2019

Waterbody Rejuvenation

A Compendium of Case Studies in India

Consortium for DEWATS Dissemination Society

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CENTRE FOR ADVANCED SANITATION SOLUTIONS

German Federal Ministry of Economic Cooperation and Development

Waterbody Rejuvenation – A Compendium of Case Studies
Publication by – **Consortium for DEWATS Dissemination (CDD) Society, Bengaluru**

'Waterbody Rejuvenation – A Compendium of Case Studies' is a compilation of 13 select cases from India that highlights the different technical aspects of the rejuvenation approach. This publication is a knowledge document and emphasises CDD Society's take on the rejuvenation methodology.

Photographs
All photographs are courtesy of Consortium for DEWATS Dissemination Society (Bengaluru) unless indicated otherwise

December, 2019

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Disclaimer :
The views, thoughts, and opinions expressed in this compendium belong solely to CDD Society.

CDD Society has developed this Compendium of case studies based on information/data collected from field visits, interactions with various stakeholders and open secondary sources. We have tried our best to provide the reader with updated status of lake rejuvenation. However, it may not exactly reflect the current status of the lake.

Grab samples were collected for testing the lake water quality. These samples indicate the water quality in specific parts of the lake on the day of sampling.

Insights have been developed based on CDD society's understanding of the water body rejuvenation space and the reader is requested to exercise discretion while interpreting information.

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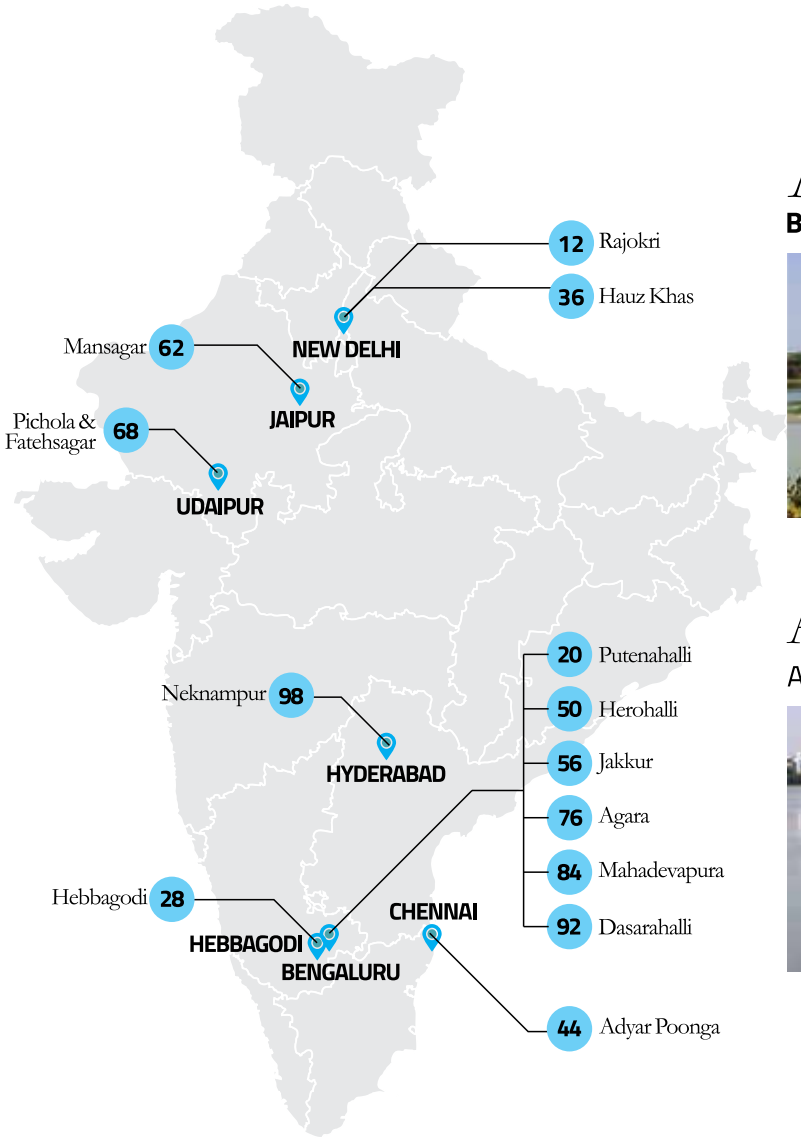


About the Organisations

German Federal Ministry of Economic Cooperation and Development

The **Federal Ministry for Economic Co-operation and Development** provides monetary and knowledge support by mutually cooperating with developing countries to create a more sustainable urban living space.

BORDA

The **Bremen Overseas Research and Development Association (BORDA)** is a German non-profit organisation, which works for poverty alleviation, sustainable protection of natural resources and strengthening of social structures.

Consortium for DEWATS Dissemination Society

Consortium for DEWATS Dissemination (CDD) Society is a technical organisation with an innovation led approach focused on delivering decentralized, contextualized and nature-based water and sanitation management solutions.

CASS
CENTRE FOR ADVANCED SANITATION SOLUTIONS

Centre for Advanced Sanitation Solutions (CASS) is a joint collaboration between CDD Society, BORDA and Rajiv Gandhi Rural Housing Corporation Ltd., Government of Karnataka for providing a one stop sanitation centre with a clear focus on building capacities of sectoral stakeholders.

Preface

There is no doubt that the momentum towards restoring and rejuvenating our Water Bodies is building up. The Government of India (GoI) has put Water Bodies in focus by creating the new *Jal Shakti* Ministry and announcing the *Jal Shakti Abhiyan* which is a mission-mode water conservation campaign. The five intervention areas cover – rainwater harvesting, renovation of water bodies and tanks, reuse and recharge structures, watershed development and intensive afforestation. In addition, the National Mission for Clean Ganga (NMCG) released a manual cum concise guide for River Restoration and Conservation. It is evident that the thinking within government is favouring a more holistic and sustainable approach to rejuvenation that recognises the importance of - ecological (nature based) solutions, participation of citizens, the need for awareness and outreach to change behaviour patterns, complete management of catchments & river basins and innovative funding to achieve these.

Simultaneously, citizen activism and participation in Water Body Rejuvenation (WBR) has also been on the rise. Bangalore is a very good case in point wherein most lakes are now overseen by local lake trusts and there are many lake groups that are operating at a grass-root level as well as in virtual platforms. These citizen groups, in recent years, have also benefitted from CSR donations that are providing the much-needed stimulus to citizen enthusiasm.

Over the years, there have been many initiatives towards WBR – some of them more successful and sustainable than the others. At CDD, we strongly feel that the in the next two decades, there is going to be lot of money spent – by governments, corporates, individual philanthropists and businesses to rejuvenate our water bodies. However, most stakeholders are not clear about how to use funds judiciously towards effective rejuvenation outcomes. To aid this, CDD brought out a publication around July 2019 titled '*Approach to WBR – A Perspective*'. This publication i.e., the compendium, aims to supplement that effort by providing a detailed account of actual initiatives from across the country.

While the effort has been to give a holistic perspective of the rejuvenation initiative, there is an extra emphasis on the technical aspects since we feel that such information is not covered adequately in the public domain.

The publication does not claim to be a very complete representation of all facts and insights of a rejuvenation effort. It is limited by the data that was accessible through primary and secondary sources and could be slightly biased in some cases by the sources that were largely consulted. However, we still feel that the entire WBR community can gain from a document like this – learning from what has worked and what has not. I would like to acknowledge key contributions from my colleagues – *Prerna for taking the lead in compiling and editing this document, Rohini for providing overall guidance, Parth, Karthik Seshan, Vrishali, Sonal, Sujaya and Susmita for their useful reviews and the many project engineers who visited the site to collect information.*

We hope that this publication goes a long way in helping lake groups and WBR enthusiasts to learn from experiences across the country and adapt it to their own contexts.

Happy reading.

Ganapathy P G
Director of Programs

List of Abbreviations

ABR	Anaerobic Baffle Reactor
ALPMS	Agara Lake Protection and Management Society
BBMP	Bruhat Bengaluru Mahanagara Palike
BMZ	Federal Ministry for Economic Cooperation and Development
BOD	Biochemical oxygen demand
BORDA	Bremen Overseas Research and Development Association
CAMUS-SBT	Continuous Advanced Multistage system - Soil Bio Technology
CDD	Consortium for DEWATS Dissemination Society
COD	Chemical oxygen demand
CPCB	Central Pollution Control Board
CRRT	Chennai Rivers Restoration Trust
CSR	Corporate Social Responsibility
DDA	Delhi Development Authority
DEWATS	Decentralized Wastewater Treatment Systems
DJB	Delhi Jal Board
DO	Dissolved oxygen
DPR	Detailed Project Report
ESG	Environmental Support Group
HMDA	Hyderabad Metropolitan Development Authority
I&FC	Irrigation and Flood Control
ILEC	International Lake Environment Committee Foundation
INTACH	Indian National Trust for Art and Cultural Heritage
JDA	Jaipur Development Authority
JNN	Jaipur Nagar Nigam
KL	Kilo litre
KLCDA	Karnataka Lake Conservation and Development Authority

KSDB	Karnataka Slum Development Board
KSPCB	Karnataka State Pollution Control Board
LDA	Lake Development Authority
MAPSAS	Mahadevapura Parisara Samrakshane Mattu Abhivrudhi Samiti
MBBR	Moving Bed Biofilm reactor
MGD	Million gallons per day
MLD	Million litre per day
MoU	Memorandum of Understanding
NEERI	National Environmental Engineering Research Institute
NGO	Non- governmental Organization
NLCP	National Lake Conservation Plan
O&M	Operation and Maintenance
PNLIT	Puttenahalli Neighbourhood Lake Improvement Trust
PPP	Public Private Partnership
SBR	Sequential Batch Reactor
STP	Sewage Treatment Plant
SWAB	Scientific Wetland System with Active Bio-digester
TDEF	Tropical dry evergreen vegetation
TNUIFSL	Tamil Nadu Urban Infrastructure Financial Services Ltd.
TTP	Tertiary Treatment Plant
UIT	Urban Improvement Trust
UPVC	Unplasticized Polyvinyl Chloride
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UWB	United Way Bengaluru
WAPCOS	Water and Power Consultancy Services

Introduction

"India is among the world's most water-stressed countries. In 1950, India had 3,000 – 4,000 cubic meter of water per person which has now fallen to around 1,000 cubic meter. India does not so much face a water crisis as a water management crisis, calling for a fundamental reassessment of the way the country manages water."

-The World Bank in its feature story on World Water Day in 2019 (*The World Bank 2019*)

Waterbodies play a critical role in the development of urban spaces. They have diverse functions including domestic purposes, wastewater dilution, ecological services, green space management, biodiversity and temperature regulation. However, they have currently become merely a sink for solid waste and wastewater. Deteriorating infrastructure and encroachments also continue to threaten the health of waterbodies. It is increasingly evident that in the medium to long term, failure to rejuvenate the water bodies will have dire implications on urban development.

Holistic waterbody rejuvenation efforts have in the past considered different aspects like catchment area development, economic activities dependant on the waterbody and social and cultural stewardship of water bodies.

This impending water management crisis has, in the current times, become a primary concern for the Indian government. The newly formed Ministry of *Jal Shakti* has integrated various water related departments to leverage the synergies of multiple disciplines and subject expertise. To address water security, a combination of centralised and decentralised approach is being brought into practice.

There is no single best practice, thumb rules or lookup tables for rejuvenation. Everything is contextual and defined by the scale of the waterbody, the value it holds among the community, the economic benefit it creates, the intent of the institutions that manage it and ultimately the vision everyone has for the waterbody. This compendium is one such effort to create a reference base, to bring all these varied contexts to the reader and inform them to understand the complexity.

'Waterbody Rejuvenation – A Compendium of Case Studies' aims to bring together select waterbody rejuvenation efforts in India with special attention to the technical aspects of the rejuvenation approach. This compendium explores varied contexts and approaches, and considers what aspects have been successful and which have failed. Our team visited the lakes, talked to key stakeholders and distilled the most significant aspects of rejuvenation.

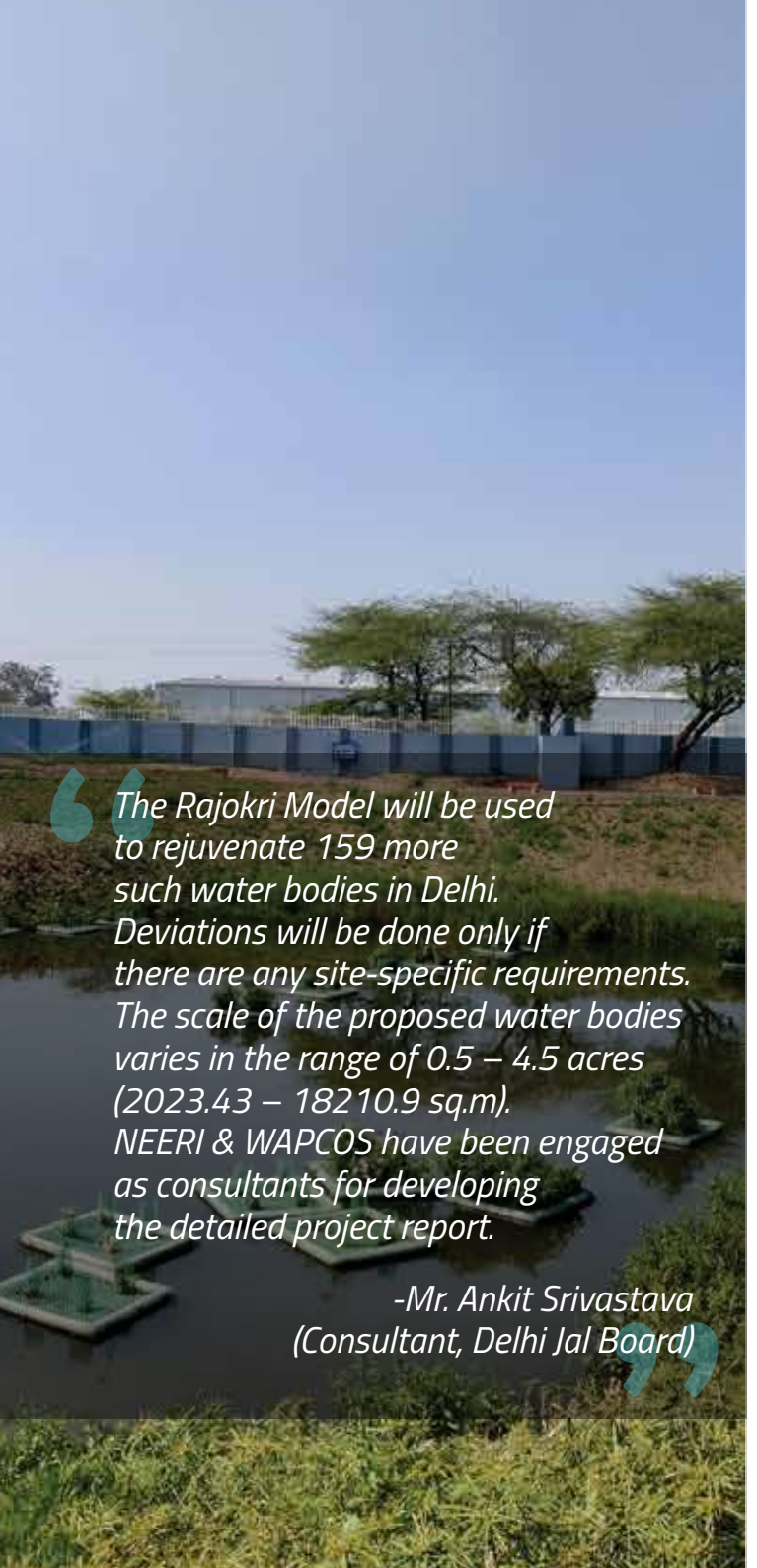
It is a starting document for anyone who wants to understand more about waterbody rejuvenation. The team has made an earnest effort to break down a complex process in lucid terms. It can similarly act as a trigger and orient interested laypersons to ask the right questions regarding the subject. However, this compendium is not a substitute for specialist advice.

