$), mg/1, Max** | **20** | **-** | **50** | **-** | **-** |

Acidic waters with pH <6.5 and alkaline waters with pH >9.5 retards reproduction and growth of fish and could lead to diseases. Low DO retards intake of food and growth in fishes. The most suitable value of total hardness for fish culture is said to be in the range of 75 – 150 mg/L. Optimum total hardness prevents the outbreak of common diseases in fish. High accumulation of humic substances through the decomposition of profuse organic matter and macro-vegetation allows the harboring of a higher number of disease producing organisms than is possible in clean waters, having transparency >20cm (Kar, 2016).

Excess quantity of ammonia in surface waters impair aquatic biota, is an indication of eutrophication. Some key environmental factors that control nitrification include dissolved oxygen (DO), temperature, substrate concentration and pH (Allen et al., 2010). Ammonia release under anoxic conditions is mediated by 2 predominant mechanisms namely (i) lack of biological nitrification activity (biological oxidation of ammonia to nitrate in sediments becomes impossible) and (ii) low rates of ammonia assimilation (by slow-growing anaerobic bacteria in sediments). Some of the nitrate may be lost from the aquatic ecosystem via subsequent de-nitrification in anoxic subsurface sediments. The toxicity of un-ionized ammonia is a function of pH, temperature, alkalinity and total ammonia concentration measured at the gill surface. Ammonia at elevated pH and temperature, which shifts the ionization equilibrium to unionized gaseous form, which is toxic to fish. Ammonia toxicity is apparent by hyperactivity, convulsions, loss of equilibrium, lethargy and coma. The ammonia toxicity in aquaculture ponds results in the sub-lethal reduction of fish growth or suppression of immuno-competence, rather than as acute toxicity leading to mortality (Hargreaves, 1998).

The sewage water containing organic components, human waste (urine and faeces), phosphate, nitrate and detergent phosphate when discharged into the water bodies causes eutrophication of lakes. Detergents can be easily absorbed from the surrounding water either through by gills or intestinal epithelium of fishes and due to their potential toxicity induces histological and biochemical alteration in the organs of fishes. The synthetic detergents can also alter pH and salinity of receiving freshwater body, which affect oxygen consumption by aquatic organisms including fishes (Pattusamy et al., 2013). The predominant mechanism responsible for phosphorus release from sediments under anoxic conditions is the microbial reduction of phosphate-containing iron-oxide complexes (utilizing ferric iron in sediment as an electron acceptor) resulting in a release of ferrous iron and phosphate into overlaying water (Beutel, 2006).

**Plankton composition of Ulsoor lake:** In Ulsoor lake, mainly 4 algal groups found were: Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyceae (figure 3). The outlet sampling point had higher algal groups than inlet and middle points. In Ulsoor lake, pollution-tolerant genera were present which includes: *Cyclotella* sp. and *Phacus* sp. (Venkatachalapathy et al., 2013), *Nitzschia* sp. (Karthick et al., 2009; Venkatachalapathy et al., 2013), *Oscillatoria* sp. (Singh et al., 2011), and *Scenedesmus* sp., *Euglena sp.* (Mahapatra et al., 2013); *Pinnularia* sp. (Hosmani, 2012). *Cyclotella* sp. was the most dominant algae at all the sampling points. The Chlorophycean growth was favoured by high dissolved contents. Among Bacillariophyceae, *Cyclotella* sp. was the most dominant member. Chlorophyceae were represented by *Scenedesmus* spp.; *Pediastrum* sp.; *Schroederia* sp.; *Tetrastrum* sp.;

*Monoraphidium* sp.; *Golenkinia* sp.; *Oocystis* sp.; *Cosmarium* sp.; *Actinastrum* sp.; *Coelastrum* sp.; *Dictyosphaerium* sp. and *Kirchneriella* sp. etc. Among Cyanophyceae, *Aphanocapsa* sp.; *Merismopedia* sp.; *Microcystis* sp. were the most dominant member. Euglenophyceae were represented by *Euglena* sp.; *Phacus* sp. and *Trachelomonas* sp.

