
# EXPERT'S COMMITTEE REPORT
ON
# REJUVENATION OF BELLANDUR LAKE

UNDER
THE CHAIRMANSHIP OF
ADDITIONAL CHIEF SECRETARY
SRI MAHENDRA JAIN, IAS

SUBMITTED ON:

TO
THE HONOURABLE CHIEF MINISTER
GOVERNMENT OF KARNATAKA

**Department of Urban Development,**
**Government of Karnataka,**
**Vikasa Soudha, Bengaluru 560 001**

## Members of the Committee:

| | | |
|---|---|---|
| 1 | Additional Chief Secretary, Urban Development Department, Bangalore. | Chairman |
| 2 | Commissioner, Bangalore Development Authority, Bangalore. | Member |
| 3 | Member Secretary, Karnataka State Pollution Control Board, Bangalore. | Member |
| 4 | Chairman, BWSSB, Cauvery Bhavan, Bangalore. | Member |
| 5 | Chief Executive Officer, KLCDA, Bangalore. | Member |
| 6 | Secretary, Dept. of Minor Irrigation, Bangalore. | Member |
| 7 | Commissioner, BBMP, Bangalore | Member |
| 8 | Deputy Commissioner, Bangalore Urban District, Bangalore | Member |
| 9 | Chief Engineer, WMM, BWSSB, Cauvery Bhavan, Bangalore. | Member |
| 10 | Chief Executive Officer, Namma Bangalore Foundation, Bangalore. | Member |
| 11 | Prof. T.V. Ramachandra, IISc, Bangalore. | Member |
| 12 | Prof. Ramaprasad, Chief of Technical Committee, LDA | Member |
| 13 | Dr. Yellappareddy, Environment Specialist, Bangalore. | Member |
| 14 | Dr. Sharachchandra Lele, ATREE, Bangalore. | Member |
| 15 | Chairman, Bellandur Residents welfare Association, Bangalore. | Member |
| 16 | Sri Ramamurthy, Original Applicant of PIL, Regarding Bellandur lake. | Member |
| 17 | Sri Siddaiah, IAS, (Retd) Commissioner, BBMP, Bangalore. | Member |
| 18 | Engineer Member, Bangalore Development Authority, Bangalore. | Executive Member |

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## ACKNOWLEDGEMENTS

The Committee could not have completed its task without the support of many individuals and organizations. While acknowledging all of them is practically impossible, we would like to thank all of them.

# LIST OF ABBREVIATIONS:

| | |
|---|---|
| MoEFCC | Ministry of Environment and Climate Change |
| CPCB | Central Pollution Control Board |
| KSPCB | Karnataka State Pollution Control Board |
| BDA | Bangalore Development Authority |
| NGO | Nom-Government Organisation |
| UDD | Urban Development Department |
| BWSSB | Bangalore Water Supply and Sewage Board |
| BMRDA | Bangalore Metropolitan Development Authority |
| KLCDA | Karnataka Lakes Conservation Development Authority |
| KIADB | Karnataka Industrial Development Board |
| BBMP | Bruhath Bengaluru Mahanagara Palike |
| CMC | City Municipal Council |
| WMM | Waste water Management |
| ATREE | Ashoka Trust For Research in Ecology and Environment |
| MLD | Million Litres Day |
| K & C valley | Koramangala & Challaghatta Valley |
| STP | Sewage Treatment Plant |
| ETP | Effluent Treatment Plant |
| DO | Dissolved Oxygen |
| BOD | Biochemical oxygen demand |
| DOC | Dissolved Organic Carbon |
| ENVIS | Environmental Information System |
| CES | Centre For Ecological Science |
| STPP | Sodium Tri Poly Phosphate |
| Cd | Cadmium |
| Pb | Lead |
| Cu | Copper |

| | |
|---|---|
| Ni | Nickle |
| Co | Cobalt |
| Fe | Ferrous |
| Mn | Manganese |
| Zn | Zinc |
| SWD | Storm Water Drain |
| UGD | Under Ground Drainage |
| RMP | Revised Maser Plan |
| CDP | City Development Plan |
| C & D | Constructional Debris |
| G.O. | Government Order |
| MLA | Member Of Legislative Assembly |
| MP | Member Of Parliament |
| NGT | National GreenTribunal |
| TMC | Thousand Million Cubic Feet |

## 1. BACKDROP:

The landscape in and around Bangalore is dotted with hundreds of man-made lakes which were originally irrigation tanks constructed over the past centuries. They were also important as sources of drinking water, for washing, fishing and wider aquatic habitat. As the city grew, agricultural lands got converted into built-up areas, and the importance of tanks as irrigation structures declined. While some traditional uses continue, viz., washing, fishing, and reed collection, the lakes have gained much more importance for the environmental amenities they provide in a highly urbanized context, viz., recreational space, micro-climatic benefits, aquatic and bird habitat, including the birds that migrate from far ofa region for breeding purposes, for vegetable growingin the downstreamareas, groundwater recharge, etc.

Unfortunately, while urbanization proceeded at a very high pace in the Bangalore region, the mismanagement of urban wastewater in particular and other environmental processes accompanying urbanization (such as solid waste generation, protection of natural stream flow channels) resulting in the pollution of most lakes during the past two decades, has ledto a variety of adverse environmental including health issues: stinking lakes, fish kills, contamination of ground water, contamination of the food chain, etc.

Bellandur and Varthur lakes are the two largest lakes, of Koramangala & Challaghatta Valley in Bangalore that have been receiving the largest amount of wastewater. During the pre-monsoon of 2015, due to high wind coupled with rainfall, massive froth and aerosol formation was noticed in the southern waste weir of Bellandur lake eventually overflowing onto the neighbouring road obstructing traffic **(Figure 1).**


**Figure 1: Froth at the waste weir of Bellandur lake**

To make things worse, on **May 16, 2015**, the froth at the northern waste weir (Yamalur weir) of Bellandur lake caught fire and this created fear and anxiety in the minds of the people living in that region, leading to a major public outcry **(Figure 2).**

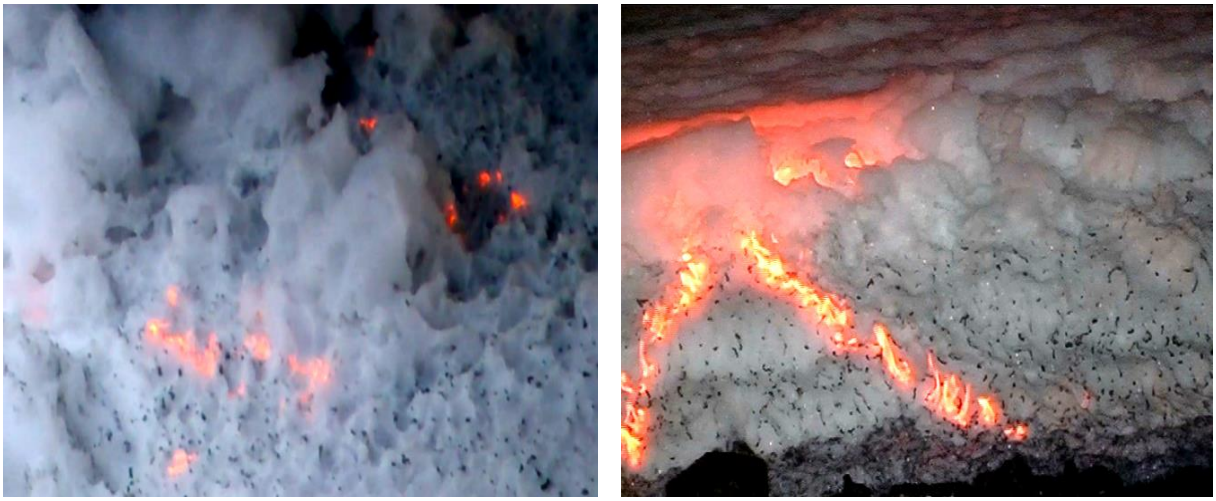

**Figure 2. Fire in the froth at Bellandur lake**

Responding to these concerns, The Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India instructed the regional office of the Central Pollution Control Board (CPCB) to carry out an analysis and submit areport within a month. According to CPCB findings, the causal factors for froth and fire are due to sustained inflow of untreated sewage and industrial effluents. Subsequently, Bangalore Development Authority (BDA) submitted two Detailed Project Reports to MoEFCC for restoration and comprehensive development of Bellandur and Varthur lakes. Subsequently, a consultative meeting on this issue was conducted on 5 May 2016 involving all stakeholders (Government Officials, Representatives from NGOs, Academic Institutions, Industries, etc. Discussants of the meeting requested the Government to setup an expert committee to understand the problem and for sustainable solutions towards the rejuvenation of lakes.