We hope you enjoy reading this compendium and we look forward to hearing your opinion on our investigation and its presentation. Your feedback will help us learn and use it to develop more efficient ways of working in the future.

Rajokri Lake

New Delhi, Delhi

Is this **nature-based** rejuvenation **scalable?**



The Rajokri Model will be used to rejuvenate 159 more such water bodies in Delhi. Deviations will be done only if there are any site-specific requirements. The scale of the proposed water bodies varies in the range of 0.5 – 4.5 acres (2023.43 – 18210.9 sq.m). NEERI & WAPCOS have been engaged as consultants for developing the detailed project report.

-Mr. Ankit Srivastava (Consultant, Delhi Jal Board)

Rajokri Lake

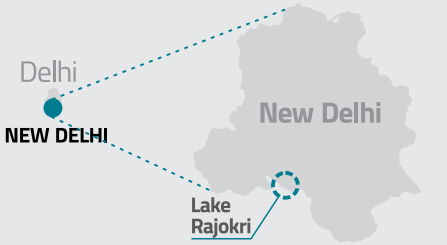
New Delhi, Delhi

Is this **nature-based** rejuvenation **scalable?**

In 2018, the Delhi government grappled with mammoth water crisis in the capital region. Reviving urban water bodies was one option and Rajokri Lake served as a handy pilot case. With a decentralised approach, this 2.33 acre lake has been revived using natural treatment concepts coupled with the usage of renewable energy and rainwater harvesting. Sustainability and scalability have been the hinge on which this project was built.

Rajokri Lake lies in the small suburban village of Rajokri located near the Delhi Gurgaon Border and was revived in the year 2018 by the Delhi Jal Board (DJB). Earlier the lake was a breeding ground for mosquitoes and communicable diseases that plagued the semi-rural community living around the lake. Wastewater from the adjoining residential areas was channelized through the open drains and collected in the lake.

The lake is significant for the local community, as it plays a symbolic role in *Chhath Puja*, an important cultural festival for them. The local MLA was proactive in pushing for rejuvenation of this lake, and hence it was chosen as a DJB Pilot Project.



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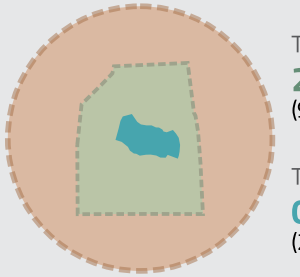


Total **Area**
2.33 acres
(9,429 sq m)

Total **Water Spread** Area
0.5 acres
(2,023.43 sq m)

Average Depth of Lake
5-6 ft
(1.5– 1.8 m)

Catchment Area
Wastewater from **Rajokri Village**

Year of Intervention
2018

Cost in INR
Cap Ex **17.8 million**
Op Ex **n/a**

Key Interventions at Rajokri Lake

Spearheaded by DJB, the following initiatives were completed in 2018:

Preparatory Interventions

- Desilting of the lake for removal of sludge and solid waste for enhancement of the water holding capacity

Lake Recharge & **Wastewater Treatment** Interventions

- Scientific Wetland System with Active Bio - Digester (SWAB) of 0.6 MLD treatment capacity
- Installation of 40 floating wetlands.
- Creation of Bio swales
- Gravel Pathways
- Plantation of Bioremediation grasses

Biodiversity Enhancement Interventions

- Plantation inside the lake premises

Allied Interventions

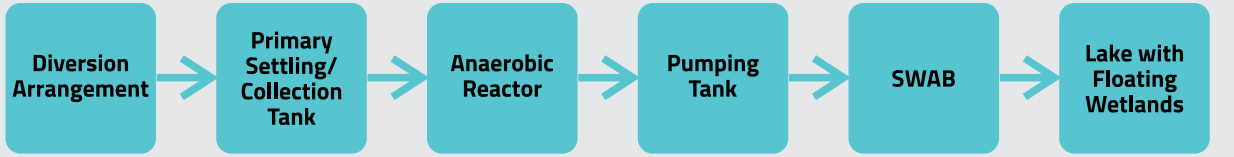
- Creation of a children's play area and open gym
- Space for conducting *Chhath Puja*

Box 1:

Wastewater Treatment System in Rajokri

- Sewage trapped from 5 manholes in the catchment
- **Anaerobic Reactor**
  Tank with six chambers created using five baffle walls with alternate slots at top and bottom having a capacity of 760 KL.
  Length: 38m, Breadth: 5m, Depth: 4m
- **SWAB**
- Length: 34.8 - 25.8m,
  Width: 10.11m,
  Depth: 2.0 to 2.6m
- No. of chambers: 15
- Filler stone aggregate of nominal size of 200 to 300mm over a depth of 77cm, 100mm over a depth of 38cm, 80mm over a depth of 115cm
- Plant used - Papyrus
- **Plants on wetland**
  Umbrella Papyrus and Canna Indica
- **Floating Wetlands**
  40 floating wetlands of the dimensions 0.5m * 0.5m having papyrus plants. Floating islands have been created from PVC Pipes and mesh which support plants that extract the nutrients from the lake, purifying it further.

Source – Information as provided by Delhi Jal Board



1. Interception and Channelization of wastewater into the treatment system
2. Collection Tank with an arrangement for filtering out the silt and any other solid particles
3. Diversion arrangement for letting monsoon flows directly into the lake
4. Collection tank for the wastewater after passing through the anaerobic reactor
5. Scientific Wetland System with Active Bio-digester (SWAB)
6. Bioremediation plants (papyrus) and gravel that aid the absorption of nutrients and filtration of water.

7. Floating wetlands installed in the lake for the final treatment of water
8. Amphitheatre and Bund as a socio-cultural intervention. This is the place where the Chhath Festival is celebrated by using the space between amphitheatre and bund to fill the water
9. Bio Swale for water retention that then leads to groundwater recharge and also regulates the flow of rainwater into the lake
10. Gravel Walkways
11. Rejuvenated Rajokri Lake

Rajokri Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Rajokri Lake

Parameter	P1 Main Inlet	P2 Bioreactor	P3 SWAB Inlet	P4 SWAB Outlet	P5 Lake
Total suspended solids (mg/l)	190.0	285.0	110.0	98.0	102
BOD 3 Days at 27˚C (mg/l)	190.0	187.0	63.0	28.0	16.0
COD (as O_2) (mg/l)	410.0	345.0	156.0	95.0	56
Total Phosphate (mg/l)	5.6	8.1	3.9	2.1	1.9
Ammoniacal Nitrogen (as N) (mg/l)	20.0	20.0	15.0	10.0	5.0

Date of sample collection – 24/02/2019[1]

Inference

1 The wastewater entering the lake is of medium strength. Usually wastewater flowing in open channels are of medium or low strength. However, if the water is flowing in a closed channel like in a sewer line, then it may be of higher strength[2].
In the case of Rajokri, the water has been channelized to flow within a closed system due to the presence of a dense residential area.

2 There is a consistent decrease in the organic content of water which is indicated by the parameters of COD and BOD. There is a 67% reduction in BOD from the primary inlet to the SWAB inlet (after completion of secondary treatment) and another 56% decrease inside the SWAB. Overall, we can see that there is approximately 85% decrease in BOD from the inlet to the release of treated water in the lake. This reduction is due to the combined usage of an anaerobic and aerobic system.

3. The lake has a treatment system in the form of floating wetlands. Floating wetlands help in the conversion of ammonia to nitrates. This conversion process is aided by the microbes present in the root of the plants as well as media through surface aeration.

4. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS E of CPCB's designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.

1 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling.

2 Composition of untreated domestic wastewater (Low Strength WW BOD – 110 mg/l, Medium strength WW BOD – 190 mg/l, High strength WW BOD – 350 mg/l) (Eddy 2003)

Rajokri Lake : Before Rejuvenation

Rajokri Lake : After Rejuvenation

Institutions Involved

Rajokri Lake Rejuvenation was a joint effort by the DJB and the Department of Irrigation and Flood Control. The project was conceptualized and designed by DJB whereas the on-ground implementation was done by Irrigation and Flood Control (I&FC). There were a couple of other smaller private organizations and trusts that did specific components of the work on a pro-bono basis. The Chhath Puja Committee was also part of the initiative.

Future Plans

For increasing treatment efficiency at the tertiary stage, aerators and sand carbon filter is being installed. Automated pumps will also be installed. To effectively use the space, funding has been sanctioned for constructing an open-air gym and a children's park. Delhi Jal Board plans to scale up this model and implement it in 159 lakes in Delhi, a budget of INR 376 Crore has been allotted for these works. Two upcoming mega lake projects are in Rohini[3] and Nilothi[4] costing the department around INR 77 Crore.

Insights

Delhi government has set a good example that can be replicated in other lakes of Delhi. Rajokri Lake looks like a well thought out intervention where there is an **integration of socio-cultural, environmental, ecological and technological aspects**.

The space earlier serving as a wastewater sink was integrated as a space for community rituals in the conceptualisation phase. This was accomplished by constructing a bund arrangement which could store water on one side for its safe use. However, it is observed that there is still some stigma attached to the use of treated wastewater for religious purposes. This suggests that **culturally conscious**

3 A suburban area in North West Delhi

4 A village near Nangloi Jat on NH 10, Delhi

Box 2:

Bioswales

Bioswales are storm water runoff conveyance systems that provide an alternative to storm sewers. They can absorb low flows or carry runoff from heavy rains to storm sewer inlets or directly to surface waters. Bioswales improve water quality by infiltrating the first flush of storm water runoff and filtering the large storm flows they convey. Much of the value of bioswales comes from infiltrating and filtering the rainwater.

Source – USDA

> *"Scaling up will be done using tried and tested technologies. We are simplifying the administrative processes related to the tendering of these projects so that more bidders can enter this space and the overall cost can be reduced while at the same time quality is not compromised."*
>
> *Mr. Ankit Srivastava*
> *(Consultant, Delhi Jal Board)*

interventions should be complemented by knowledge dissemination among the locals.

Though the plant is operational, it remains to be seen how well the treatment system can be maintained. The **simplicity and aesthetics of the treatment system** stand out clearly. The ease with which an unskilled operator could explain the technology to our investigative team was a testament to the uncomplicated nature of the treatment system. Simple landscaping solutions such as the bioswale was another unique initiative that is a simple solution towards trapping rain water runoff and recharging ground water without incurring much expense. Overall the **implementation of nature-based treatment systems**, in the form of SWAB or floating wetlands, all indicate to a sustainable way forward.

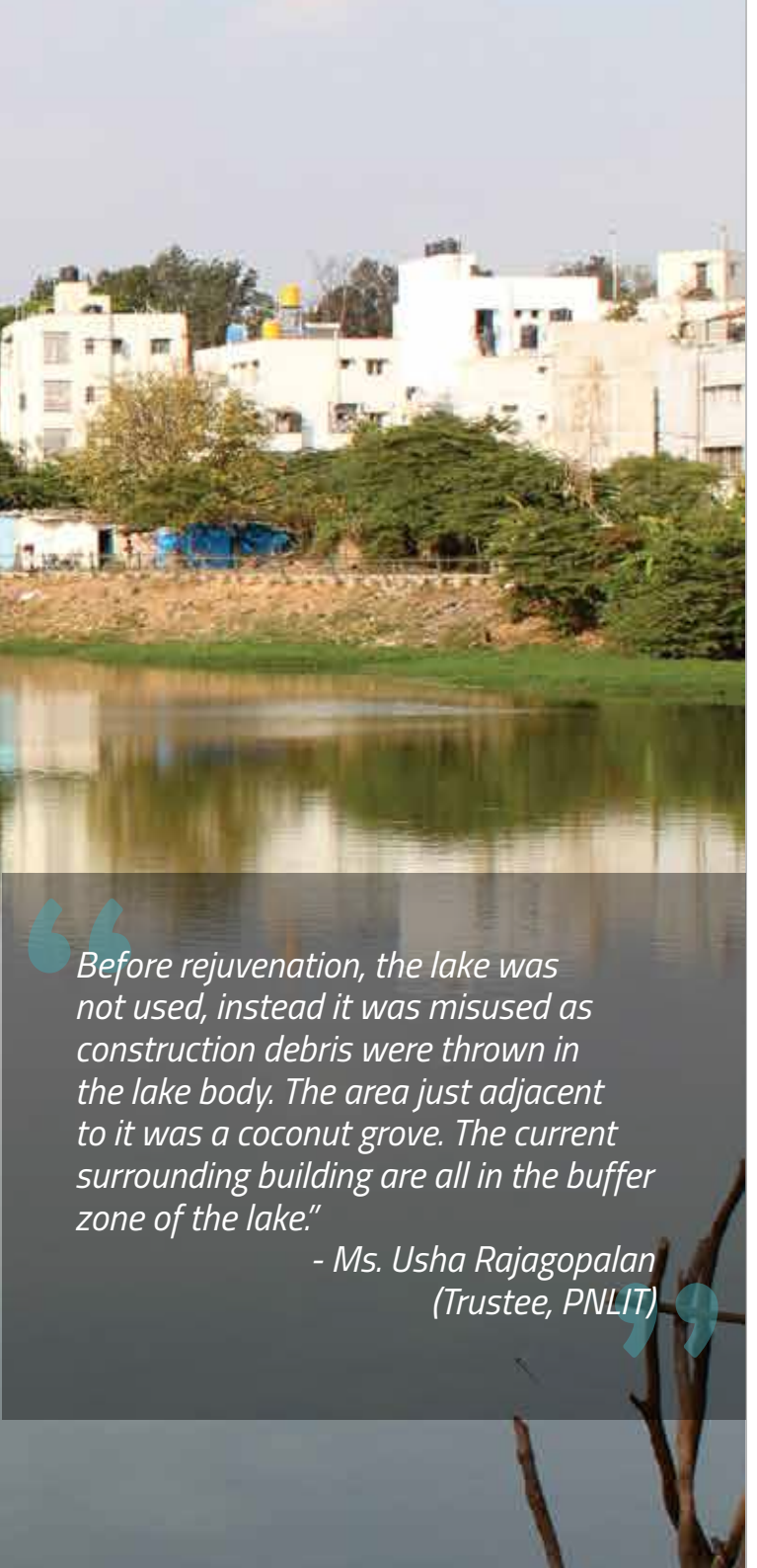
Scaling this up will require attention and investment on strengthening the collaborative structures/ institutions for coherently working on the different components like, preparing the concept, detailing out the plan, improving community acceptance and ownership, developing the system and institutions for maintaining it. These do not require new structures, rather **understanding the limits of the existing systems** and building on them will serve the purpose of scaling up. Continuous monitoring and evaluation of these systems is called for.