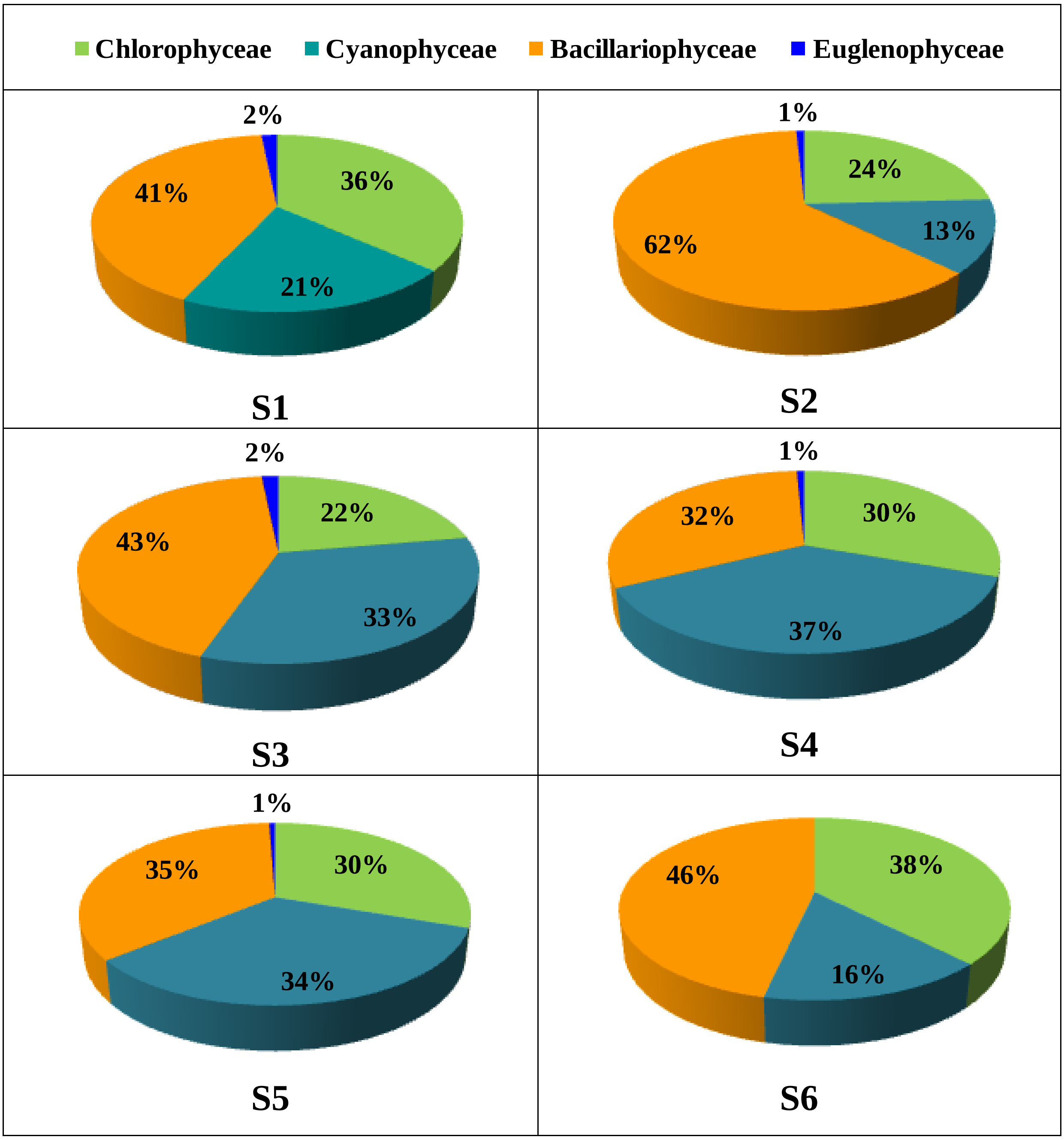


**Figure 3:** Distribution of phyoplankton in Ulsoor lake

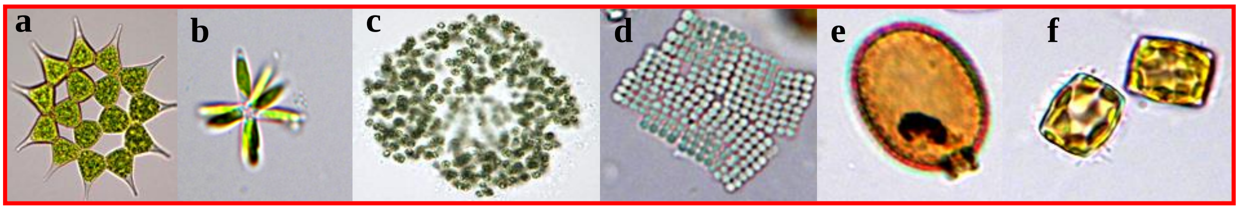

**Figure 4:** Phyoplankton in Ulsoor lake: a) *Pediastrum* sp.; b) *Actinastrum* sp.; c) *Microcystis* sp.; d) *Trachelomonas* sp. and e) *Cyclotella* sp.

Zooplanktons are the primary consumers occupying the second trophic level in the food chain after phytoplankton. Zooplankton diversity responds rapidly to changes in the aquatic environment, serves as bioindicators and are being used in the investigation of water pollution. Four groups of zooplanktons found In Ulsoor lake are Rotifera, Copepoda, Ostracoda and Protozoa. The distribution of zooplankton population varied among sites and were in the order: Copepoda > Rotifera > Protozoa > Ostracoda (figure 5 and 6).


**Figure 5:** Zooplankton in Ulsoor lake: a) *Macrocyclops* sp.; b) *Lecane* sp.; c) Nauplius larva; d) Chironomid larvae and e) *Arcella* sp.