## 2. FORMATION OF THE COMMITTEE AND ITS TERMS OF REFERENCES:

In response to this, an Expert Committee comprising of experts in the field under the chairmanship of Additional Chief Secretary to Government, Urban Development Department, Government of Karnataka was constituted to take up astudy addressing the problems of lake contamination as well as the feasible technical solutions towards the restoration of lakes. Consequently, Urban Development Department, Government of Karnataka issued an order constituting an Expert Committee under the chairmanship of Additional Chief Secretary to Government of Karnataka, Urban Development Department vide Government Order No. UDD 212 MNJ 2016, dated 10-05-2016 with the following as members.

| | | |
|---|---|---|
| 1 | Additional Chief Secretary, Urban Development Department, Bangalore. | Chairman |
| 2 | Commissioner, Bangalore Development Authority, Bangalore. | Member |
| 3 | Member Secretary, Karnataka State Pollution Control Board, Bangalore. | Member |
| 4 | Chairman, BWSSB, Cauvery Bhavan, Bangalore. | Member |
| 5 | Chief Executive Officer, KLCDA, Bangalore. | Member |
| 6 | Secretary to Government, Minor Irrigation Department, Bangalore. | Member |
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**3. TERMS OF REFERENCES:**

(1) To suggest vendor agnostic appropriate technology that can be used / adopted for one-timeRestoration / Rejuvenation of the lake.

(2) To recommend targeted quality parameters of the lake water to be achieved at the end / completion of the restoration project, for short term as well as long term.

(3) The mode of maintenance after completion of the project.

(4) To suggest structure and support for planning and implementation as well as follow up of "sustainable and critical biodiversity conservation" project.

(5) Prepare timely detailed or summarized technical reports, letters and documents.

(6) Arrange individual or group field visits to the project sites to monitor the progress.

(7) To document the events properly, prepare news for the website and communicate with media for advocating the project.

(8) To work closely with project staff members, consultant's partners, stakeholders to facilitate fulfillment of the project objectives.

(9) Provide communications input to project activities where required.

(10) Support activities related to organization of conferences, seminars, training courses etc.

The Committee was given a time frame of 6 weeks to submit the report.

## 4. ACTIVITIES UNDERTAKEN AND APPROACH ADOPTED BY THE COMMITTEE.

Ever since the formation of an Expert Committee, the Committee has conducted as many as 10 meetings commencing from 24-05-2016 under the chairmanship of Additional Chief Secretary, Urban Development Department. The Committee deliberated on the subject as extensively as possible and elicited the views from experts as well as from others.The Committee alsocarried out field visits and went round the lakes (Bellandur lake on 1st June and Varthur lake on 9th June 2016) in the boat to understand the magnitude of the problem. The Committee also conducted a public hearing,(at Varthur kodi on 9th June 2016) and received representations from affected local residents, NGOs and resident welfare associations.

## 5. FINDINGS / FIELD OBSERVATIONS BY THE COMMITTEE

The Committee took note of the prevailing environmental conditions of the lakes, evident from intolerable levels of smell and a very poor unhygienic conditions. The Committee was in full agreement with the view that the management of waste water that flows into these lakes has not kept pace and as a result, the lakes have come to suffer abnormal levels of pollution in terms of septicity, obnoxious odour, aerosols with toxic volatile organic compounds, eutrophication, breeding of mosquitoes, disappearance of native fish species, algal bloom, and profuse growth of invasive exotic aquatic macrophytes. There have been adverse environmental and public health consequences.The local community complained about the water borne diseases, contaminated bore well water (due to poor environmental conditions), etc. The Committee is convinced of the problems faced by the local biological entities (humans, livestock, etc.) of serious water and soil contamination and consequent impacts in the food chain. The Committee also witnessed massive formation of froth / foam and floating of froth with aerosols in the atmosphere. The Committee took note of earlier event of fire possibly due to industrial effluent contamination.

## 6. BASIC FEATURES OF THE LAKES

Bellandur and Varthur lakes are located in the south-eastern portion of Bangalore metropolitan region **(Figure 3)** with spatial extent of 370 hectares and 180 hectares respectively. Catchment of these lakes **(Figure4)**ranges from 158.5 sq.km. to 279. sq.km.

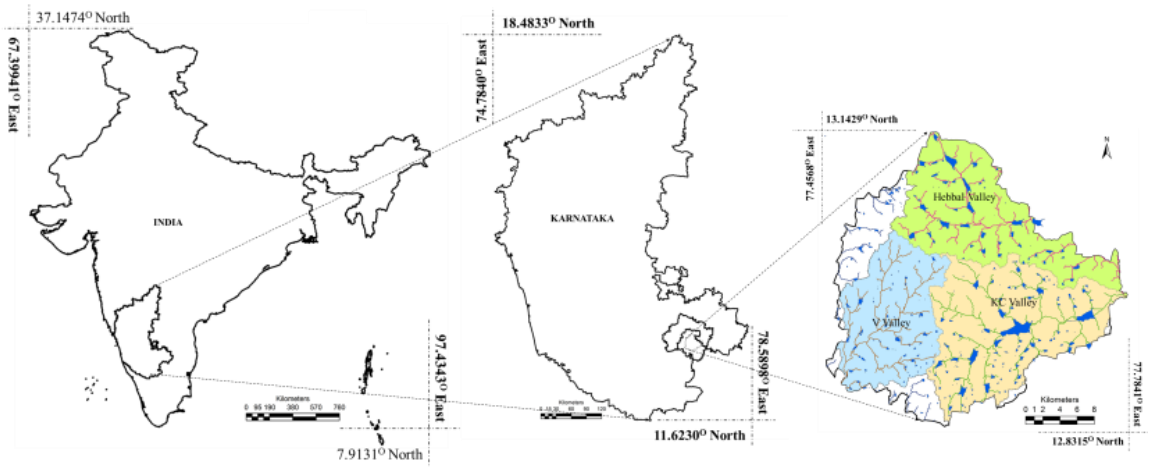
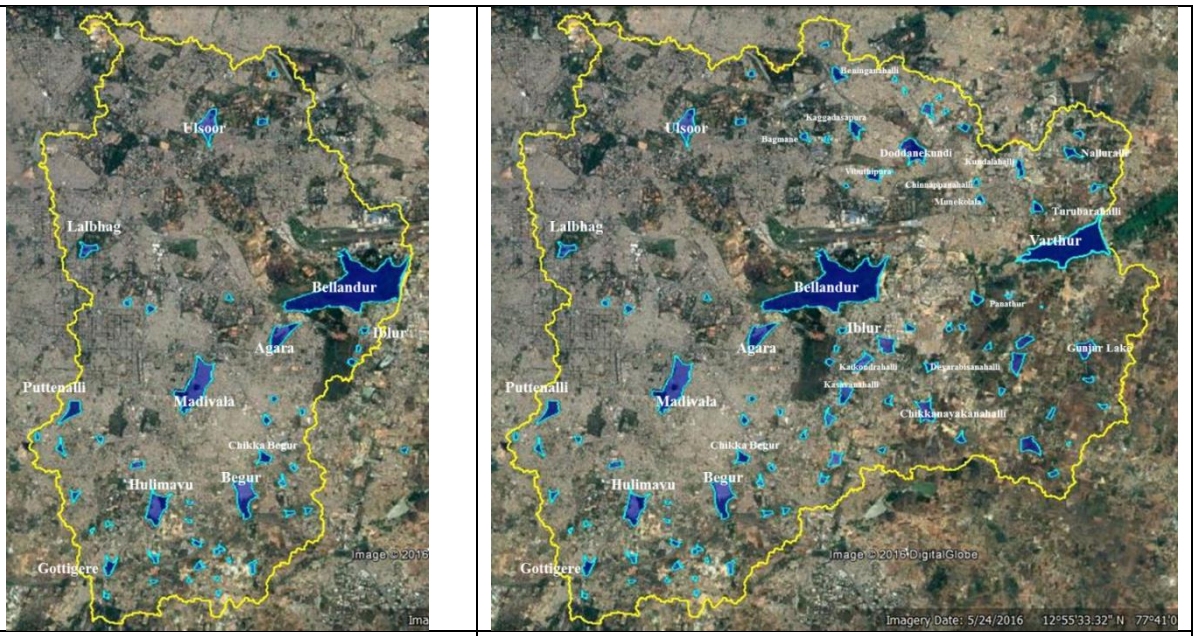