Rajokri as a simple exemplar of waterbody rejuvenation offers many insights but DJB's proposed plan of rejuvenating the next set of 159 water bodies is a different ball game all together. An **incremental approach** is feasible going forward. The pace at which activities will be rolled out will require set processes, multi-level partnerships, engagement strategies and quality leadership. **Evidence and constant re-evaluation** will also be required to be part of the scale up intervention to understand contexts better.

Puttenahalli Lake

Bengaluru, Karnataka

A model for **waterbody stewardship**



Before rejuvenation, the lake was not used, instead it was misused as construction debris were thrown in the lake body. The area just adjacent to it was a coconut grove. The current surrounding building are all in the buffer zone of the lake."

- Ms. Usha Rajagopalan (Trustee, PNLIT)

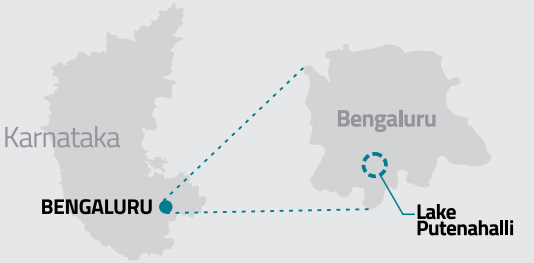
Puttenahalli Lake

Bengaluru, Karnataka

A model for **waterbody stewardship**

Puttenahalli Lake is an iconic lake located in JP Nagar, Bengaluru and is one of the first few lakes revived through citizens action. Its rejuvenation inspired many citizens to form alliances and save more lakes in Bengaluru. It demonstrates that effective action by citizen groups can revitalise the civic culture, improve the nature of public discourse and generate the political will necessary to address pressing problems.

Puttenahalli Lake was filled with solid waste, wastewater and storm water runoff from residential areas nearby in addition to construction debris. The lake's rebirth began in the year 2010, when a group of concerned citizens came together and formed the Puttenahalli Neighbourhood Lake Improvement Trust (PNLIT). In collaboration with Bruhat Bengaluru Mahanagara Palike (BBMP), the trust helped bring the lake back to life through a series of interventions.



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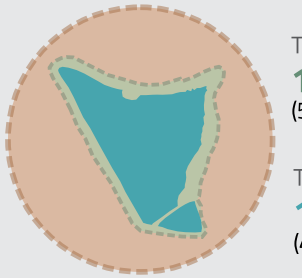


Total **Area**
13.63 acres
(55,158.65 sq m)

Total **Water Spread** Area
10 acres
(40,468.6 sq m)

Average Depth of Lake
16–18 ft
(4.9–5.5 m)

Catchment Area
- Storm water runoff from **JP Nagar**
- Treated Wastewater from **South City STP**

Year of Intervention
2010

Cost in INR
Cap Ex **10 million**
Op Ex **1 million p.a.**

Key Interventions at Puttenahalli Lake

Spearheaded by PNLIT and BBMP, the preparatory and biodiversity enhancement interventions was completed by 2011. Interventions related to lake recharge and wastewater treatment was done in the year 2015.

Preparatory Interventions

- Boundary demarcation & fencing of lake boundary
- Desilting of the Puttenahalli Lake
- Construction of bunds and revetment
- Construction of sedimentation basin/wetland
- Installation of solid waste screens

Lake Recharge & **Wastewater Treatment** Interventions

- Diversion of tertiary treated wastewater from South City sewage treatment plant
- Installation of floating wetlands inside the sedimentation basin

Biodiversity Enhancement Interventions

- Plantation of native plant species
- Artificial bird perching islands

Allied Interventions

- Deweeding
- Tree Tagging
- Composting of organic waste
- Volunteering by corporates and residents

Box 3:

Wastewater Treatment Arrangement

South City Apartment Complex located adjacent to the Puttenahalli Lake currently releases tertiary treated wastewater into the lake.

- Capacity of the STP – 11 MLD
- Technology – Sequential Batch Reactor
- Priority of water reuse
  - Water distribution for flushing
  - Water distribution for gardening and watering the premises
  - Water sent to the lake for recharge

There is an in-situ arrangement of floating wetlands for the treatment of wastewater.

- No. of floating wetlands – 70 nos.
- Total area occupied by wetlands – 1400 sq ft (130 sq m)
- Plants used – Canna Indica, Papyrus, Duckweed, Collacasia, Elephant grass

Box 4:

Rehabilitation of slum dwellers

Slum dwellers residing near the lake premises had filed a writ petition against the development of the lake. For their relocation and rehabilitation, the Revenue Department identified a land in Bettadasanapura and handed it over to the KSDB (Karnataka Slum Development Board). After obtaining written consent from each of the slum dwellers, KSDB agreed to fund the construction of the temporary sheds of 120 square feet each. However, the slum dwellers demanded 600 square feet space per family.

The slum dwellers rejected the alternate land allotted for their relocation and demolished the temporary sheds (fully constructed and ready for occupancy) - causing a loss of more than INR.70 lakhs to the exchequer.

After 4 years, on March 7th, 2019 the writ petition was adjudicated by the Karnataka High Court which permitted the slum dwellers to continue to occupy their existing dwelling space and directed the KSDB to look for alternate land for rehabilitation.

Source – PNLIT

1. Tertiary treated wastewater from the South City Apartment Complex (in background) diverted to the lake
2. South City STP (Technology – Sequential Batch Reactor) which releases tertiary treated wastewater to the lake intermittently
3. Solid Waste screening arrangement at one of the storm water inlets
4. A permeable bund is used to mark the boundary of the sedimentation basin

5. 70 artificial floating wetlands have been placed in the lake to treat the wastewater

   Canna Indica and elephant grass have been grown hydroponically. Additionally, water hyacinth, an invasive species has also naturally grown over the floating rafts
6. Artificial bird perching islands made inside the lake to enhance biodiversity. These are isolated zones to prevent any anthropogenic activity
7. Unfenced portion of the lake occupied by slums where 144 families reside
8. Coracle used for fishing and lake maintenance by the fisherman
9. Pergola with creepers to provide shade to the walkway in the lake premises

Puttenahalli Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Puttenahalli Lake

Parameter	**P1** Inside Wetland	**P2** Outside Wetland	**P3** Waste Weir	**P4** Viewing Deck	**P5** Lake
pH	9.1	8.1	8.8	9.2	8.9
Temperature (˚C)	27.0	27.5	26.7	26.9	26.8
Electrical Conductivity (µS/cm)	628	825	617	615	611
Total Dissolved Solids (ppm)	400	600	400	400	400
Suspended Solids (mg/l)	49	71	49	53	54
Turbidity (NTU)	55.2	60.9	59.9	63.3	65.6
Biochemical Oxygen Demand (mg/l)	20	22	22	26	22
Chemical Oxygen Demand (mg/l)	139	95	79	79	71
Phosphate as PO_4 (mg/l)	0.6	3.1	0.4	BDL	BDL
Ammonia as NH_3-N (mg/l)	0.8	5.8	0.9	0.7	0.3
E. coli (MPN/100ml)	240	300	350	64	23

Date of sample collection – 20/02/2019[5]

Inference

1. An increase in concentration of ammonia is recorded near the outlet of wetland. It could be due to presence of dead zones. Also, non-uniform flow of water creates zones where anaerobic activity increases leading to increase in ammonia concentration. Another reason could be the immediate by pass of water without allowing sufficient retention time. This can be managed by clearing the blockages in the bund. A next level intervention would be to put one more layer of floating wetlands adjacent to the bund towards the side of the lake.
2. All parameters have not been analysed hence a conclusive remark on the water quality cannot

5 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

be made. But based on the few parameters that were analysed, the lake water resembles CLASS E of the designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.

3. STP water sample is unavailable due to no flow of treated wastewater into the lake on the day of sampling.

Institutions involved

An MoU was signed between BBMP and PNLIT in the year 2011. From then onwards the lake has been maintained by PNLIT. Tertiary treated water from the South City STP was first diverted on 17th May 2015, with permission from the Karnataka State Pollution Control Board (KSPCB).

PNLIT has forged partnerships with multiple organisations for activities such as water quality sampling, organising cultural events, source volunteering support and leverage CSR (Corporate Social Responsibility) funds via the residents working in corporate companies.

Future Plans

PNLIT plans to convert the garbage dump located near the lake into a lotus pond and also construct a playground for the specially abled children. Slum dwellers have been permitted to continue staying in the buffer zone of the lake until the KSDB makes an arrangement for their rehabilitation.

Financial sustainability is still a huge challenge for PNLIT as it is dependent on public donations and CSR grants for managing the operation and maintenance of the lake.

Insights

The forces that came together to rejuvenate the Puttenahalli Lake gives us a glimpse of the positive implications of citizen groups as lake managers. These were residents who had witnessed first-hand, the urban sprawl around the lake and were deeply concerned about its health. These motivated individuals then came together to rejuvenate the lake with the support of civic authorities. The **ULBs can leverage such form of citizen engagement and enhance its ability to monitor and manage the lakes more effectively**.

Rejuvenation of the Puttenahalli Lake is also the only case where treated wastewater from a privately owned STP is being used to recharge the lake. Back in 2015 it was relatively a new idea and the group/PNLIT had their reservations regarding the risk associated with such a measure. As a preventive measure, PNLIT proposed to provide an in-situ treatment system (floating wetlands) to take care of any fluctuations/shock loads associated with discharge of treated sewage into the lake. This indicates the foresightedness of PNLIT members and a **sense of ownership** taken by them for what essentially is an urban common.

Bird perching islands/sites incorporated in the rejuvenation design has helped in enhancing the avian fauna of the lake. These sites are isolated from any anthropogenic disturbance. PNLIT has been actively recording the species sighted at the lake which is a commendable practice as it enhances knowledge and also acts as evidence of interventions.

This case compels us to take a very critical look on what really was the cause for the deterioration of the lake. Is it rightful to blame the slum dwellers who had occupied the land around the lake before the sprawl took place? Or is the unplanned development process embedded with flaws that failed to take all the stakeholders on board? Who should be accountable for the loss of public money? Who is answerable for encroached buffer zone?

The questions remain unanswered.

Aerial views of Putenahalli Lake over the years

Hebbagodi Lake

Hebbagodi, Karnataka

Corporate Social Responsibility delivers

Hebbagodi Lake

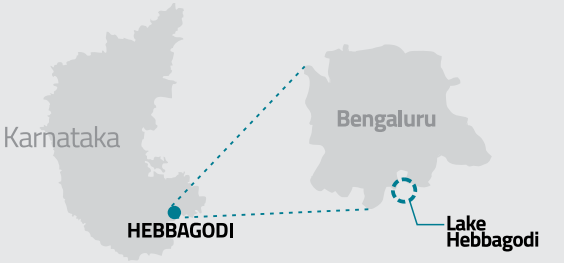
Hebbagodi, Karnataka

Corporate Social Responsibility delivers

While governments in India have the responsibility of providing good living conditions for its citizens, societal needs currently far exceed the government's capacities to fulfill them. Markets are an integral part of society and they have the potential and responsibility to contribute to the improvement of water bodies. The rejuvenation of Hebbagodi Lake is a beautiful example of creating a balance of responsibilities between the government and a corporate entity.

The Hebbagodi Lake in Hebbagodi town (Karnataka) has been embellished and revived in recent times, with support from Biocon Foundation. Once a polluted lake with barely any life surrounding it, post rejuvenation the lake has received international recognition by entering the Limca Book of Records for having India's largest artificial floating island.

The story began in 2016 when Karnataka Lake Conservation and Development Authority (KLCDA) conducted a workshop to bring corporate foundations on board to further the work on lake rejuvenation. Post this workshop, Biocon Foundation got on board with KLCDA to rejuvenate Hebbagodi lake. Conceptualizing the treatment mechanism was challenging due to the space constraints and hence a combination of some unconventional methods like the usage of bio-enzymes and floating wetlands was tried on the ground.



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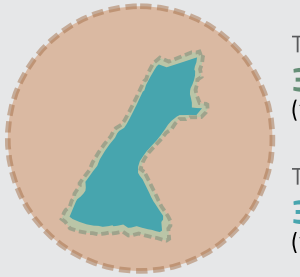


Total **Area**
35 acres
(1,41,640 sq m)

Total **Water Spread** Area
32 acres
(1,29,499 sq m)

Average Depth of Lake
6-13 ft
(2–4 m)

Catchment Area
Untreated domestic wastewater from **Golahalli, Shikaripalya & Thirupalya**

Year of Intervention
2016 August

Cost in INR
Cap Ex **70 million**
Op Ex **2.4-3 million p.a.**

Key Interventions at Hebbagodi Lake

The following interventions were part of the Hebbagodi Lake Rejuvenation

Preparatory Interventions

- Clearance of weeds, silt and garbage
- Boundary demarcation and fencing
- Creation and strengthening of bund
- Installation of bar screens to prevent the entry of solid waste
- Channelization of multiple inlets into one main channel to overcome the challenge of scattered wastewater inflow

Lake recharge & **wastewater treatment** Interventions

- Bio-enzyme treatment
- Treatment through artificial floating wetlands
- Mechanical Aeration
- Diversion of previously flowing wastewater away from the lake using an underground drainage system

Biodiversity Enhancement Interventions

- Green belt development

Allied Interventions

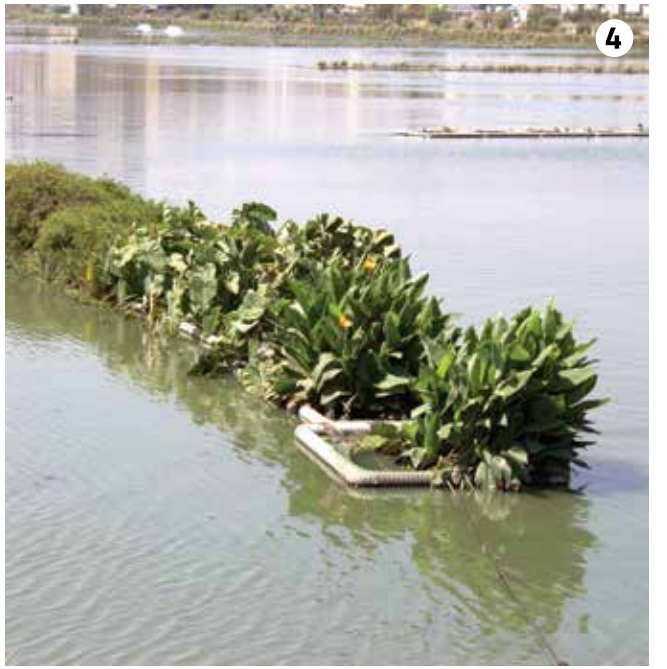
- Creation of walkway and children's park

Box 5:

Bio-Enzyme Treatment

The wastewater entering the Hebbagodi Lake is subjected to bioremediation, where a proprietary bio-enzyme (JMS Bio-enzyme) breaks the sewage into smaller components, thereby aiding the treatment process. 2500 litres of bio-enzyme solution is dosed into the inlet stream 1 Kilometre before it enters the lake and another 500 litres is introduced directly into the lake. Approximately 20 – 30% of the treatment currently happens in the drain itself.