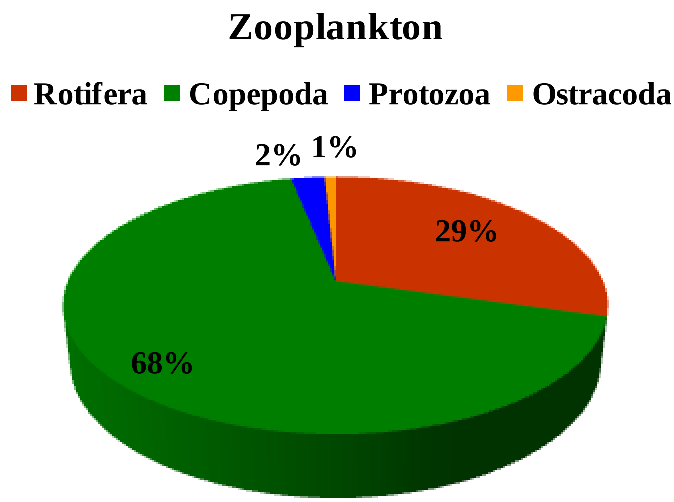


**Figure 6:** Distribution of zooplankton in Ulsoor lake

Predominant fish species that were impacted due to water contamination with the sustained flow of nutrient rich sewage and industrial effluents are *Tilapia nilotica*, *Puntius ticto*, *Labeo rohita*, *Catla catla* and *Gambusia affinis* (figure 7 and table 6). Among these, *Puntius ticto* has higher mortality.

**Table 6:** Impacted fish species of Ulsoor lake

| Sl.No. | Fish species | English Name | Kannada Name |
|---|---|---|---|
| 1 | *Catla catla* | Catla | Catla, Dodda Gende |
| 2 | *Gambusia affinis* | Mosquito fish | Gambusia, Hechige pakke, Solle meenu |
| 3 | *Labeo rohita* | Rohu | Rohu |
| 4 | *Oreochromis niloticus* | Tilapia | Jilebi |
| 5 | *Puntius ticto* | Ticto barb | Bud – Pakke, Naya paisa |

***Oreochromis niloticus***

***Catla catla***

***Puntius ticto***

***Labeo rohita***

***Gambusia affinis***

**Figure 7:** Dead fishes in Ulsoor lake

*P. ticto* a small fish commonly known as "ticto" or "two-spot" barb is found in fresh and brackish-water subtropical species. It is the most popular aquarium fish among barb species in Asian countries. Ticto barb inhabits still shallow, marginal waters of tanks and rivers, mostly with muddy bottoms. It feeds on crustaceans, insects, plankton, plants and other benthic invertebrates (Hossain et al., 2015).

Mortality of fish species was mainly due to lowered dissolved oxygen levels, which needs to be improved on priority in Ulsoor Lake through the introduction of aerators (water fountains or introduction of ducks). Aeration increases DO levels causing fish to be less stressed. It also removes hydrogen sulphide, methane and various volatile organic compounds responsible for bad taste and odour in lakes. Aeration improves the quality of water and decreases the treatment costs. Aeration also provides an aerobic environment for the degradation of organic matter by microorganisms (Ramachandra et al., 2015).

Conservation programmes help in maintaining diversity while enhancing the scope for sustainable production. Conserving diversity also improves the likelihood by maintaining minimal viable populations of rare and late-successional species. Diversity reduces instances of pathogens attack and allows recovery from disturbance. Some measures such as de-siltation, letting only treated sewage to the lake would lead to appreciable improvement in the water quality (parameters like pH, dissolved oxygen, etc.), and quantum jump in fish yield within a short period (Kar et al., 2006). Sustainable wetland management mainly include strategies to control of invasive species, encroachment, drastic land cover changes in the catchment and identification of buffer zone, providing aquatic resources with adequate water quality and limiting the spread of exotic biota (Ramachandra et al., 2011).

## RECOMMENDATIONS:

Following recommendations has to be taken in Ulsoor lake:

1. Regular monitoring of the lake will help in understanding the physico-chemical characteristics and will help in evolving appropriate sustainable management measures.
2. Aeration will help in maintaining dissolved oxygen levels, which reduces toxic effects and prevent excessive buildup of vegetation and organic matter.
3. Allow only treated sewage which helps in reducing enrichment of nutrients that induces profuse algal growth.
4. Restrict dumping of solid waste in the lake bed and lake catchment.
5. Leave only treated sewage through construction wetlands and algal ponds (to remove nutrients) as in Jakkur model.
6. Implementation of ‘polluter pays’ principle as per water act 1974.

7. Dredging (mostly wet dredging) to remove sediments (rich in nutrients) in the lake.
8. Public awareness and public participation is necessary.

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**ENERGY AND WETLANDS RESEARCH GROUP**
**CENTRE FOR ECOLOGICAL SCIENCES**
**NEW BIOLOGY BUILDING, 3RD FLOOR, E-WING, LAB: TE15**
**INDIAN INSTITUTE OF SCIENCE, BANGALORE 560 012**

Telephone : 91-80-22933099/22933503(Ext:107)/23600985
Fax : 91-80-23601428/23600085/23600683[CES-TVR]
Email : cestvr@ces.iisc.ernet.in, energy@ces.iisc.ernet.in
Web: http://ces.iisc.ernet.in/energy, http://ces.iisc.ernet.in/biodiversity
Open Source GIS: http://ces.iisc.ernet.in/grass