**Figure 3: Interconnected Lake systems in Bruhat Bangalore**

These lakes were originally built by our ancestors to meet the domestic and irrigation demands in the region Their current storage capacities (after sedimentation) are estimated to be 5.5 $Mm^3$ and 1.6 $Mm^3$ respectively.

Currently, due to the complete urbanization of the Bellandur catchment and partial urbanization of the remaining Varthur catchment, they are estimated to receive a steady (dry season) flow of480 MLD from the K&C valley (city sewage) and 60 to 70 MLD from local storm water drains (at Varthur lake)[1]. In addition, of course, during the monsoon, the lakes receive surface runoff (precipitation) through storm water drains.




| Bellandur Catchment | Varthur catchment |
|---|---|

**Figure 4: Bellanduru and Varthuru Lake Catchments**

[1]These measurements are from 2008. The flows need to be re-measured now.


**Figure 5: Location of inlets to Bellandur Lake**


**Figure 6: Locations of inlets into Varthur lake**

These inflows come from various inlets. As seen in **Figure 5 and 6,** Bellandur lake itself has 4 main stormwater drain inlets (2 inlets from K&C Valley STP). The 4 main inlets are Ejipura drain, Agara valley drain, Challaghatta valley drain and Ibbalur drain **(Figure 5).** For Varthur lake, the main inflow comes from Bellandur lake, in addition to which there are 28 local minor inlets**(Figure 6)** for details.

The catchments of these lakes have become heavily urbanized over the past decades. **(Figure 7)** shows the rapid urbanization that has taken place in these lakes' catchments since 1973, particularly after 1992. Significant part of the catchment of both the lakes has been largely urbanized as of date.

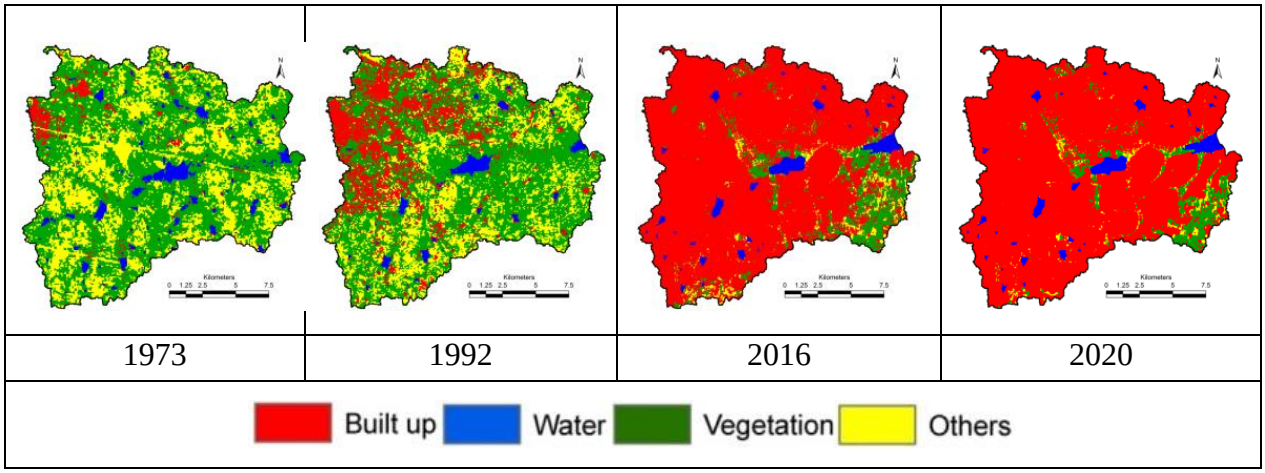



**Figure 7. Urbanization of the Bellandur and Varthur lake catchment**

## 7. CONTEMPORARY RELEVANCE OF THE LAKE AND BENCHMARKS FOR LAKE MANAGEMENT:

Keeping in mind the short time-frame, the Committee's approach has been to:

- Maintain the minimum water quality standard to fulfil the vital role of lakes in urban ecosystem and
- Identify a series of short-term and long-term measures that need to be taken or need to be strengthened in order to bring the lakes to the desired standards.

**The Committee is of the opinion that there may be no easy or quick techno-fixes, and that even long-term solutions will need a combination of technological, ecological solutions with social processes**. The latter include increased citizen involvement in the monitoring and management of the lake and its catchment and indeed of all activities that are likely to impact the lake environment.

The lakes provide diverse ecosystem services – fishing, fodder, microclimate improvement, space for recreation, ground water recharge, aesthetic value, biodiversity, medicinal plants. Also there is a proposal to divert treated sewage from this region to meet irrigation demand in Kolar district by the Government of Karnataka. Hence **the "Designated Uses" of these lakes include fisheries, fodder, irrigation, recreation, ground water recharge, and biodiversity conservation. In view of these, lake management need to focus on achieving and maintaining the quality and quantity of water apart from maintaining the lake environment.**

The Central Pollution Control Board has notified Water Quality Criteria for different designated uses, ranging from irrigation (Class E) to drinking water with disinfection (Class A).ClassDcorresponds to "Propagation of wildlife and fisheries"and Class C corresponds to "Drinking water (after treatment)", which comes closer to our designated uses. However, the Ministry of Environment & Forests & Climate Change (Govt of India) has insisted Class B for all central fundedschemes of lake and river rejuvenation. **We therefore aim for a quality that corresponds to CPCB water quality criteria Class B and also includesstandards with stringent regulation on heavy metal contamination**. The standards to be achieved are as follows:

- pH 6.5 to 8.5
- Total Coliforms <5000 MPN/100ml
- Dissolved Oxygen above 5 mg/L
- Free Ammonia (as N) less than 1.2mg/L
- Biological Oxygen Demand (BOD) (5 days $20^0$C) less than 5 mg/L, to be achieved to <3 mg/L by 2020
- Heavy metals: ($Cr^{+6}$< 16µg/L; Cd <1.8µg/L; Cu <4.8µg/L; Pb <65µg/L) .

Progress in lake water quality improvement must then be monitored and measured with reference to these benchmarks.

## 8.DESCRIPTION OF THE PROBLEM

In light of the above desired uses, and the quality criteria that follow, the condition of the two lakes (and many other lakes in Bangalore) is far from the desired level. This manifests in different forms and leads to a variety of socio-environmental impacts.