Source -
Jalavahini Management Services Pvt Ltd
(Proprietor of JMS Bio-enzyme)



1. Primary Inlet that brings 80% of the wastewater. Approximately 7-8 MLD of wastewater enters the lake through this inlet after being treated using bio-enzymes
2. Installation of bar screens to prevent the entry of solid waste
3. Raw wastewater entering the lake directly through another inlet
4. Artificial Floating Islands with nutrient absorbing plant species such as Canna, Colocasia, Nutgrass, Alligator Weed, Water Cabbage and Cyperus haspan were grown hydroponically. There are 400 wetlands covering 12,000 sq.m area in the lake

5. Floating Aerators
6. Dosing Solution being prepared at the Bioreactor
7. Hebbagodi Lake Outlet - (The water from this lake overflows into the Kamasandra Lake)
8. Unpaved walkway around the lake
9. Flora around the lake

Hebbagodi Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Hebbagodi Lake

Parameter	**P1** Inside Sedimentation Basin	**P2** Outside Sedimentation Basin	**P3** Waste Weir
pH	7.5	7.5	8.3
Temperature (°C)	23.8	23.9	23.9
Electrical Conductivity (µS/cm)	2400	2200	2100
Total Dissolved Solids (ppm)	1700	1600	1500
Suspended Solids (mg/l)	144	286	60
Turbidity (NTU)	34.2	231	57.8
Biochemical Oxygen Demand (mg/l)	40	150	35
Chemical Oxygen Demand (mg/l)	137	297	131
Phosphate as PO_4 (mg/l)	41.0	19.0	8.4
Ammonia as NH_3-N (mg/l)	40	37	29
Total Solids (mg/l)	1867	1933	1603

Date of sample collection – 12/12/2018[6]

Inference

1. Wastewater entering the lake from the primary inlet is of low strength. A combination of three treatment approaches have contributed well to the reduction in the organic content of water. One key reason could be the dosing of bio enzymes in the upstream region which gives it enough space and time to form colonies for treatment.
2. There is about 77% decrease in organics from the primary inlet to the outlet. While it is difficult to attribute specific contribution of each approach to the overall treatment efficiency, but the combination is working well.
3. Additionally, as mentioned earlier, aeration and floating wetlands also contribute in conversion

6 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

Box 6:

Slope Stabilisation using **Vettiver** plant

Vettiver grass has been planted to strengthen the slopes of the bund at Hebbagodi Lake. The interaction of vettiver roots with soil forms composite comprising roots with high tensile strength and adhesion embedded in a matrix of lower tensile strength. Vettiver roots are very strong with high mean tensile strength of 75 MPa or approximately 1/6th of strength of mild steel. Its roots are as long as 2 – 3.5 m with a very short growing time. This makes Vettiver a better option for bund strengthening compared to other trees which normally take 2-3 years to become as effective.

Source - Hengchaovanich

of ammonia to nitrate. However, in the case of Hebbagodi Lake, there is not a significant decrease in the nutrient content.

4. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS E of the designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.

Institutions

Biocon Foundation is the Corporate Social Responsibility arm of 2 companies i.e., Biocon and Synergene International. Hebbagodi Lake has been jointly rejuvenated by Biocon Foundation, Hebbagodi City Municipal Council, Zila Panchayat, and District Commissioner's office under the guidance, support and leadership of the then Karnataka Lake Conservation and Development Authority (KLCDA). A Dharwad based organization - Jalavahini Management Systems is currently taking care of the operation & maintenance of the whole system.

Future Plans

Biocon Foundation is the primary implementation and maintenance agency until 2021 according to the MoU (Memorandum of Understanding) signed between Biocon Foundation and the Government of Karnataka. In the next phase, there are plans for setting up a solid waste segregation system and composting facility. This is a progressive step that the foundation's CSR is taking to improve the space and incorporate some good practices.

The work on the Hebbagodi Lake has made way for more work in the waterbody rejuvenation space.

Biocon Foundation is now going to take up work in the Kamasandra Lake, Yerahanahalli Lake and Bommasandra Lake.

Insights

Corporate social responsibility in environmental and social management efforts helps businesses gain trust and make progressive social transformations. But for CSR efforts to be effective, the public and private sectors need to form healthy collaborations, and contribute in their unique roles. Hebbagodi Lake is a good example of corporate engagement yielding value in the environmental space. The rejuvenation of this lake has gained a lot of attention globally, with the use of floating wetlands lending it's unique and impressive character.

The overall treatment of wastewater is attributed to three different types of interventions. In such a case it is hard to determine the extent to which each treatment contributed. However, the choice of bio-enzymes dosing as a treatment mechanism was driven due to the unavailability of land for an STP and an accurate assessment of the actual impact of the mechanism will have to be undertaken independently.

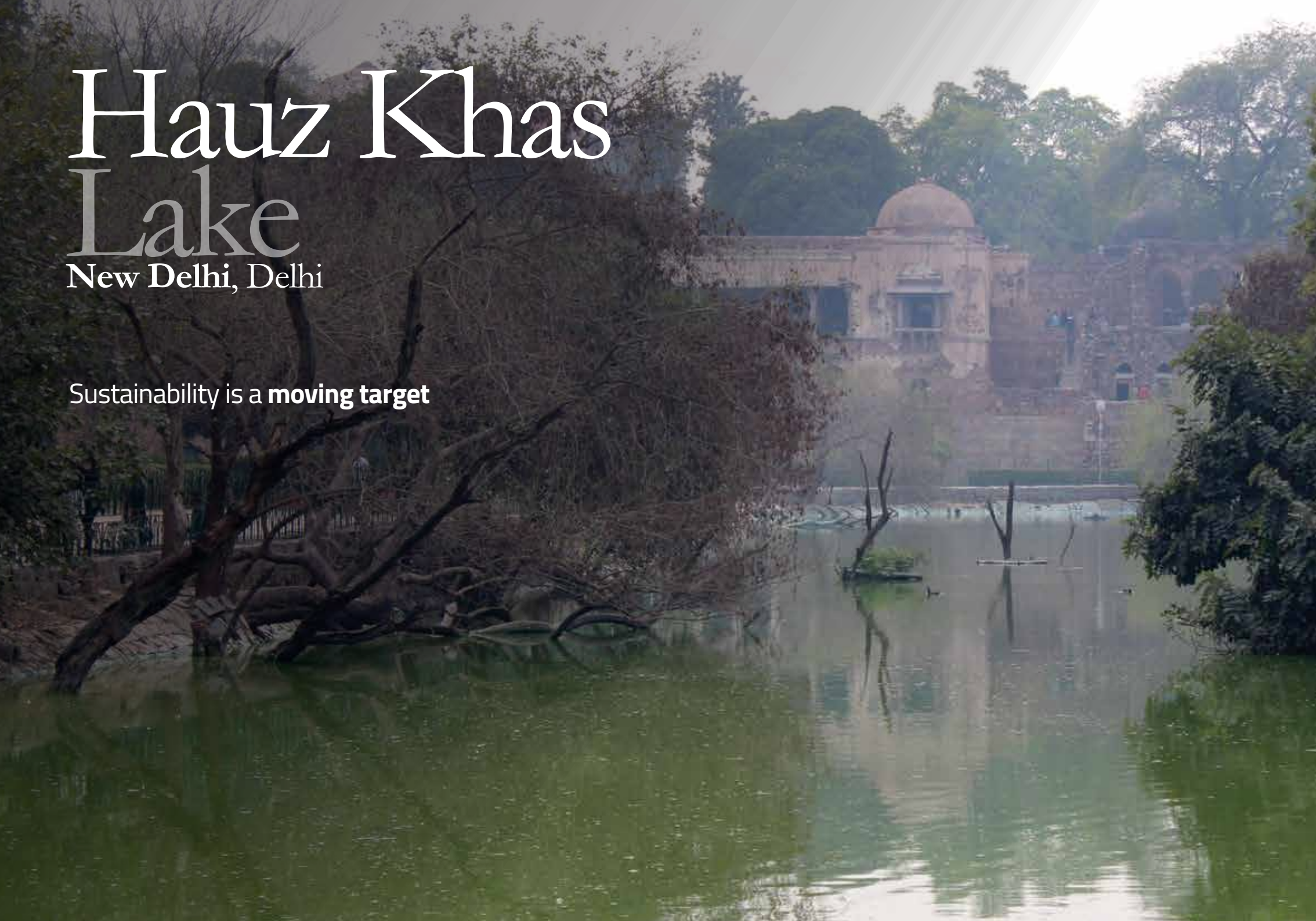
While some studies show bio-enzymes causing reduction of nutrients like nitrates and phosphorus in wastewater, other studies also conclude that they have minimal to negligible impact on the volume of sludge or suspended solids. Hence, in the absence of sufficient evidence and with literature indicating mixed results, the reliability of this method is still questionable.

In conclusion, we can say that a **healthy partnership between government and corporate entities can contribute significantly** to address issues related to the health of lakes and other water bodies in urban spaces.

Hauz Khas Lake

New Delhi, Delhi

Sustainability is a **moving target**



Hauz Khas Lake

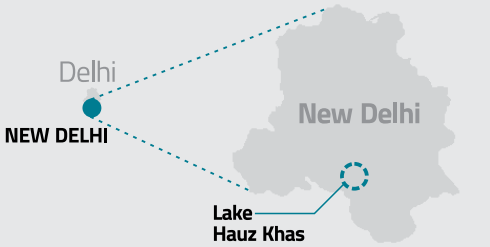
New Delhi, Delhi

Sustainability is a **moving target**

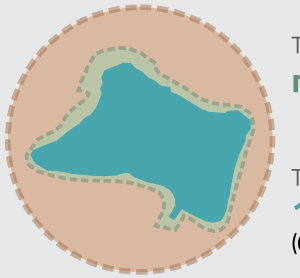
Urban spaces are so intensely teeming with human behaviour that one could forget that they are sustained by ecological processes. The need for communicating the importance of urban lakes as an integral part of the larger ecosystem is more important than ever. Hauz Khas lake has been contributing towards the biological richness of the South Delhi Area. However, as Delhi undergoes significant urban expansion, multiple factors have led to the deterioration of the Hauz Khas Lake.

Hauz Khas is a 700-year-old artificial lake made by Sultan Alauddin Khilji during the early fourteenth century to provide water to new city of Siri and his military camp. Subsequently, Firoz Shah Tughlaq during 1350s carried out extensive repairs of the tank. During the re-establishment of the Hauz Khas Village in the 1980s it was ensured that the monuments and the water tank remain protected (*INTACH*).

The lake is spread over an area of 15 acres, surrounded by historical structures, a district park, a deer park, a rose garden, a wooded area and a commercialized village. Originally, the lake was fed by three main storm drains. Currently the lake is fed by treated effluent from a sewage treatment plant in Vasant Kunj and rainfall from the catchment area. People are often seen enjoying the lake's green premises.



SALIENT FEATURES



Total **Area**
n/a

Total **Water Spread** Area
15 acres
(60,702.8 sq m)

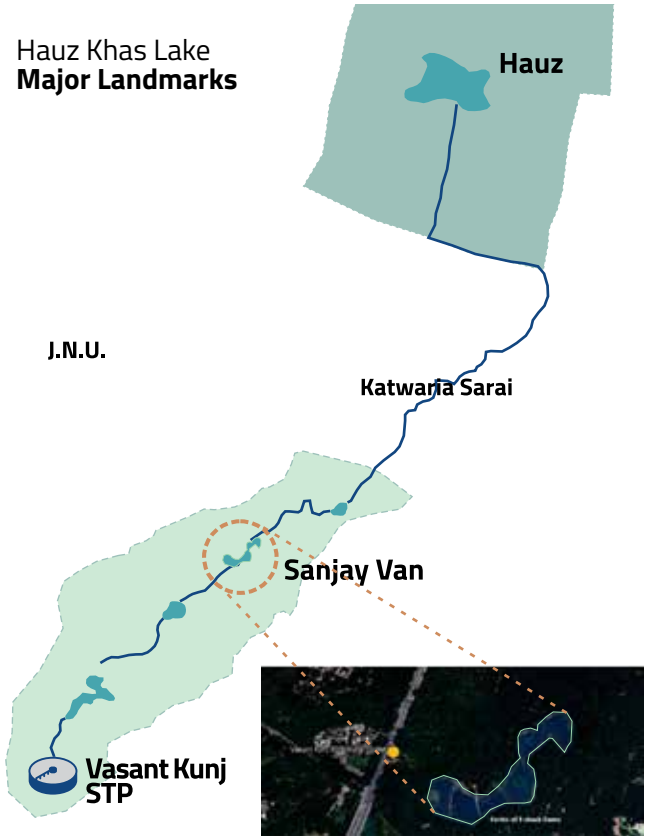
Average Depth of Lake
7.2 ft
(2.2 m)

Catchment Area
Domestic wastewater and stormwater from **Katwaria Sarai & Munirka Village**

Years of Intervention
1968, 2002, 2017

Cost in INR
Cap Ex **9.6 Lakh** (2002)
Op Ex **n/a**

Multiple attempts were made to rejuvenate this lake, and rejuvenation elements are successful to varying degrees. There is a lot to learn in the varied approaches followed in the process of rejuvenating this lake. Despite the problems, Hauz Khas lake still remains a haven for those who seek a moments peace in the fast-paced life of the capital city.



Map above shows the location of the Hauz Khas Lake, Vasant Kunj STP and check dams within the Sanjay Van. The circled portion has been expanded in the figure to the right

Box 7:

Hydrological Options for Revival

0.9 – 1.4 MLD treated effluent from Vasant Kunj STP was available as an inflow to the lake. This STP provides secondary treatment to raw sewage and the effluent water is available upstream of the Hauz and was thus considered a reliable source for filling the Hauz Khas lake.

Source - INTACH

Series of the 5 check dams inside the Sanjay Van through which the treated wastewater passes before entering the Hauz Khas Lake

1. Entry point of the treated wastewater into the Sanjay Van
2. Passage for the flow of treated wastewater within Sanjay Van
3. Water retained in the check dam before moving to the lake
4. Green colour water of the Hauz Khas Lake along with trees that have taken root along the sides of the lake. This vegetation multiplies the in-situ organic load through decay and leaf fall

5. Heritage Buildings surrounding the Hauz Khas Lake
6. Floating Wetland almost on the verge of drowning (inside Hauz Khas Lake)
7. Constructed Wetland arrangement at the entry point of water into the lake
8. Bio enzyme being dosed along the boundary of the lake

Key Interventions at Hauz Khas Lake

The following interventions were part of the Hauz Khas Lake Rejuvenation

Lake Recharge & **Wastewater Treatment** Interventions

- Diversion of storm water and treated wastewater through Sanjay Van (2002)
- Bio engineering of check dams in Sanjay Van by introduction of aquatic plants (2002)
- Installation of Floating aerators in Hauz Khas Lake (2002)
- Bacterial Bioremediation in Hauz Khas Lake (2002 until now)
- Installation of Floating wetlands in the Hauz Khas Lake (2017)
- Creation of planted gravel filter/constructed wetland arrangement at the primary inlets to the lake (2017)

Biodiversity Enhancement Interventions

- Introduction of fish species in the lake and the reservoirs inside Sanjay Van (2002)

Allied Interventions

- Concretisation of lake bed to prevent percolation losses (1968)

Box 8:

Bio engineering of **Check Dams**

There are five check dams inside Sanjay Van. The water stored behind the dams were populated with duckweeds (spirodella, lemna, wolffia and water hyacinth) which uptake the various organic pollutants through their root system and transfer oxygen to the waters, thereby reducing the organic load. The water is then conveyed through a system of pipes. The entire flow of water from the outlet of the STP to the Hauz Khas lake is via gravity

Source - INTACH

Hauz Khas Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Hauz Khas Lake

Parameter	**P1** Lagoon Inlet	**P2** Lagoon Outlet	**P3** Lake Inlet	**P4** Lake Periphery	**P5** Lake Periphery
Total suspended solids (mg/l)	112.0	87.0	101.0	85.0	109.0
BOD 3 days at 27˚C (mg/l)	340.0	215.0	35.0	130.0	244.0
COD (as O_2) (mg/l)	620.0	456.0	140.0	260.0	464.0
Total Phosphate (mg/l)	8.2	9.0	3.8	8.6	8.2
Ammonical Nitrogen (as N) (mg/l)	22.0	18.9	14.0	19.7	19.0

Date of sample collection – 25/02/2019[7]

Inference

1. There is a visible green algae layer in the entire lake that indicates eutrophication and unhealthy conditions. Relatively better organic concentration is observed near the inlet of the lake. This could be because of regular dosing of bioenzymes and flow of water through the constructed wetlands. However, at other locations, due to stagnancy and accumulation of organic content, high organic load is visible.
2. During the sample collection, the water was stagnant inside the lake as well as the inlets. Bio enzyme dosing can become ineffective in the absence of proper mixing and microbial colony formation can be hindered.
3. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the water quality does not even resemble Class E. Hauz Khas lake requires a lot of effort to improve its water quality.