### *8.1 POLLUTED CONDITION OF THE LAKES:*

That the lakes are heavily polluted is probably visible even to the naked eye (the black colour of the water) and sensible by the human nose (the stench). Nevertheless, several studies over several years have provided detailed information on the extent and nature of the degradation of the lake ecosystems. On the basis of these studies, a summary picture for both lakes of the values of the parameters mentioned above that characterise the criteria for meeting designated use is presented inTable 1.

**Table 1. Values of key water quality parameters observed in the two lakes over past several years**

| Parameter | Bellandur Lake | Varthur Lake | Studies referred to |
|---|---|---|---|
| pH | 6.8-8.4 | 6.9-8.2 | (Ramachandra et al., 2008, 2009, 2013; 2015, Mahapatra et al., 2011, 2010; 2014; Mahapatra, 2015; Ramachandra et al., 2015). |
| Total Bacterial Count (cells/ml) | $10^4$-$10^7$ | $10^5$-$10^7$ | |
| Dissolved Oxygen (mg/L) | 0 to 3 | 0-5 | |
| BOD (5-day 20degC) (mg/L) | 25 to 180 | 32-175 | |
| COD (mg/L) | 44-330 | 51-280 | |
| Cadmium (mg/L) | 0.03-0.76 | 0.04-0.25 | |
| Lead (mg/L) | 0.01-1.77 | 0.04-2.84 | |
| Chromium (VI) (mg/L) | 0.02-0.67 | 0.014-1.66 | |
| Nickel (mg/L) | 0.002-0.41 | 0.026-1.89 | |
| Copper (mg/L) | 0.01-0.461 | 0.02-0.46 | |

From the above, it is clear that both the lakes are severely polluted, and have been in this condition for several years.

***8.2SOCIO-ENVIRONMENTAL IMPACTS OF LAKE WATER POLLUTION:***

The contamination of lake has resulted in multiple socio-environmental impacts.

- **DECLINE IN AQUATIC DIVERSITY:**

Temporal analyses of occurrence of fish species of these lakes reveal the decline in native fish species (Table 2 and 3)

**Table 2:List of major fish species in Varthur lake during 1962, 1998 and 2009**

| Species name | 1962 | 1998 | 2009 |
|---|---|---|---|
| *Catla catla* (Catla) | - | + | - |
| *Labeo rohita* (Rohu) | - | + | - |
| *Cirrhinus mrigala* (Mrigal) | - | + | - |
| *Clarias gariepinus* (African catfish) | - | + | + |
| *Oreochromis mossambica* (Tilapia) | - | + | - |
| *Clarias batrachus* | + | - | - |
| *Heteropneustes fosslis* | + | - | - |
| *Mystus dittatus* | + | - | - |
| *Minor carps* | - | + | - |

**(Source: Ramachandra T. V., Alakananda B, Ali Rani and Khan M A, 2011, Ecological and socio-economic assessment of Varthur wetland, Bengaluru (India), *J Environ Science & Engg,* Vol 53. No 1. p 101-108, January 2011)**

**Table 3: Fish species that occur in Bangalore Lakes**

**(based on 13 lakes survey during 2014 and 2015)**

| Sl.No. | Fish species | English Name | Kannada |
|---|---|---|---|
| 1 | *Catla catla* | Catla | Catla, Dodda Gende |
| 2 | *Cirrhinus mrigala* | Mrigal | Mrigal, Bangari |
| 3 | *Clarias batrachus* | Magur | Ane-meenu, Murgodu |
| 4 | *Clarias gariepinus* | African catfish | Ane-meenu |
| 5 | *Ctenopharyngodon idellus* | Grass carp | Hullu Gende |
| 6 | *Cyprinus carpio communis* | Common carp | Samanya Gende, Pare |
| 7 | *Gambusia affinis* | Mosquito fish | Gambusia, Hechige pakke,Solle meenu |
| 8 | *Labeo fimbriata* | Fimbriatus | Kem-meenu,Wengarlu, Kijan |
| 9 | *Labeo rohita* | Rohu | Rohu |
| 10 | *Oreochromis mossambicus* | Tilapia | Jilebi, Baduvara meenu |
| 11 | *Oreochromis niloticus* | Tilapia | Jilebi |
| 12 | *Parambassis ranga* | Indian glassy fish | Bachanike meenu |

- **CONTAMINATION OF THE FOOD CHAIN WITH HEAVY METALS:**

The high concentration of heavy metals in the lake water translates into very high concentrations of heavy metals in the fish from the lake and also in the crops that are cultivated downstream and consumed in and around Bangalore. For instance, the vegetable samples grown on these wastewater towards the lower reaches of the Varthur lake showed high heavy metal content (Cd: 8.5 -11 mg/kg; Cr: 51-131 mg/kg; Pb 24-147 mg/kg; Cu 89-323 mg/ka and Ni from 0.5-91 mg/kg) compared to the Indian safe limits (Cd: 1.5 mg/kg; Cr: 20 mg/kg; Pb: 2.5 mg/kg; Cu: 30 mg/kg and Ni: 1.5 mg/kg) (sample analysis done during May-June 2016 by IISc).

- **CONTAMINATION OF GROUNDWATER:**

The pollution from the lake has also contaminated groundwater in borewells in the surroundings of the lakes. For instance: water samples from borewells in the buffer region of Varthur lake (up to a distance of 1 km) had high values of nitrates, coliforms, heavy metals, etc. much beyond the permissible limits for drinking water (IS 10500).

- **LOSS OF LIVELIHOODS:**

Valuation of tangible benefits (fish, fodder, etc.) reveal that Varthur Lake and sustains the local livelihood by providing goods worth Rs.119 per hectare per day (compared to Rs.10500 per

hectare per day when lake is unpolluted as in Rachenahalli Lake). Also, it is assessed that people spend about Rs. 697 per year per family on repellents (to control mosquito). This emphasises the need for rejuvenation of contaminated lakes on priority.

- **SPREAD OF WATER HYACINTH, HARBOURING MOSQUITOES:**

Water hyacinth, an invasive species, proliferates in polluted water, covering the lake surface and reducing the penetration of sunlight, thereby reducing the dissolved oxygen levels threatening the existence of native biota, evident from the disappearance of native fish species. Both these lakes are currently to a large extent covered by water hyacinth, and during summer these invasive macrophytes covered 2/3$^{rd}$ of water spread (evident from remote sensing data, Google Earth).

- **FISH MORTALITY**:

Recurring fish mortality in recent months further highlights the level of contamination and irresponsible management of water bodies. Sustained inflow of untreated sewagehas increased the organic content beyond the threshold of remediation capability of respective water bodies. Increasing temperature (of 34 to 35 °C) with the onset of summer, enhanced the biological activities (evident from higher BOD and Ammonia) that lowered dissolved oxygen levels leading to fish death due to asphyxiation. Comprehensive review of fish mortality with the occurrence details are given in Table 4.