7 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

Institutions Involved

The management and maintenance of the lake largely falls under the aegis of the Delhi Development Authority (DDA), who collaborated with INTACH and later Evolve Engineering to rejuvenate the lake. All the initiatives have been funded by the DDA.

Insights

Hauz Khas lake rejuvenation plan was implemented by INTACH. It undertook a detailed study in 2002 to get a comprehensive understanding of the problem. This has helped set precedence in the way water body rejuvenation can be approached. However, the sector has evolved over the years and different methods have been tried and tested. Improvisation of existing methods can be taken up as part of waterbody rejuvenation.

Floating wetlands were installed as one of the intervention strategies, but it did not survive long. There are other lakes which are showcased in this compendium where this low cost and simple technology intervention has functioned well. **Continuous monitoring and maintenance are essential to ensure that the treatment infrastructure is performing its intended purpose.**

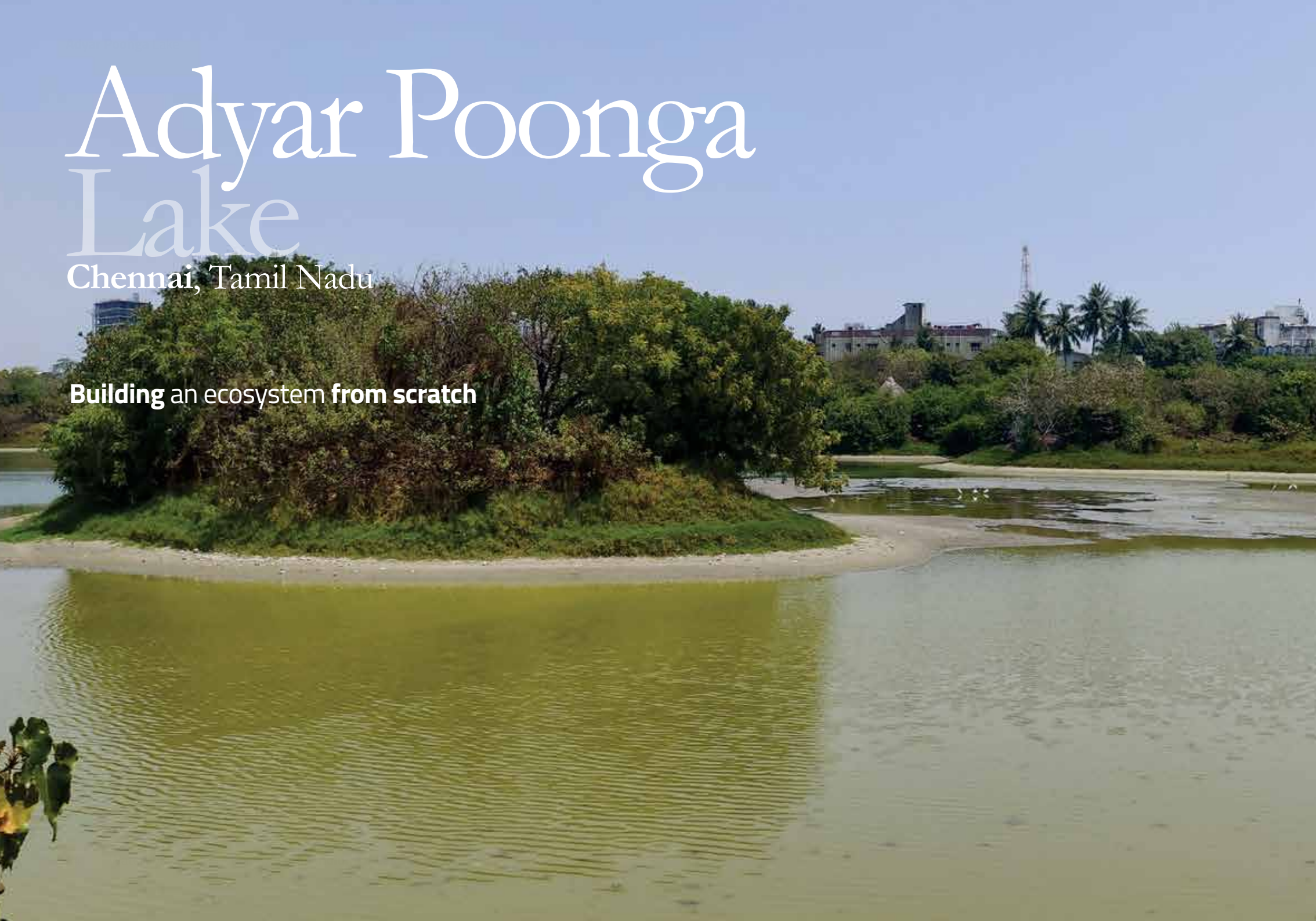
In Hauz Khas it is seen that despite treated water, flowing in through a series of check dams, it is contaminated when it enters the lake. This calls for ascertaining any leakages that leads to re-contamination of water. In the case of a possible re-contamination, the planted gravel filters might not be adequate to treat the high organic load in the incoming water. Additionally, bio-enzyme dosing when administered incorrectly in terms of dosage and frequency of application might not lead to any positive changes in the lake water quality. On the contrary, it might actually lead to deposition of more organic matter on the surface of the lake thereby worsening the situation. Moving forward it is to be considered that the **development of solutions need to be contextual and the implementation of the same needs to be done in a proper manner to justify the investment made for the purpose**.

Efforts towards rejuvenation of a water body will be defined by the purpose that people and authorities want to derive from it. The Hauz Khas lake still is a beacon of tranquillity for the residents of a bustling and busy South Delhi, but it is still a few miles away in its journey to being a healthy lake teeming with life and diversity.

Adyar Poonga Lake

Chennai, Tamil Nadu

Building an ecosystem **from scratch**



Adyar Poonga Lake

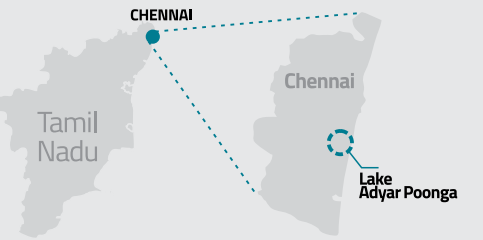
Chennai, Tamil Nadu

Building an ecosystem **from scratch**

Eco-restoration of Adyar Poonga (Tamil meaning – park) is a prime example of enterprising conservation action. It is a progressive effort that shows foresight and recognises the importance of protecting nature in the long run, and its direct impact on human survival. The custodians of this lake have weighed in their efforts to prioritize the long-term health of this estuarine ecosystem over its short term utility.

This 58-acre (234718 sq m) eco-park is a part of the larger Adyar Estuary (358 acres) and has been restored close to its pristine state by the Government of Tamil Nadu. The Adyar Poonga is part of a creek, where the freshwater contribution is coming from the Adyar River. The lake is central to the Adyar Eco-Park, which aims to demonstrate how a major city can rehabilitate its coastal ecosystems. It shows how cities can live in harmony with delicate estuarine environments by managing their interactions with the surroundings better.

Prior to the restoration, storm water from the surrounding areas filled the creek which functioned as a retention and infiltration pond and excess water overflowed into the estuary. The area also served as a reservoir for tidal waters during high tides and over time the creek began to be used as sewage and solid waste disposal point which caused degradation of the unique eco system.



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Total **Area**
58 acres
(2,34,718 sq m)

Total **Water Spread** Area
34 acres
(1,37,593 sq m)

Average Depth of Lake
6.5-10 feet
(2-3 m)

Catchment Area
Wastewater from **Mandaveli area**

Year of Intervention
2008

Cost in INR
Cap Ex **230 million**
Op Ex **20 million p.a.**

The entire Adyar Poonga is divided into 3 zones:

Zone 1

- This is essentially a storm water retention and infiltration zone. The Periphery of this area is composed of earth berms covered with tropical dry evergreen vegetation (TDEF) along with few freshwater ponds.

Zone 2

- This is a storm water discharge area, where the water from zone 1 overflows over a weir and reaches zone 2 and water from the major storm water inlet located in the North western portion of the Poonga opens up into zone 2.

  Zone 2 is planted with TDEF vegetation as well as mangroves. This zone 2 can be brackish during the high tides.

Zone 3

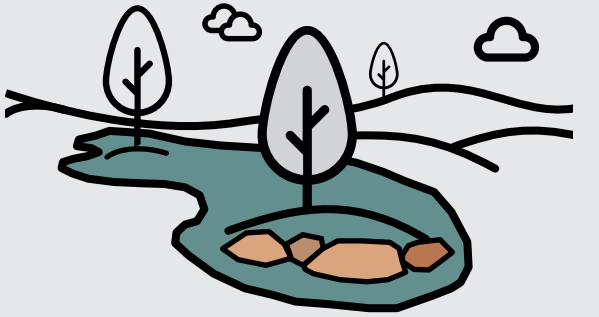
- This Zone is brackish and connected directly to the creek and estuary. Mudflats naturally occur in this zone. Mangroves have been planted here that improves the quality of the creek and estuary and create a safe haven for estuarine plant and animal species.

Key Interventions at Adyar Poonga

Following are some of the major interventions implemented for the restoration of Adyar Poonga.

1. Removal of debris and silt from the creek – 2.80 Lakh cum of accumulated sludge and debris was excavated from the creek. A part of the removed matter was used for landscaping and plantation activities.
2. An invasive plant Prosopis Julifera that exhausts the groundwater resources was completely removed from the restoration area.
3. Stormwater drains that were earlier channelizing sewage into the Adyar Creek area were diverted to the sewerage lines.
4. Portions of the earth excavated from the project area were utilized to create mounds around the waterbody, which support coastal vegetation such as intertidal plants like mangroves, mangrove associates, reeds and terrestrial plants.
5. 110,161 plants belonging to 172 species were planted to provide a green cover and typical vegetation of the Coromandel Coast surrounding the water bodies. 6 species of Mangroves have been planted, which are indigenous to the estuary and creek. Addition of flora also helped in the diversification of the faunal species.

Box 9:
Earth Berms

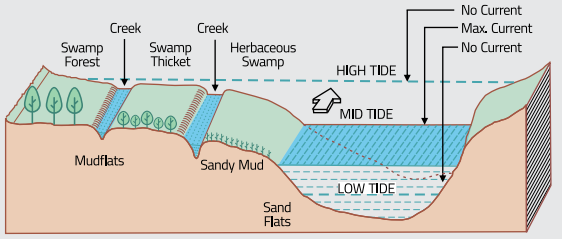


A berm is a simple way to add interest and height to a landscape, especially in a dull, flat area. Berms are simply mounded hills constructed for blocking out unwanted views, redirecting foot traffic or drainage or simply emphasizing a particular area or focal point.

Source - Tilley 2019

1. Zone 1 of Adyar Poonga which went dry for the first time in 10 years
2. Amphitheatre inside Adyar Poonga for conducting environment education programmes. Visiting school students are inducted on the basic principles of ecology, watershed rehabilitation, familiarization of the flora and fauna that are native to Chennai
3. Artificial islands for the faunal species (As on June 2012, 27 species of Fish, 10 species of Amphibians, 19 species of Reptiles, 90 species of Birds and 13 species of Mammals are recorded in Adyar Poonga)
4. Waterbody inside Adyar Poonga
5. Tropical dry evergreen vegetation along Zone 2

Box 10:
Mudflats



Mudflats refers to land near a waterbody that is regularly flooded by tides and is usually barren. Also known as tidal flats, mudflats are formed upon the deposition of mud by tide or rivers. Since most of the sedimented area of a mudflat is within the intertidal zone, the mudflat experiences submersion under water and is exposed twice daily. They attract a large number of migratory shorebirds and also house a number of species of crab, fish and molluscs which form the food base for migratory birds.

Mudflats protect the inland landforms from erosion and act as a barrier to waves from eroding land in the interior portions. Dredging for navigational requirements, domestic and chemical pollution are threatening the mudflat habitat. Further, global warming triggered sea level rise is submerging significant sections of these mudflats. The loss of these tidal flats will make coastal areas vulnerable to the forces of erosion and also floods.

Source - Nag 2017

Institutions involved

The erstwhile Adyar Poonga Trust, or Chennai Rivers Restoration Trust (CRRT) as it is known now was created to facilitate the development, maintenance and conservation of Eco-parks around this lake.

The Tamil Nadu Urban Infrastructure Financial Services Ltd., Chennai (TNUIFSL) was appointed by the Government of Tamil Nadu to plan and fund the initiative

The Pichandikulam Forest consultants, an offshoot of the Auroville Foundation, along with other consultants were responsible for creating a master plan for the Adyar Poonga restoration and Eco-park. They are also managing the eco-park under a contractual agreement with the government.

Future Plans

The project is currently in the second phase which has been dedicated to complete the restoration of the remaining 300 acres of the estuary. Future plans entail restoration of the river in Phase 3. CRRT has also prepared restoration plans for many of the water bodies that incudes creeks, estuaries, rivers, waterways, lakes and ponds in various parts of Tamil Nadu.

Insights

Estuarine ecosystems are very important natural spaces and in the recent past, anthropological actions have caused an imbalance in these systems. The complexity of fresh water interaction with estuarine ecosystems has been recognized and understood by the project developers. The **monitoring of human access** to the Poonga and the sharp focus on replanting native species has contributed to a healthier lake and increased biodiversity. These have come at significant financial costs and the impact makes one hopeful that the investment will be recovered.

Since the Poonga also serves as an **environmental education centre**, it serves as an important **node for instilling environmental consciousness** in young students.

The sustainability of this system lies in the understanding of the integration of the simplest components of these ecosystems. It is also to be understood that the revival of a waterbody does not merely mean the presence of water but also the **healthy interaction between aquatic and terrestrial ecosystems**.

The project has changed the way the impact of development activities on the natural environment is understood at the government level. The success of this project has influenced the interventions on other adjacent water bodies by setting an ethos for development planning that values integrity of the natural environments.

Herohalli Lake

Bengaluru, Karnataka

Terrestrial ecosystem assists rejuvenation

Herohalli Lake

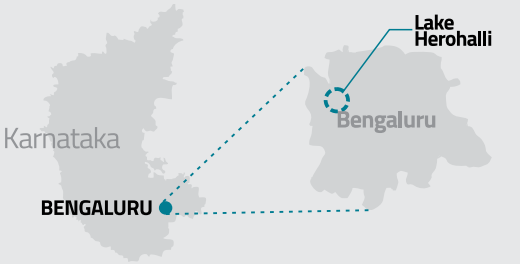
Bengaluru, Karnataka

Terrestrial ecosystem assists rejuvenation

Herohalli Lake is located on the western fringes of Bengaluru. Before the lake was restored in the year 2012, it was mostly dry in the summers; solid waste and wastewater from adjoining area created a murky puddle. Domestic sewage from independent households and chemical effluents from Peenya industrial area were the primary source of pollutants. Small dyeing industries in Peenya industrial area and Jalahalli released untreated effluents into the storm drains that were discharged into the lake.

Additionally, rapid urbanisation over the past decade put a huge strain on groundwater as bore wells were the only source of water in the area. With depletion of groundwater levels over a period of time, the lake became an important aspect for groundwater recharge. In this context, the BBMP decided to rejuvenate the lake. The aim was to ensure that the lake is full of water throughout the year that would subsequently increase the groundwater levels, improve the overall aesthetics of the lake and enhance biodiversity.

In Herohalli lake, a portion of the incoming wastewater is treated through a nature-based treatment system called Soil Biotechnology and the treated water is used to recharge the lake. This technology is based on a bio-conversion process where fundamental reactions like respiration, photosynthesis and mineral weathering take place in a filter media that houses micro and macro organisms which bring about the desired purification (*Vision Earthcare*). The system is purely aerobic in nature.



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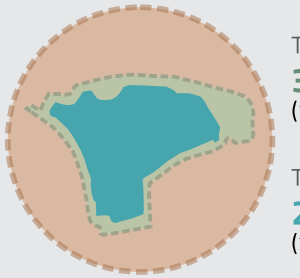


Total **Area**
33 acres
(1,33,546 sq m)

Total **Water Spread** Area
25 acres
(1,01,171 sq m)

Average Depth of Lake
n/a

Catchment Area
- Industrial wastewater from **Peenya and Jalahalli**
- Domestic wastewater from **Andarahalli, Mahadeshwara and Nagawara**

Year of Intervention
2012

Cost
Cap Ex 110 million
Op Ex 1 million p.a.

Key Interventions at Herohalli Lake

The following initiatives were implemented at the Herohalli Lake

Preparatory Interventions

- Removal of encroachments
- Boundary demarcation
- Fencing around the lake
- Creation and strengthening of the bund

Lake recharge & **wastewater treatment** Interventions

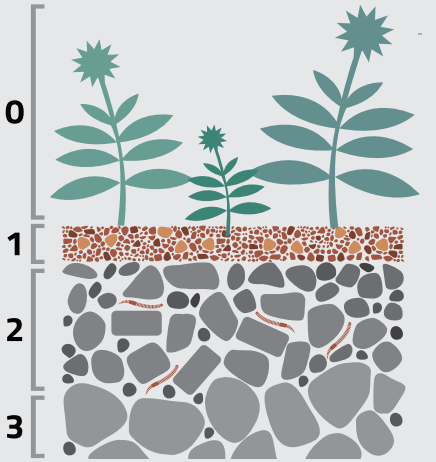
- Screening of solid waste at the inlet
- Demarcation of sedimentation basin zone
- Soil Biotechnology based wastewater treatment plant
- Diversion of industrial wastewater to prevent breakdown of the SBT system

Box 11:

Soil Bio Technology System at Herohalli Lake

Herohalli Lake has the CAMUS-SBT (Continuous Advanced Multistage system using Soil Bio Technology) system installed within the lake premises by the Mumbai based company Vision Earthcare.

1. Design Capacity – 1.5 MLD (upgradation to 1.8 MLD)
2. Source of Wastewater – Domestic wastewater flowing through open channels
3. Level of Treatment provided – Primary, Secondary and Tertiary



Depth of the Layer	Composition	Function
LAYER 0	Green Plant	Bioindication of the health of the system
LAYER 1	Gravel	Prevents soil erosion Traps grease
LAYER 2	Crushed laterite rock Soil Clay brick Earthworms Active bacterial culture	Biodegradation of organic matter in wastewater Aeration Filtration Increase of retention period for treatment
LAYER 3	Boulders	Facilitates the drainage of treated water

1. Solid Waste screening arrangement for incoming wastewater and stormwater
2. Boundary between the wetland and the lake along with screens for preventing solid waste from entering the lake
3. Additional equalisation tank under construction for upgradation of plant capacity
4. Treated water sample
5. Visible portion of the Bio Reactor – SBT System
6. Artificial bird Island

Herohalli Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Herohalli Lake

Parameter	P1 Inlet Drain 1	P2 Inlet Drain 2	P3 Pre-Treatment	P4 SBT	P5 Outlet of SBT
pH	7.4	7.5	7.0	7.0	6.9
Temperature (°C)	24.7	22.8	23.0	23.0	23.1
Electrical Conductivity (µS/cm)	1300	1500	1900	1700	1700
Total Dissolved Solids (ppm)	900	1000	1100	1100	1100
Suspended Solids (mg/l)	419	515	245	17	17
Turbidity (NTU)	233	288	209	10	10
Biochemical Oxygen Demand (mg/l)	380	440	180	30	28
Chemical Oxygen Demand (mg/l)	653	745	306	52	62
Phosphate as PO_4 (mg/l)	18.7	22.3	35.1	2.5	1.9
Ammonia as NH_3-N (mg/l)	29.2	31.0	65.1	20.8	20.2
E. coli (MPN/100 ml)	21000	9300	21000	Nil	Nil
Alkalinity as $CaCO_3$ (mg/l)	500	550	700	600	500

Date of sample collection – 15/03/2019[8]

Inference

1. The analysis results show that both the inlets are carrying high strength wastewater.
2. SBT has been designed for the removal of both organics and nutrients. The system records more than 80% removal of organics. Removal of the phosphate stands at 94% while that for nitrates stands at 69%. This suggests that oxygen requirement of nitrates is not sufficient for its removal.
3. Lake water sample was unavailable due to accessibility issues.

8 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

Institutions Involved

Herohalli lake rejuvenation work was led by BBMP. The treatment plant is designed and implemented by Vision Earthcare who has an annual maintenance contract with BBMP to manage the treatment plant. A separate contract for lake management (upkeep of the plants, walking track and all infrastructure within the lake premises) is awarded to a local contractor.

Future Plans

The STP is built to handle 1.5 MLD of wastewater. It is being up graded to 1.8 MLD for which an additional equalization tank in under construction.

Insights

Adoption of a nature-based treatment system over a conventional treatment shows the inclination of the government authorities to implement new technologies. One possible reason for this shift could be the risks associated with operations of conventional technologies along with the high capital and operational expenditure.

The quality of wastewater generated from the urban catchment is a challenge as it not only contains domestic but also industrial effluents that are chemically more complex to treat. **Nature based treatment plants have their own limitations in treating industrial effluents.** The case of Herohalli clearly demonstrates that having an SBT Treatment system as a final solution might not be adequate and appropriate for treatment of industrial effluents. Additional measures of regulating industrial effluent discharge at source and ensuring its **compliance by industries** would be required.

An additional treatment mechanism in the form of sedimentation basin has been left completely unutilized. Conversion of sedimentation basin into a well designed constructed wetland with plantation of proper plants can help leverage the treatment potential of this space. Wetlands are natural, low-cost, effective and easy to operate treatment systems. Integration of this space with the existing treatment infrastructure can go a long way in increasing the overall quantity of wastewater treated.

The separate maintenance of the lake premises and the treatment system is economically and logistically sub-optimal. For a public infrastructure spread across an area of 33 acres, it is logical to have a single entity manage the lake premise and wastewater treatment infrastructure. Moving forward two levels of integration is called for. The first one being the **integration of new and existing infrastructure and the second one of lake operation and maintenance with that of the treatment plant**. This will help ensure the overall health of the lake ecosystem.

Jakkur Lake

Bengaluru, Karnataka

Reimagining the **sustainability** of a lake

To conserve a lake, people need to connect with the lake. Jakkur Lake is an example of collaborative efforts of the civic agencies, citizens, corporates, educational Institutions and the locals.

- Dr Annapurna Kamath (Jalposhan Trust)

Jakkur Lake

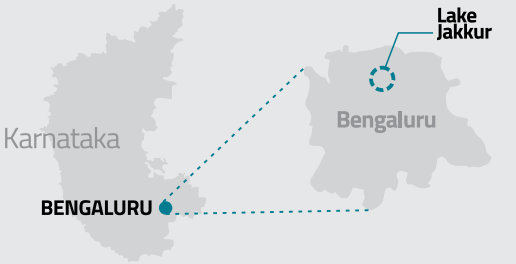
Bengaluru, Karnataka

Reimagining the **sustainability** of a lake

Jakkur Lake is an example of collective action – the implementation of a node for social and scientific innovation to help improve the lake ecosystem and social relations among stakeholders.

Jakkur Lake is one of the largest lakes in the grid of man-made lakes in the city and is located in the north eastern part of Bengaluru. Unplanned development in the area surrounding the lake had led to solid waste filling its feeder channels. This choked the natural watershed so much that the lake resembled a dumping yard.

Jakkur Lake interestingly has a very well designed wetland system. According to the USEPA, a wetland is a complex assemblage of water, substrate, plants (vascular and algae), litter (primarily fallen plant material), invertebrates and an array of micro-organisms (most importantly bacteria).



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Total **Area**
160 acres
(6,47,497 sq m)

Total **Water Spread** Area
139 acres
(5,62,513 sq m)

Average Depth of Lake
9.8 feet
(3 m)

Catchment Area

- Domestic wastewater and stormwater runoff from **Tirumunahalli, Agrahara, Chobandanahalli, Attur, Puttenahalli, Allasandra, Yelahanka, Kogilu**
- Treated wastewater from **Jakkur STP**

Years of Intervention
2008 & **2014**

Cost in INR
Cap Ex **210 million**
Op Ex **2.4 million p.a.**

Key Interventions at Jakkur Lake

The following initiatives were completed in the case of Jakkur Lake at various points in time.

Preparatory Interventions

- Desilting
- Dewatering
- Construction of bunds and pathways
- Boundary demarcation and fencing of the lake.

Lake recharge & **wastewater treatment** Interventions

- Creation of Constructed Wetland System
- Diversion of treated wastewater from Jakkur STP through Constructed Wetlands into the lake
- Construction of Sedimentation Trap

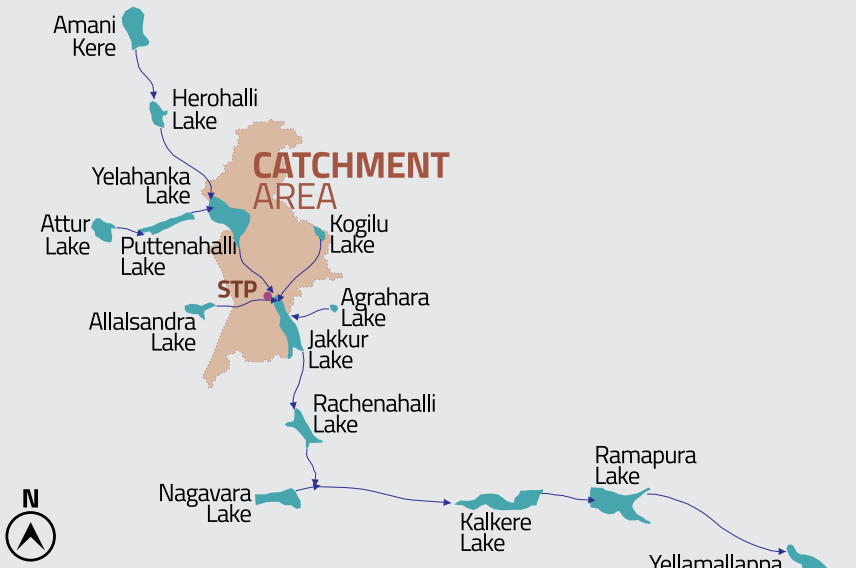
Biodiversity Enhancement Interventions

- *Vanmahotsav* for tree plantation and increasing the interaction of the residents with the lake
- Bird Watching and Tree Tagging
- Bifurcation of community and conservation zone within the lake premises

Allied Interventions

- Harvesting of plants in the constructed wetland

Box 12:
Jakkur and the **Yellamallappa Shetty Lake Series**



YELLAMALLAPPA SHETTY LAKE SERIES

Jakkur Lake receives water from the eastern, western and northern side.

- Eastern Side
  The water flows in through Tirumunahalli, Agrahara and then Chobandanahalli and finally enters the Jakkur Lake
- Western Side
  The water flows in through the Shivanahalli Lake
- Northern Side
  Water flows in through Attur, Puttenahalli, Allasandra, Yelahanka, Kogilu and then finally into Jakkur.
- Outlet
  The overflow from Jakkur Lake feeds the downstream lake of Rachenahalli and Nagawara Lake.

1. Jakkur Lake
2. Sediment Trap near the eastern Inlet
3. Eastern Inlet - The water flows in through Tirumunahalli, Agrahara and then Chobandanahalli and finally enters the Jakkur Lake
4. Constructed wetlands that were earlier part of the tertiary treatment of water from the STP. Currently the STP treats the water upto the tertiary level and releases into the lake. The CW continue to treat the raw wastewater that enters the lake from another inlet
5. Outlet of Jakkur Lake
6. Treated wastewater from the Jakkur STP entering the lake. Earlier 10 MLD of secondary treated wastewater was released into the lake through the constructed wetlands. At present due to recent upgradation, 15 MLD tertiary treated water is released.
7. Treated Wastewater along with raw sewage is channelized into the constructed wetlands from the northern side

Jakkur Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Jakkur Lake

Parameter	**P1** Northern Inlet	**P2** STP Outlet	**P3** Lake	**P4** Outlet
pH	7.0	7.2	9.4	9.5
Temperature (°C)	23.4	27.2	23.1	23.1
Electrical Conductivity (µS/cm)	2000	1200	1100	1100
Total Dissolved Solids (ppm)	1500	900	800	900
Turbidity (NTU)	-	4.78	288	79.9
Biochemical Oxygen Demand (mg/l)	1500	2	20	10
Chemical Oxygen Demand (mg/l)	2780	27	163	87
Phosphate as PO_4 (mg/l)	2200	13.7	3.7	2.3
Ammonia as NH_3-N (mg/l)	600	0.1	1.1	0.7
E. coli (MPN/100ml)	1500	30	10	9

Date of sample collection – 31/12/2018[9]

Inference

1. The treated water being discharged from the STP to the lake is meeting CPCB's treated effluent discharge standards.
2. At present the wetlands are performing very well in the removal of organics and nutrients. There is more than 98% removal of organics and nutrients by the time the water reaches the lake.
3. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS E of the designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.
4. If seen another way, raw sewage is getting diluted with the treated wastewater and the remaining treatment is then taking place in the constructed wetlands.

9 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

Institutions Involved

Multiple organisations have been involved in the journey of restoring this lake. Jakkur Lake was originally under the Lake Development Authority. In 2008, all rejuvenation works were handed over to the Bangalore Development Authority when all the major interventions took place. Moving forward, the custody went to BBMP and currently rests with them. An MoU was signed with Jalposhan Trust to take over the maintenance of the lake.