**Table 4: Fish kill episodes in Bangalore:**

| Sl. No. | Name of water bodies | Reasons | Month and Year |
|---|---|---|---|
| **1** | Sankey lake and Lalbagh lake, Bangalore | Depletion of DO levels in some locations caused by sewage let into the lake resulting in asphyxiation | June-July 1995 |
| **2** | Ulsoor Lake, Bangalore | Increased oxygen demand and chemicals flushed into lake. | Jan 26, 2005 |
| **3** | Jakkur lake, Bangalore | Oxygen depletion in some locations caused by sustained inflow of sewage into the lake, resulting in asphyxiation. | January 2015 |
| **4** | Sankey lake, Bangalore | Oxygen depletion, toxic algal blooms and sudden changes in temperature and increased ammonia levels | August 2013 |
| **5** | Deverabisanahalli Lake near Marathalli | Organic pollutants discharged into the aquatic ecosystem | 24$^{th}$ November 2010 |

| | | | |
|---|---|---|---|
| | Ring road, Bangalore | | |
| **6** | Dorekere, Bangalore | Sewage flooded into the lake after heavy rain | 25 April 2015;<br>30 May 2014 |
| 7 | Jakkur lake,Bangalore | 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 | 5 Jan 2009<br>08 Jan 2015 |
| **8** | Cubbon Park pond, Bangalore | The sewage water had triggered a severe depletion of oxygen level. | 15 April, 2010 |
| ***9*** | Puttenahalli lake, Bangalore | A major storm water drain that flowed along the lake could have entered the lake resulting in the depletion of dissolved oxygen level. | 16 Jun 2005 |
| **10** | Vengaiana lake, Bangalore | Drastic drop in oxygen level in the water, which in turn was caused by untreated sewage water | May 2005 |
| **11** | Ulsoor lake, Bangalore | 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<br>7 March 2016 |
| 12 | Devarabeesanahalli lake, Bangalore | Inflow of sewage and industrial pollutants into the lake | 17 June 2015<br>7 March 2016 |
| 13 | Hebbal Lake | Inflow of sewage | 31 May 2016 |

**(Source: ENVIS Technical Report 105, CES, IISc, Bangalore, India)**

- **INCREASED GHG (GREENHOUSE GAS) FOOTPRINT**:

Mismanagement of solid and liquid wastes has increased the anaerobic condition leading to emissions of greenhouse gases (methane, $CO_2$, etc.).

- **FROTHING**:

Foams are formed in lakes due to sustained inflow of sewage (rich in phosphates). Decomposition of algae, fish and macrophytes, releasing a variety of organic compounds into the water body. These organic compounds act as surfactants (foaming agents) that has a hydrophilic (water attracting) end and hydrophobic hydrocarbon chain (water repelling) at the

other end. Also, surface-active agents in wastewater include synthetic detergents, fats, oils, greases and bio surfactants. These agents rise to the surface of lakes and interact with water molecules thus, reducing the attraction of water molecules to each other (i.e. surface tension of the water). When the surface tension decreases, air mixes with the water molecules and foaming agents resulting in bubbles formation. These bubbles aggregate together and forms foam in lakes. The surface-active agents or surfactants reduce the surface tension of water, allowing air bubbles to persist at the water's surface. Natural surfactants include carboxylic fatty acids derived from lipids from macrophytes /weeds etc. These are released into water and contribute to a large variety of soluble organic material known as dissolved organic carbon (DOC). Though DOC is produced within lake waters, the major source is the sustained inflow of sewage from the vicinity of the lakes and the watershed. Higher DOC concentrations in lakes, generally impart a brown colour to the water. However, white colour of the lake foam indicates that is caused by synthetically produced surfactants released through sewage to surface waters. Synthetic surfactants are widely used in household cleaning products (detergents/soaps), cosmetics and personal care products (shampoo, toothpaste etc.). Common detergents also contain branch-chained alkyl benzene sulfonate surfactants, which are non-biodegradable and results in extremely persistent foam accumulating below the fall levels in the lake and other wastewater outfalls.

Detergents and soaps mostly contain phosphate (P, ~30 % STPP) softeners to enhance the effectiveness of surfactants through the reduction of water hardness. P-loading in lakes has contributed to nutrient enrichment with the proliferation of cyano-bacterial blooms and macrophytes (aquatic plants). There are set of advanced detergents that exclude phosphates but contain biodegradable linear alkyl benzene sulfonate surfactants, such as sodium or ammonium laurate or lauryl sulfate. Surfactants are also used by many industries as wetting agents, dispersants, de-foamers, de-inkers, antistatic agents, and in paint and protective coatings, pesticides, leather processing, plastics and elastomer manufacturing, and oil extraction and production.

A portion of phosphates is taken up by aquatic plants while the balance gets trapped in the sediments. Pre-monsoon showers coupled with gusty winds leads to the churning of lake water with upwelling of sediments. Vigorous mixing of surface water coupled with high flow across narrow channels, leading to bubble formation that persist and build up as foam. The foams formed in large quantities moves to shorelines by wind and water currents. Natural foams are usually linked to humic and fulvic acid substances, fine colloidal particles, lipids and proteins released from aquatic or terrestrial plants, saponins (plant glycosides), the

decomposition products of phytoplankton containing carbohydrates and proteins and the organic matter in sediments. In these lakes, foam /froth gets accumulated along windward shores. Continuous sewage fed in Bellandur and Varthur lakes, has been witnessing foam at downstream in chocked channels or below fall/discharge point since one decade (this is witnessed since 2000 and the quantum of foam has gone up by manifolds in recent times – post 2012).

Sampling and water quality analysis (subsequent to frothing in May 2015) reveals the presence of higher amount of different physico-chemical parameters like total dissolved solids (332-1246 mg/l); electrical conductivity (460-1470µS); dissolved oxygen (0-8.16 mg/l); chemical oxygen demand (40-325.33 mg/l); biochemical oxygen demand (24.39-140.8 mg/l); alkalinity (56-520 mg/l); chloride (88.04-191.7 mg/l); total hardness (198-436 mg/l); calcium hardness (56.11-344.27 mg/l); magnesium hardness (18.08-124 mg/l); sodium (9-1046 mg/l) and potassium (0-130 mg/l), indicate pollution/sewage entry into the lake.

- **FIRE:**

Foam caught fire perhaps due to compounds with high flammability i.e. hydrocarbons and organic polymers that came from nearby industries in the vicinity of Bellandur lake. Discharge of untreated effluents (rich in hydrocarbon) with accidental fire (like throwing cigarettes, beedi) has led to the fire in the lake on 16$^{th}$ May 2015.

- **HEAVY METALS IN BELLANDUR AND VARTHUR LAKES:**

The presence of heavy metals in the Bellandur and Varthur lakes are indicative of contamination of industrial and untreated municipal wastewater. Heavy metals in the sediment materials are well within the metal levels found in cultivable lands in India and within the critical limits as per Awasthi et al., 2000 (Cd: 3- 6 mg/kg; Pb: 250-500 mg/kg; Cu 135-270 mg/kg and Ni: 75-150 mg/kg). Values are Cd: 7 mg/kg; Co: 8 mg/kg; Cu: 68 mg/kg; Fe: 20 g/kg; Mn: 140 mg/kg; Ni: 26 mg/kg, Pb: 7 mg/kg and Zn: 106 mg/kg (Table 5).

The lake water samples were found to have a slightly high values of heavy metals (Cd: 0.55 mg/L, Cr: 0.4 mg/l, Pb: 1.35 mg/l, Cu: 0.21 mg/l and Ni: 0.27 mg/l) value than the permissible levels (Cd: 0.01 mg/L, Cr: 0.1 mg/l, Pb: 0.5 mg/l, Cu: 0.2 mg/l and Ni: 0.2 mg/l). The vegetable samples grown on these wastewater towards the lower reaches of the Varthur lake also showed high heavy metal content (Cd: 8.5 -11 mg/kg, Cr: 51-131 mg/kg, Pb: 24-147 mg/kg, Cu: 89-323 mg/kg and Ni: from 0.5-91 mg/kg) compared to the Indian safe limits

(Cd: 1.5 mg/kg, Cr: 20 mg/kg, Pb: 2.5 mg/kg, Cu: 30 mg/kg and Ni: 1.5 mg/kg) that is alarming.

The elemental analysis of the lake systems reveals high nutrient potential of the sedimentary material with organic matter (14-31%), C: (8-18%), N: (0.35-35%), P: (0.28-2.5 %) and K (0.6 -0.7%). This concentration of nutrients in the sedimentary material with other trace and essential mineral nutrients are of superior quality and can be used directly as organic manures or as bio-fertilisers in the agricultural fields.