Additionally, the Karnataka State Pollution Control Board (KSPCB) regularly monitors the water quality of the lake. This is supplemented by the Indian Institute of Sciences and Ashoka Trust for Research in Ecology and the Environment who also do the same for research and development purposes. Biome has actively supported the lake rejuvenation work.

Fisheries department by way of release of tender for fishing continues to be involved in the overall management of the lake. Forest department is continuously involved as they support Jalposhan Trust by providing them with native plant species and structured removal of invasive species.

Future Plans

The project is ongoing, developments like outdoor fitness stations, children's park using recycled material, better walkways and more seats are still in the pipeline. There is also an imminent threat to the lake as the water from the STP in Jakkur will be diverted to a new power plant in Yelahanka in the near future. Jakkur STP of 10 MLD capacity was earlier treating water up to the secondary level and releasing it into the lake. Currently the plant has been upgraded to treat 15 MLD of wastewater (2018) to treat water up to the tertiary level. Currently all the 15 MLD tertiary treated water is coming to the Jakkur Lake which in turn also sustains the downstream lakes of Rachenahalli and Nagawara. But the diversion of tertiary treated water for use by the thermal power plant, will threaten the existence of these 3 lakes.

Insights

The first attempt to rejuvenate the lake failed because the community continued to litter the lake and its vicinity and there was no sense of ownership. This changed when Satya Foundation and Jalposhan Trust got involved. **Involving the community** through a month-long tree plantation drive was the beginning of a relationship between the lake and the people. The reliance on corporate volunteers alone for maintenance of the lake will reduce the sense of ownership and responsibility for the lake among the locals and will have negative implication on the health of the lake. Jalposhan Trust, realising this, involved a self-help group giving job opportunities to the economically weaker women in the community, thereby benefitting the lake's maintenance – both economically and socially. Moving forward, these methods and variations in the way community is involved will be beneficial for mobilising such groups for other lakes that need rejuvenation.

Simple landscaping solutions like bifurcating the zones for community use and biodiversity conservation; and propagating the plantation of native plant varieties along with **maintaining a comprehensive record of bird species are good practices** being implemented at Jakkur Lake. In addition to research organisations conducting tests to collect data about the lake's water quality local fishermen have also developed their own tacit understanding and observational indicators through which they are able to ascertain the health of the lake. These simple thoughtful measures can in the long run be incorporated in lake rejuvenation measures.

The constructed wetland is a suitable method for treatment of a mix of secondary and tertiary treated wastewater. These are natural and robust systems and are capable of taking shock loads. But with the diversion and channelling of Jakkur STP's treated water to the thermal power plant in Yelahanka, the lake's only steady source of water will be robbed and there will be reduction in dilution and a simultaneous increase in the treatment pressure on the constructed wetlands. In this scenario, there is a possibility that the quality of the lake will be compromised. The future of the lake looks uncertain unless an alternate source of water is explored. Preservation of the Jakkur lake ecosystem is critical for preservation of the downstream lakes

Mansagar Lake

Jaipur, Rajasthan

Balancing the needs of **tourism** and **nature**

Mansagar Lake

Jaipur, Rajasthan

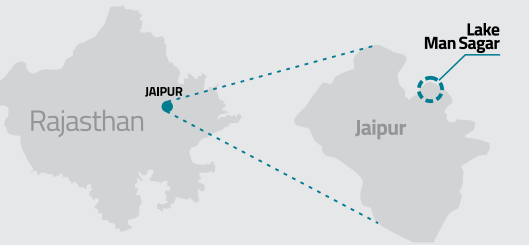
Balancing the needs of **tourism** and **nature**

The integration of landscapes with water can capture anyone's attention and imagination. The Jal Mahal surrounded by the Mansagar Lake does this particularly well. Restoring such an ecosystem implies additional responsibility and complexity of a steady stream of tourists thronging the historical site, though the environmental system that supports the Mansagar Lake is actually much larger in area than the tourist premises.

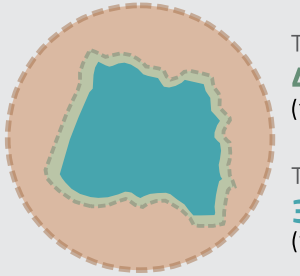
Mansagar Lake is a man-made lake commissioned by Maharaja Mansingh I, by impounding River Drabhavati and Nagatalai drain by constructing a dam in the year 1610. The lake deteriorated as the city of Jaipur grew, the situation worsened when Jaipur administration diverted the city's sewage to the lake through the Brahmapuri and Nagtalai drains.

Water hyacinth flourished and invaded the lake's natural flora, thus destroying aquatic life in the waterbody. Eventually migratory birds stopped visiting the lake. The lake bed got filled with silt from soil erosion and sewage sludge, resulting in further eutrophication that choked the lake.

Mansagar Lake had been extremely vulnerable to the urbanization and tourism pressure. The Lake was ecologically restored under the National Lake Conservation Plan (NLCP) in December 2002 at a cost of Rs. 24.72 Crore with a 70:30 funding pattern between the Central and the State Government.



SALIENT FEATURES



Total **Area**
432 acres
(1.74 sq km)

Total **Water Spread** Area
300 acres
(1.21 sq km)

Average Depth of Lake
5-15 ft
(1.4-4.5 m)

Catchment Area

- Wastewater from the **older portion of Jaipur City 23.5 sq km**
- Stormwater runoff from the adjacent **hills of Nahargarh and Amargarh**

Year of Intervention
2002

Cost in INR
Cap Ex **247.2 million**
Op Ex **n/a**

Key Interventions at Mansagar Lake

Spearheaded by the Jaipur Development Authority, the following interventions were done as part of the ecological restoration of Mansagar Lake.

Preparatory Interventions

- Manual deweeding
- Mechanised dredging
- Realignment of drains
- Construction of a sedimentation basin

Biodiversity Enhancement Interventions

- Creation of nesting Islands for residential and migratory birds
- Afforestation

Allied Interventions

- Creation of Lake Front Promenade and walking track

Lake Recharge & **Wastewater Treatment** Interventions

- Construction of a 27 MLD STP that can treat wastewater up to the secondary level.
- Construction of a 7 MLD Tertiary Treatment Plant (TTP)
- Construction of contour trenches and dykes
- Construction of loose rubble check dams
- Constructed Wetlands
- Diffusors for aeration

Box 13:

Current Status of Treatment Infrastructure

The 27 MLD STP and 7 MLD TTP are currently non-functional leading to the drying up of the constructed wetlands. All the sewage has now been diverted to a 50 MLD STP run by the Jaipur Nagar Nigam (JNN). Simultaneously refurbishment of the 27 MLD STP into an 8 MLD STP is underway. Once completed, 8 MLD of sewage will be trapped for treatment and released into the Mansagar Lake, while the rest will continue to be bypassed to the 50 MLD STP.

Box 14:

Catchment Area Treatment

Catchment Area Treatment is a term used to describe the process of implementing land use practices and water management practices to protect and improve the quality of the water and other natural resources within a watershed by managing the use of those land and water resources in a comprehensive manner.

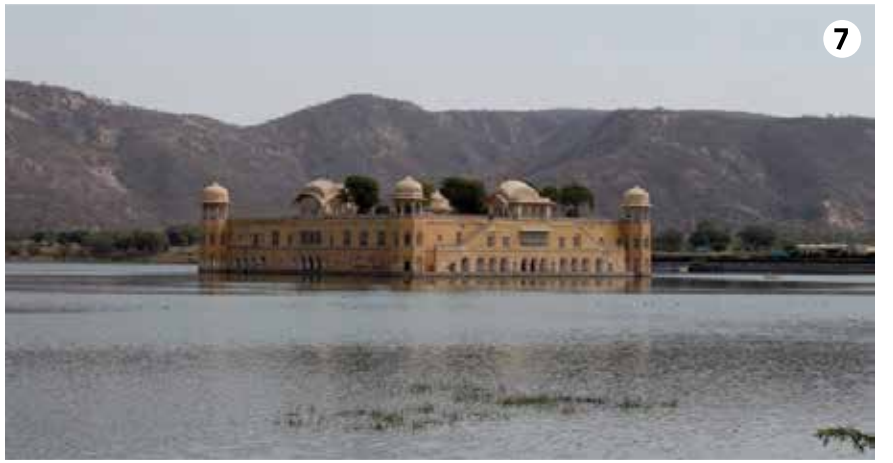
This approach was done for the Rejuvenation of Mansagar to control the amount of silt into the lake.

Jaipur Development Authority (JDA) with the support of the State Forest Department worked to improve the lake catchment falling in the Nahargarh Hill area. Loose rubble check dams along with trenches and dikes along with afforestation were done as part of this process.

Box 15:

National Lake Conservation Plan (NLCP)

NLCP was a centrally sponsored scheme aiming to restore and conserve the urban and semi urban lakes of India degraded due to wastewater discharge into the lake through an integrated ecosystem approach. The scheme was launched in the year 2002 by the then Ministry of Environment & Forests.



1. 27 MLD STP being refurbished into a 8MLD SBR Technology STP
2. Sewage trapping arrangement in progress. This area will be used to trap 8 MLD of sewage for treatment and the remaining will be bypassed to the 50 MLD STP
3. Non-functional 7 MLD TTP
4. Constructed Wetlands that have dried up as there is no treated wastewater flowing through them
5. Wastewater continues to enter the lake through 4 stormwater drains in the urban catchment - Police Line, CID Line, Hotel Trident Line, Gujar Ghati Inlet
6. Lake Promenade
7. Jal Mahal, Mansagar Lake

Mansagar Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Mansagar Lake

Parameter	**P1** Police Line/ Jaipur Golden Wastewater Inlet	**P2** CID Line Wastewater Inlet	**P3** Hotel Trident Line Wastewater Inlet	**P4** Gujar Ghati Line Wastewater Inlet	**P5** Lake	**P6** Lake
Total suspended solids (mg/l)	180	142	1878	156	64	58
Chemical oxygen demand (mg/l)	418.40	318.72	486.93	341.48	88.53	79.68
Bio chemical oxygen demand (mg/l)	108.40	82.80	126.50	88.70	23.10	20.70
Phosphate (as PO_3) (mg/l)	2.56	2.13	4.72	3.02	1.62	1.54
Ammonia (as NH_3) (mg/l)	14.93	13.70	24.24	16.09	10.96	9.60

Date of sample collection – 04/03/2019[10]

Inference

1. All the storm water inlets to the lake are carrying low to medium strength wastewater indicating contamination along the drains.
2. Aeration as a standalone treatment mechanism is helping reduce the organic content by approximately 78%.
3. High ammonia and phosphate concentration indicate eutrophic conditions in the lake.
4. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS E of the designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.

Institutions Involved

Mansagar Lake Rejuvenation was a joint effort by the Jaipur Development Authority and the Jaipur Nagar Nigam through the centrally sponsored National Lake Conservation Programme. Given the nature and characteristics of the project, a Public Private Partnership (PPP) model was considered desirable for the sustenance of lake maintenance. Through a bidding process, a Mumbai based group named Kothari Group was awarded the maintenance. Hence the Jal Mahal Resorts Private limited was formed and was responsible

10 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

for developing the newly reclaimed 100-acre land for tourism on a lease for 99 years. Post a Public interest Litigation (PIL) raised in the Rajasthan High Court, the case is sub-judice.

At present, the maintenance of the lake is taken care by the JDA while the lake front and the STPs are managed by JNN.

Future Plans

The Jaipur Nagar Nigam is remodeling the 27 MLD STP to an 8 MLD SBR based treatment plant which will treat just enough water that is required to ensure water in the lake. Until the treatment plant is ready the wastewater is being bypassed to the 50 MLD STP.

Insights

Approximately 18 years back, the rejuvenation of Mansagar Lake set the governments intentions for the holistic management of water bodies in India. The principles of National Lake Conservation Plan have been well integrated into the rejuvenation plan for Mansagar.

The design capacity for the refurbished treatment plant is in alignment with the water requirement of the lake. in addition to this, the lake can accommodate storm water runoff. Designing treatment systems to recharge the lake should ideally take these factors into consideration as lakes can act as an important infrastructure to offset high intensity rainfall events in a city.

However, we do see that with the passage of time some key treatment infrastructure has been abandoned namely the tertiary treatment plant and the constructed wetlands. **Integrating elements of the existing infrastructure with new ones help in capacity augmentation and cost reduction.** Revival of the constructed wetlands in Mansagar can ease the load of the upcoming STP. Moving forward, the importance of old and new infrastructure integration needs to be reinforced.

A key intervention in the rejuvenation of Mansagar lake has been manual deweeding as against mechanical or chemical deweeding. Mechanical measures are expensive, biological measures are time consuming and chemical measures are very sensitive and need to be done under supervision. On the other hand, **manual deweeding is labour intensive but a more sustainable practice**. This practice has been adopted in many lake rejuvenation activities by mobilising the support of volunteers thereby helping build a strong connect with the waterbody.

Mansagar lake has a diverse catchment where a significant 60% lies in the hills of Nahargarh, Amer and Amargarh. Another major component of rejuvenation has been catchment area treatment which is essentially a land use and water management practice to protect and improve the quality of water. Implementation of check dams, trenches coupled with afforestation helped in slowing down the velocity of water and reduced the incoming silt. Moving forward, we see that most lakes have a more dense urban residential catchment, in which case the strategies for managing wastewater and stormwater will need careful investigation.

Mansagar Lake is a significant tourism destination in its own right and as such demands careful management and planning not only to retain its physical integrity but also to ensure the quality of the experience of the visitors.

Pichola & Fatehsagar Lake

Udaipur, Rajasthan

Supporting the **growth** of an **urban agglomeration**

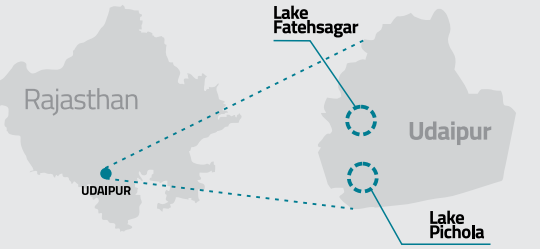
Pichola & Fatehsagar Lake

Udaipur, Rajasthan

Supporting the **growth** of an **urban agglomeration**

Urban infrastructure for water supply, treatment and reuse requires governments to integrate various elements and entities. Udaipur is a city that manages its age-old water systems with modern technological inputs, as it tries to meet the demand to provide water for citizens' drinking water needs, tourism activities and for industrial requirements. Both the Urban Improvement Trust and the Udaipur Municipal Corporation are dealing with complex issues which require significant investment to ensure efficient distribution of the limited water supplies and effective disposal and reuse of water borne waste.

Udaipur's lake system emerges from the River Berach and River Ayad, one of its primary tributaries cutting across the city. Downstream of Berach, there is a formation of two gigantic lakes Lake Pichola and Lake Fatehsagar. There are two large lakes namely Udaisagar and Bari Lake. Located a little outside the city is the Rajsamand and Jaisamand Lake. Udaipur's lake system fulfils its ground water recharge, drinking and tourism requirements.