**Table 5: Elemental and nutrient analysis (heavy metals and essential trace elements)**

| Sl no. | Description | Measuring units | SLUSH | SEDIMENT |
|---|---|---|---|---|
| 1 | Bulk Density | kg/cum | 500 | 1700 |
| 2 | Organic Carbon | % | 18 | 8 |
| 3 | Nitrogen | % | 3 | 0.35 |
| 4 | Phosphorous | % | 2.5 | 0.28 |
| 5 | Cadmium | mg/kg | 7 | 2.4 |
| 6 | Cobalt | mg/kg | 8 | 5 |
| 7 | Copper | mg/kg | 68 | 30 |
| 8 | Iron | mg/kg | 20935 | 13580 |
| 9 | Manganese | mg/kg | 140 | 98 |
| 10 | Nickle | mg/kg | 26 | 20 |
| 11 | Lead | mg/kg | 7 | 6.5 |
| 12 | Zinc | mg/kg | 106 | 45 |
| 13 | Sodium | mg/kg | 2175 | 2075 |
| 14 | Potassium | mg/kg | 7750 | 6025 |
| 15 | Calcium | mg/kg | 581 | 608 |
| 16 | Magnesium | mg/kg | 433 | 1452 |

Manifestation of contamination beyond the bioremediation capacity due to the sustained inflow of large quantum of untreated sewage and industrial effluents in addition to effluents from small industries, commercial establishments, slaughterhouses, etc.

Overall, the lakes have reached eutrophic conditions leading to significant socio-environmental-health impacts, which necessitate urgent attention.

## 9. CAUSES OF THE PROBLEM:

In order to understand the pollution status of Bellandur and Varthur lakes, sampling (water, slush, sediment, biota - phytoplankton, zooplankton, macrophytes) was carried out at 70 locations (Bellandur) and 47 locations (Varthur) during 4-14$^{th}$ April, 2016. The physico-chemical characteristics of these lakes revealed that the lake had received higher amounts of nutrients and ionic components whereas the dissolved oxygen levels were equal to zero which, indicate pollution/sewage entry into the lake (Class E as per CPCB's Classification of Inland Surface Water). Pollution tolerant phytoplankton and zooplankton population were present in these lakes, which indicates pollution as well as eutrophic conditions and water is completely unfit for human use (**Source:ENVIS Technical Report 93, CES, Indian Institute of Science, Bangalore**).

### *9.1 SINGLE MAJOR PROXIMATE CAUSE:*

The most obvious and biggest cause of the polluted condition of the lakes is **the release of untreated sewage, inadequately treated industrial effluents and sub optimally treated domestic sewage into the lake**. These come from different sources, in different magnitudes, and with different concentration and type of pollutants.

- A large volume of highly polluted water (260 MLD from the city - through underground or covered roadsides drains to which households have traditionally connected their grey and/or black water outlets) enters lakes through **storm water drains** (SWDs) to Bellandur lake. Figure 8 depicts sewage inflow from various drains to Bellandur and Varthur lakes.

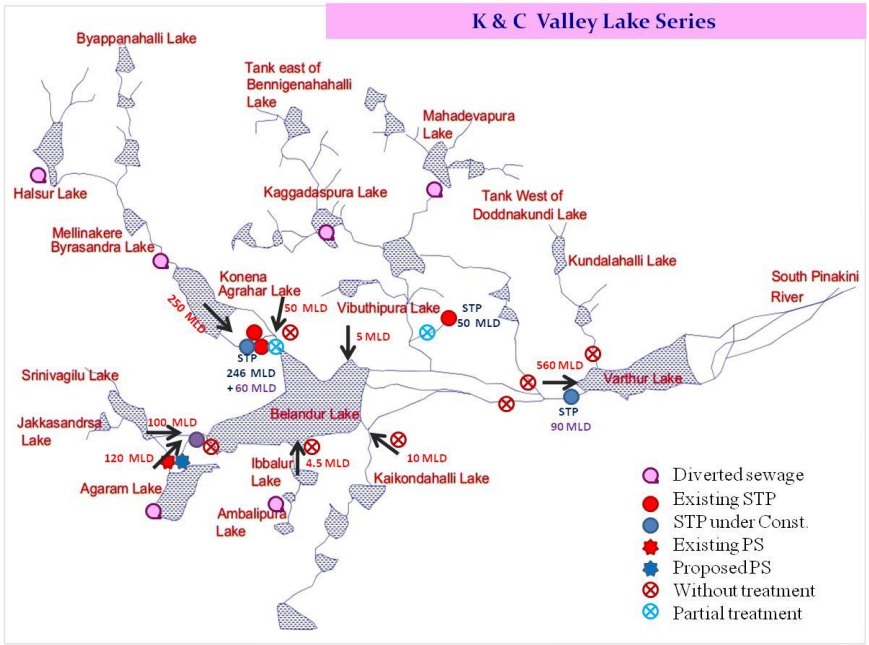



**Figure 8: Sewage inflow through drains to Bellandur and Varthur lakes**

- Field quantification (during 15-19th May 2016) of sewage entering Varthur lake reveal about 480 MLD (from Bellandur both treated and untreated) and about 60-70 MLD from local drains in the vicinity of Varthur enter Varthur lake.

- There are 252 residential apartments in Bellandur catchment area and though all the apartments have installed sewage treatment plants, there is still large quantum of untreated sewage enters the lake. An estimated ~480 MLD of total wastewater flows in the catchment area partly treated by the STPs. The existing treatment facility running in the KC valley is the K & C valley STP 248 MLD (163+55+30); Madivala STP (4 MLD) and Kadubeesena halli STP (50 MLD) (indicated in Figure 8). These treatment units running at 90 to 95% of theirinstalled capacities areinadequate to treat the wastewater of the region. Though there are new provisions for many new STPs at crucial important sewage drawing location proposed by BWSSB under SWD Plan a strategic know how of the drainage basin and the sewage load is still missing in the conceptual plan. Some of the STPs in the K and C valley have been already commissioned and are projected to work from march, 2017 as an extension of the K and C valley STP for another 60 MLD, Bellandur Ammanikere STP (90 MLD). These systems still need a huge quantity of electricity to pump sewage from the pumping units located at Agaram lake (additional pumping unit being built) to the STPs i.e. 60 MLD to additional treatment unit to K andC valley and 90 MLD to Bellandur Ammanikere STP upstream of Varthur. To save the cost of laying UGD to these centralised STPs, and capital and O&M cost of the present pumping station and the additional pumping requirement a potential option is to treat the wastewater right at the collection node near the mouth of the trunk sewers, by setting up an STP in the land earmarked (in RMP 2015) for public utilities like waste management in this area (Figure 9).


**Figure 9: Inlets (wastewater influx) to Bellandur lake, Apt location for STP - area earmarked for public utility as per CDP (Bellandur – Agaram wetlands)**

- **Overall Observation:**

Due to the sustained influx of fresh sewage over the last several decades, nutrients in the lake are now well over safe limits. Bellandur and Varthur lakes being the end of the lakes series in the KC valley Varthur Lake has been receiving about ~45% of the city sewage for over last 60 years resulting in eutrophication. There are substantial algal blooms, Dissolved Oxygen (DO) depletion and malodour generation, and an extensive growth of water hyacinth that covers about 70–80% of the lake in the dry season. Sewage brings in large quantities of C, N and P which are responsible for eutrophication, profused growth of macrophytes and algal bloom.

### *9.2 AGGRAVATING FACTORS:*

This main cause—inflow of polluted water or sewage—interacts with avariety of factors to create specific problems. For instance:

1. **SPEED AND TURBULENCE AT THE WASTE WEIRS AND PRESENCE OF SURFACTANTS:**

Disappearance of storm water drains, blockage of storm water drains, and constrained waste-weirsapart from untreated sewage are responsible for aggravating lake contamination (froth formation). Detergents and soaps mostly contain phosphate (P, ~30 % STPP) softeners to enhance the effectiveness of surfactants through the reduction of water hardness. P-loading in lakes has contributed to nutrient enrichment with the proliferation of cyanobacterial blooms and macrophytes (aquatic plants). Decomposition of algae, fish and macrophytes, releasing a variety of organic compounds into the water body. These organic compounds act as surfactants (foaming agents) that has a hydrophilic (water attracting) end and hydrophobic hydrocarbon chain (water repelling) at the other end. When the surface tension decreases, air mixes with the water molecules and foaming agents resulting in bubbles formation. These bubbles aggregate together and forms foam in lakes. The white colour of the lake foam confirms that foam is caused by synthetically produced surfactants released through sewage to surface waters.

The combination of pre-existing pollution, high flows, constrained weirs and blocked drains (encroachment and dumping of solid waste) further aggravate the situation and result in persistent massive foaming the lake at outlets.

2. **SOLID WASTE:**

Solid waste dumping is observed in a big way, both of C & D (construction and demolition) waste and of garbage. Garbage adds organic matter and plastics to the lake water. C & D waste has destroyed the riparian vegetation and thereby reducing the ability to uptake of nutrients (nitrates and

phosphates). This is confirmed by KSPCB and BBMP and a significant set of measures need to be taken to ensure the Storm Water drains are free of Solid Waste.

***9.3 DEEPER CAUSES:***

So far, we have only talked of the proximate cause (polluted inflows) and the aggravating factors that together lead to the multi-dimensional pollution problem. But the **deeper causes** also need to be understood as to why has sewage infrastructure not kept pace with generation, why are storm water drains carrying sewage even from areas where underground sewerage existsand why are sewage treatment plants not always releasing water of a fair standard.

- **PLANNING ISSUES:**

  - BWSSB, the agency responsible for treating all domestic and commercial effluents in the city of Bangalore, has struggled to keep pace with the rapid urbanisation of Bangalore. The estimated sewage generated in the city is about 1400 MLD, the installed capacity of sewage treatment plants was only 721 MLD and at present about 600 MLD of sewage is being treated in 14 STPs. Thus, STPs run below capacity even as sewage is discharged into SWDs. Moreover, a focus on conveying sewage over long distances to centralized treatment plants has prevented BWSSB from rigorously exploring more de-centralized (lake-side) sewage treatment options. Also, BWSSB needs to have a policy of insisting on installation of on-site treatment or sewage conveyance infrastructure concurrently with giving water supply connections.

    Government has issued G.O. making mandatory sewage treatment plant in an apartment having more than 20 houses or having 2000 sq.mtr built up area. BBMP and BDA, the agencies responsible for both facilitating and also regulating the real estate development in the lake catchments and in Bangalore in general, have not fully incorporated the issue of wastewater disposal into their plans. Plan sanctions for individual houses and smaller apartments complexes are given without due consideration of sewage treatment and conveyance infrastructure.

    - **OPERATIONAL SHORTCOMINGS:** Many BWSSB STPs continue to operate below capacity for a variety of reasons.The same is much more true for industrial effluent treatment plants (ETPs) and apartment-level STPs. The responsibility here lies not just with government agencies, but also with the citizens of Bangalore who operate these industries and dwell in the apartments.

- **REGULATORY ISSUES:** KSPCB is the agency responsible for ensuring that disposal of all effluents into surface water bodies meets discharge standards, and that surface water bodies meet the water quality criteria for the designated use of these bodies. KSPCB has not,adequately implemented the concept of designated use, and has used the water quality criteria only to rank

the water bodies (i.e., to warn the public that the water quality is at C, D, or (in this case) mostly below E class). At the same time, KSPCB has found it difficult to enforceexisting effluent discharge standards through effective monitoring protocols.

- Installation of online water quality monitors at the treated water outlets from K&C valley 250MLD STP, and up-linking of the monitoring data to a public website: Agency: BWSSB in collaboration with a research institute. Budget: 20 lakhs (assuming free lab testing by BWSSB).

# 10. RECOMMENDATIONS:

The restoration and conservation strategies has to be implemented for maintaining the ecological health of aquatic ecosystems, aquatic biodiversity in the region, inter-connectivity among lakes, preserve its physical integrity (shorelines, banks and bottom configurations) and water quality to support healthy riparian, aquatic and wetland ecosystems. The regular monitoring of water bodies and public awareness will help in developing appropriate conservation and management strategies.

## 10.1 THE SUCCESS OF REJUVENATION WILL DEPEND ON:

- **Good governance** (too many parastatal agencies and lack of co-ordination). An integrated agency with the statutory and financial autonomy to be the custodian of natural resources (ownership), regular maintenance and action against polluters (encroachers as well as those contaminate through untreated sewage and effluents, dumping of solid wastes). Effective judicial system such as tribunal for speedy disposal of conflicts related to encroachment/pollution etc.The pollution control board should strictly enforce the provisions of the Water Act and EP Act.
- **Digitisation of land records** (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query based information system to public;
- **Removal of encroachment of lakes / wetlands, lake beds and storm water drains** (connecting feeders) after the survey based on reliable cadastral maps; Ensure proper fencing of lakes and to make land grabbing cognizable nonbailable offence;
- **Restriction / Preventionof the entry of untreated sewage and industrial effluents into lakes;** Decentralised treatment of sewage (preferably at ward levels). Letting only treated sewage into the lake (as in **Jakkur lake model**); Ensure that sewage generated in a locality /ward is treated locally;
- **Removal of nutrient rich sediments** – to enhance the storage capacity, improve groundwater recharge, to minimise further contamination of treated water, etc.;
- **Ban on use of phosphates by appropriate agency in the manufacture of detergents may be examined** as it will minimise frothing
- Regular removal of macrophytes (*Eichhornia* sp., *Alternanthera* sp. etc.) in the lakes;

- ❖ Implementation of 'polluter pays' principle as per Water Act 1974;
- ❖ Plant native species of macrophytes in open spaces of lake catchment area;
- ❖ Stop solid wastes dumping into lakes / in the lake bed; Banning of filling of a portion of lake with building debris.
- ❖ Regulation on the diversion of lake water as per the provision of the Water Actfor any other purposes.
- ❖ Total Prohibition of any physical interventions in the valley should be banned to facilitate smooth flow of water especially during flash floods.
- ❖ Decentralised management of lakes through local lake committees involving all stakeholders.

## 10.2 Short term Remedial Measures– within 6 months

| Cause | Recommendations | Agency |
|---|---|---|
| **1. Poor water quality – untreated sewage inflow** | 1. Regular harvesting of macrophytes – helps in curtailing nutrients accumulation | **BDA** |
| | 2. Stop dumping of municipal solid waste | **BBMP** |
| | 3. Evict all waste processing units (in the vicinity of lakes and lake bed) | **BBMP and Revenue Department** |
| | 4. Stop dumping of construction and demolition (C & D) wastes in Rajakaluve, Valley zones and Lake beds | **UDD** |
| | 5. Ensure that all apartments let only treated water to the lake. Implement mechanisms such as separate electric meters (net metering) and updating of details at respective resident association websites (including a copy at BWSSB web site) | **KSPCB and BWSSB** |
| | 6. Providing water quality details (each apartment discharge) – inflow to the lake at respective resident association websites (including a copy at BWSSB web site) | **KSPCB** |
| | 7. Installation of online water quality monitors at the treated water outlets from K&C valley 250MLD STP, and up-linking of the monitoring data to a public website. | **KSPCB** |

| | | |
|---|---|---|
| | 8. Installation of surveillance cameras at the outlet of BWSSB STP (inlet of the lakes) and availability of electricity consumption details and surveillance camera streaming details to the public (through cloud sourcing or any other efficient and optimal mechanisms) | |
| | 9. Functional ETP's to ensure zero untreated effluent discharges by industries. KSPCB to ensure zero untreated effluent discharges. | **KSPCB** |
| | 10. Evolving surprise environment audit mechanisms to ensure zero untreated effluent discharges to storm water drains (and lakes). Vetting of inspection report by the respective resident lake association. | **KSPCB and Lake Monitoring Committee** |
| **Froth Reduction** | 1. Reduce the velocity of the flow at the waste weirs and the extent of drop by constructing ramps at the waste weirs (3 out of 4 weirs, since 1 ramp is already in existence), | **BDA** |
| | 2. Ensure free passage of water (by restoring storm water drains, waste weirs, freeing of all debris) | **BBMP** |
| | 3. Move MoEFCC - Government of India to ban phosphorous use in detergents or regulate detergent with phosphorous in market | **KSPCB and UDD** |
| **Improving Oxygen Levels** | Improve aeration – (i) installing fountains, removing all blockages, (ii) widening and increasing number of channels / outlets | **BDA and UDD** |
| **Physical integrity of lakes and storm water drains** | 1. Surveying and mapping of water body (including flood plains) and buffer zones (30 m as per BDA; 75 m as per NGT)<br>Surveying and mapping valley zones (eco-sensitive zone as per RMP 2015, and green belt as per CDP 2005).<br>Remove all encroachments (lake bed, Raja kaluves, storm water drains) to prevent calamities related to floods. | **Revenue Department** |
| | 2. Identify the common lands, kharab lands, streams, | **Revenue** |

| | | |
|---|---|---|
| | drains, tracks and paths (as per cadastral / revenue maps) in K and C Valley and on priority between the Agara, Bellandur and Varthur Lakes. This land would be useful to setup waste water treatment plants (STPs) and constructed wetlands. | **Department** |

## 10.3 Long Term Remedial Measures

| Current Status | Recommendations | Agency |
|---|---|---|
| **Untreated Sewage** | BWSSB has committed to the following measures:<br>• 90 MLD STP at Ammanikere (upstream of Varthur lake), to which 60MLD will be pumped from Agara pumping station [to be completed by March 2017]<br>• 60 MLD STP at K&C Valley plant, to which 60 MLD will be pumped from Agara pumping station [to be completed by March 2017]<br>• 150 MLD STP at K&C Valley plant to treat sewage from Koramangala Valley - Ejipura drain [to be completed by March 2020]<br>2 MLD STP at Ulsoor lake (upstream of Bellandur) and 55 MLD capacity 4 treatment plants at Hulimavu, Chikkabegur, Sarakki and Agara lakes upstream of Bellandur expected to be completed by the end of 2018 completion of sewers in all parts of the catchment, new (110 villages &erstwhile CMCs) and Core area by March 2020. | **BWSSB** |
| | Cancelling of allotment made by KIADB of land between Agara lake and Bellandur lake (40 acres) to be pursued legally to enable establishment STP (40 acres as per RMP 2015) in the region between Agaram and Bellandur lakesto enable establishment of 210 MLD STP at that location itself, to treat sewage locally and to prevent unnecessary waste of electricity for pumping 60 MLD to K&C valley and 90 MLD to Amanikere STP | **UDD** |

| | | |
|---|---|---|
| | Independent audit of existing STP operation | **Lake Monitoring Committee** |
| | Install additional decentralised STPs along with constructed wetlands along the lakes in the catchment and if required acquire necessary lands for this public purpose | **BWSSB** |
| | One-time cleaning of the lake, especially removal of accumulated silt (enriched with nutrients),to be initiated by (i) April 2017 or (ii) after the inflow of untreated sewage reduces to 100 MLD or below, whichever is earlier. | **BDA** |
| | The problem of sewage reaching SWDs from slums and houses unable to connect to UGDs would be addressed as per ***Annexure 4*** | **BWSSB** |
| | Slum board should relocate the settlement that is in the Bellandur Varthur catchment | **Slum Board** |
| | Identification of Disposal points for sludge and silt with chemical analysis for appropriate end uses | **BDA** |
| | Developing Bellandur and Varthur lakes as secondary water supply source for Bengaluru. It may use as a source of additional revenue to supply the treated water to large construction projects. | **BWSSB** |
| **Strengthening Bio remediation capability of Lakes** | A Natural Treatment system (Constructed wetlands and algae ponds; similar to treatment systems at Jakkur lake) to be developed to augment the existing and proposed STPs in order to remover nutrients (Nitrates and Phosphates) there by providing relatively safe water to Kolar, Anekal, *etc.* | **BWSSB, KSPCB and Minor Irrigation** |
| | Macrophytes harvesting at regular interval | **BDA** |

## 10.4 Long term Monitoring and Compliance

| | | |
|---|---|---|
| **Citizen Lake Monitoring Committees** | Citizen Lake Monitoring Committees (1 for each lake) would be chaired by a Retired Judge or Environmental Expert, consisting of 5 eminent citizens from the locality, 1 NGO representative, 2 eminent scientific experts, KSPCB regional environmental officer, BWSSB executive engineer (concerned STP), BBMP Executive Engineer (SWD), and BDA Assistant Executive Engineer (of concerned lake). | **UDD, Department of Forests, Ecology and Environment** |
| | Notification of these Monitoring Committees will be issued u/s 3(3) of Environment Protection Act (either by central Ministry of Environment or by Government of Karnataka). | **UDD, Department of Forests, Ecology and Environment** |
| | TORs (responsibilities and powers) to be as follows:<br>• Monitor progress of lake clean-up and rejuvenation programme, including all activities by all agencies in the catchment area that have been given responsibilities under the rejuvenation programme<br>• Conduct inspections of all sewage treatment plants and effluent treatment plants (private and public) in the catchment; authorized to take samples for testing of water | **UDD, Department of Forests, Ecology and Environment** |
| | Training programme for Lake Monitoring Committees. | **BDA and Research Institutes** |
| | Setting up of a network of concerned citizen sub-committees or support groups: one for each stretch (approximately 5-7 per lake) including elected representatives (Councillors, MLA), who will work to support the Lake Monitoring Committee. | **BBMP** |
| | Standing orders from GoK all concerned departments | **UDD** |

| | | |
|---|---|---|
| | (BWSSB, KSPCB, BDA, BBMP, Revenue Dept, BESCOM) to provide all necessary data to the Lake Monitoring Committees with implicit permission to put this data in the public domain. | |
| | 3-monthly meetings of the Lake Monitoring Committees with the Principal Secretary UDD to discuss progress being made, at which all concerned departments must attend and submit progress reports. | **UDD** |
| **Enforcement of existing Environmental norms** | Strengthen legal cell (at BBMP, BDA, Forest Department, KLCDA) to address all illegalities and evolve fast track mechanism to speedy disposal and eviction of encroachers and for penalising polluters | **UDD** |
| **Enforcement of safer Urban planning norms** | Exercise caution in granting any consent for establishment for large scale projects in these catchments with immediate effect | **UDD** |

## 10.5 MONITORING AND RESEARCH FOR IMPROVING EFFICACY OF MEASURES AND ADAPTIVE MANAGEMENT OF LAKES

| | | |
|---|---|---|
| **Monitoring** | Periodical (Annual) sewage quantification | **BWSSB and Research institutes** |
| | Full-fledged online lake water quality monitoring system | **KSPCBand Research institutes** |
| **Research** | Research project to estimate inflows and outflows at all inlet/outlet points of both lakes, including storm water and dry season wastewater flows, discharges, infiltration rates, evapotranspiration rates, and sedimentation rates. | **Funded by BWSSBand Research by institutes** |
| | Research project to develop an integrated hydrological-water chemistry-ecological model of the lakes, from which predictions can be made of the effectiveness of different interventions. | **Funded by KSPCBand Research by institutes** |

| | | |
|---|---|---|
| | Research project to study the chemical and biological composition of the froth, to identify reasons for its high stability and suggest ameliorative measures | **Funded by KSPCBand Research by institutes** |
| | | |

**NOTE:**

**It is also recommended that an Expression of Interest may be called to obtain proposals for feasible and viable short term solutions to ameliorate frothing, odour, weeds overgrowth and some solutions to improve quality of waste water flowing in the drains leading up to the Bellandur lake and to improve oxygen level in the lake.**

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