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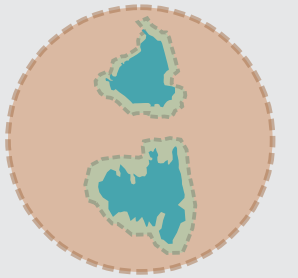


Lake **Pichola**	Lake **Fatehsagar**
Total **Water Spread** Area	
1719.85 acres (6.96 sq km)	**617.76 acres** (2.5 sq km)
Average Depth of Lake	
34.4 ft (10.5 m)	**36-43 ft** (11-13 m)

Catchment Area

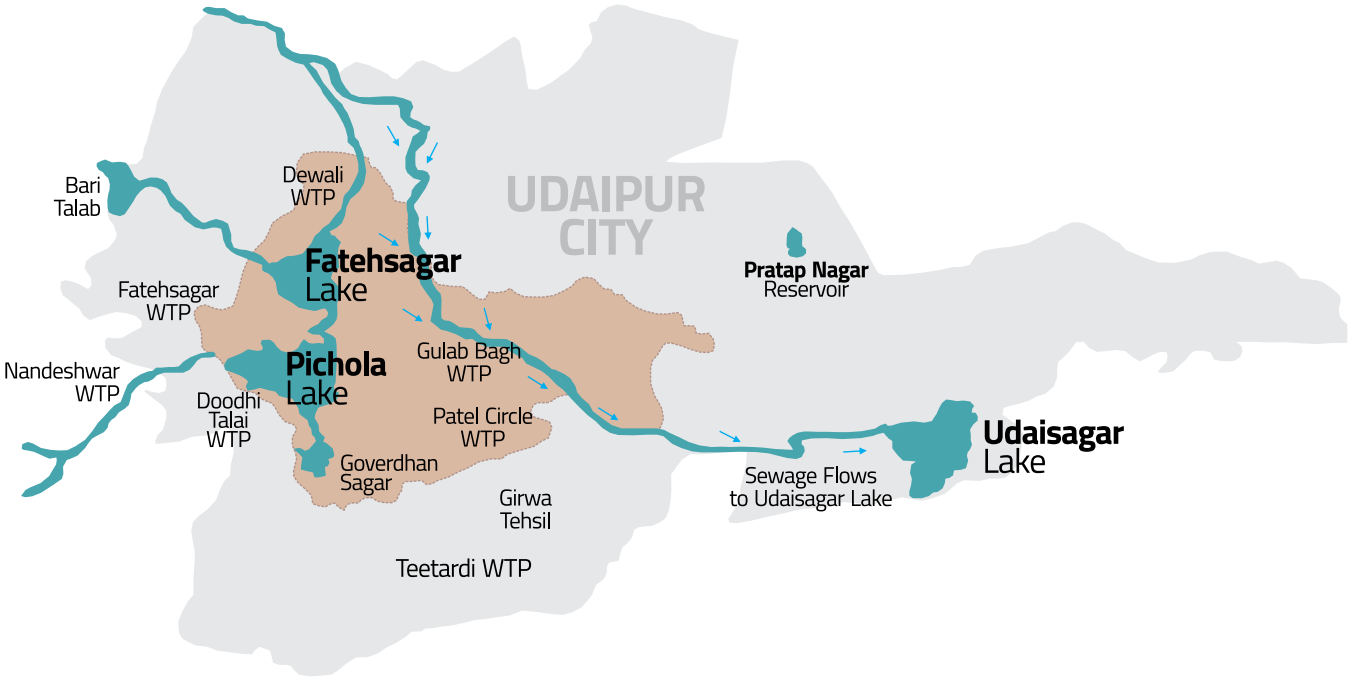
Rainwater and stormwater runoff from **Udaipur City and adjacent villages**

Years of Intervention

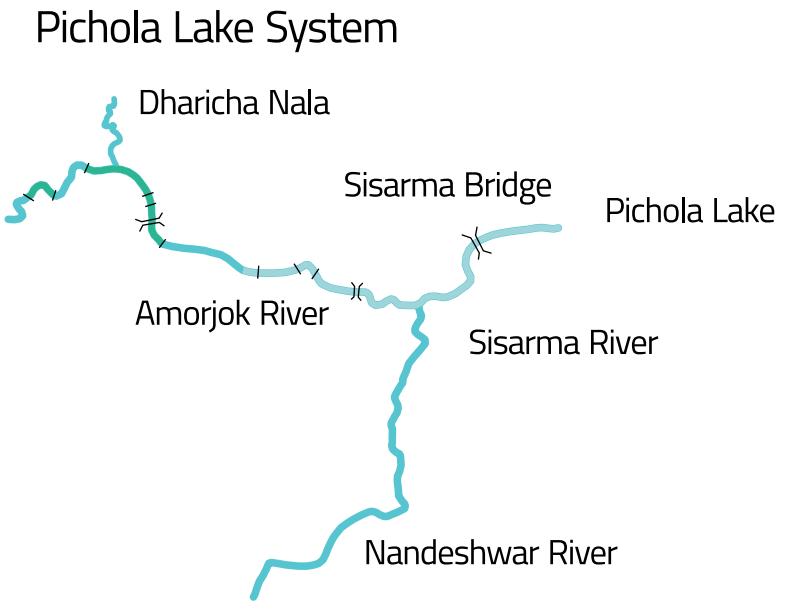
2008-15

Cost in INR

Cap Ex **254.2 million**	Cap Ex **418.6 million**
Op Ex **n/a**	Op Ex **n/a**



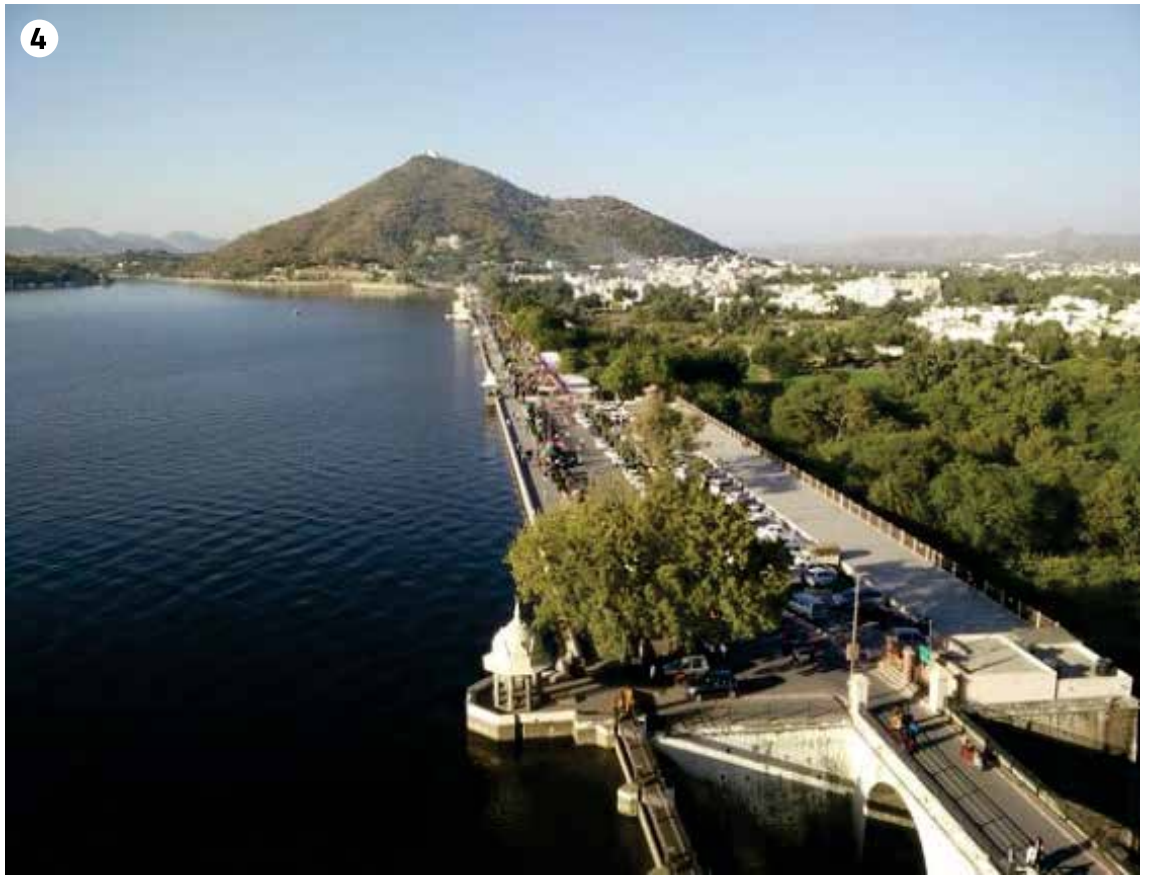
Udaipur Lake System

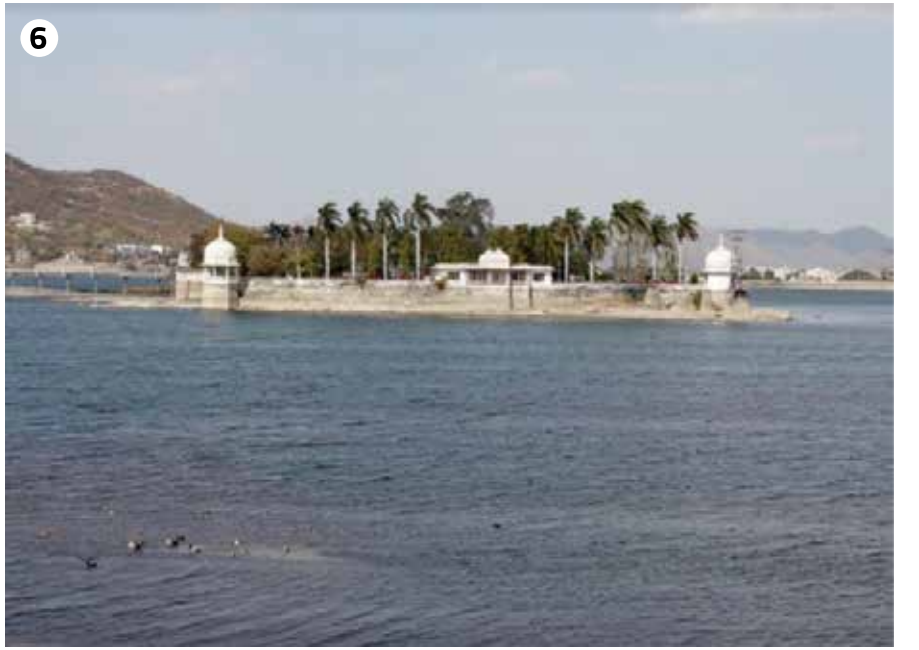


Pichola Lake System

Various works were implemented for the hydraulic improvement of inflow channels. Green lines indicate works related to deepening, widening and reshaping of inflow channels while the yellow lines mark the locations for the construction of retaining walls

1. Screens for separating the solid waste that flow with the stormwater runoff and wastewater. The screens are cleared on a regular basis
2. These wastewater systems are intermediary wastewater treatment systems where it is retained for some time before it is released into the trunk line of the underground drainage system
3. MBBR Sewage Treatment system that sends the treated wastewater to Hindustan Zinc Limited (www.uitudaipur.org/uitweb/div2_proj_cmplt1.php)





4. Lake front development work executed at Fatehsagar Lake
   Link - https://media-cdn.tripadvisor.com/media/photo-s/0e/04/a4/4c/view-of-fateh-sagar-lake.jpg
5. Pichola Lake with the iconic Jag Mandir
6. Fatehsagar Lake

Key Interventions at Pichola & Fatehsagar Lake

Following are the key interventions done to rejuvenate both the lakes:

Preparatory Interventions

- Deweeding and desilting

Lake recharge & **wastewater treatment** Interventions

- Interception and treatment of Sewage
- Catchment area treatment
- Hydraulic improvement of feeders and Inlets

Allied Interventions

- Solid Waste Management
- Shoreline Development
- Public Awareness

Box 16:

Udaipur and its sewage treatment infrastructure

Udaipur city has an underground drainage system and sewage treatment plant to manage all the wastewater generated. There are 2 sewage treatment plants of capacity 20 MLD and 25 MLD running on the Moving Bed Bio Reactor (MBBR) technology.

Wastewater is treated up to the tertiary level and then reused for process application inside the Hindustan Zinc Industrial Complex which is linked to the STP through a 78 kms pipeline. The remaining is used for recharge of the Ayad River. This wastewater was earlier contaminating Pichola, Udaisagar and Ayad river.

Pichola & Fatehsagar Lakes **satellite map**

Lake Water Quality

Following is the water quality analysis for Pichola and Fatehsagar Lake

Parameter	**P1** Fatehsagar Lake	**P2** Fatehsagar Lake	**P3** Pichola Lake	**P4** Pichola Lake
Total suspended solids (mg/l)	40	36	48	38
Bio chemical oxygen demand (mg/l)	2.18	2.04	2.06	2.10
Chemical oxygen demand (mg/l)	8.12	7.84	7.95	7.96
Phosphate (as PO_3) (mg/l)	Not Detected	Not Detected	Not Detected	Not Detected
Ammonia (as NH_3) (mg/l)	5.28	5.45	4.35	4.73
Dissolved oxygen (mg/l)	7.4	7.5	7.5	7.3

Date of sample collection – 01/03/2019[11]

Inference

1. There is a small concentration of ammonia at all the sites which is an indicator of either some form of wastewater or agricultural runoff entering these sites.
2. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS B of the designated best use classification system which makes it fit for the purpose of outdoor bathing.

Institutions Involved

Lake Pichola and Fatehsagar were rejuvenated under the National Lake Conservation Plan sanctioned by the erstwhile Ministry of Environment and Forests. Urban Improvement Trust (UIT) spearheaded all the work. At present the maintenance of Lake Pichola is with the Urban Improvement Trust while that of Fatehsagar is with the Udaipur Nagar Nigam. The overall sewerage network work is also being managed by UIT. However, the sewage treatment plant is owned, was constructed and is being maintained by Hindustan Zinc through third party vendors.

11 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

Insights

Pichola and Fatehsagar Lake are huge manmade lakes that are interconnected. The catchment for both the lakes is a mix of dense residential and open rural areas.

When UIT pursued the rejuvenation, significant focus was on hydraulic improvement of inflow channels at the catchment scale to mitigate the impact of excessive stormwater runoff. Additionally, the construction of retaining walls helped in controlling soil erosion and prevented them from joining the inflow channels. For lakes with catchment characteristics similar to Pichola and Fatehsagar, these **hydraulic improvement measures can be considered for rejuvenation based on the size of the lake, large number of inlets and diversity in LULC (land use/ land cover) in the catchment**.

The underground drainage system and sewage treatment facility covering the city has had a crucial impact on the water quality improvement in both the lakes. Wastewater that was earlier diverted into the lake is now being treated up to the tertiary level and is being reused for industrial purposes. The lake water is pumped for drinking purposes and the space around the lake is used for recreation. Though this system is invariably investment and water intensive, it is serving multiple purposes and has been designed for long term usage. However, considering the increasing water and fund scarcity in addition to institutional inefficiencies, implementing such a system moving forward will be a big challenge.

These interventions aimed to address issues of water security, public health and socio-economic development for the city of Udaipur. The intervention design for these lakes relies on the principle of safe and sufficient water being an essential resource for the growth and prosperity of an urban agglomeration. Udaipur and its lakes present a great example of how to integrate water resources into city planning without impeding its development potential.

Agara Lake

Bengaluru, Karnataka

A lake **thrives** amidst **institutional gridlock**

Agara Lake

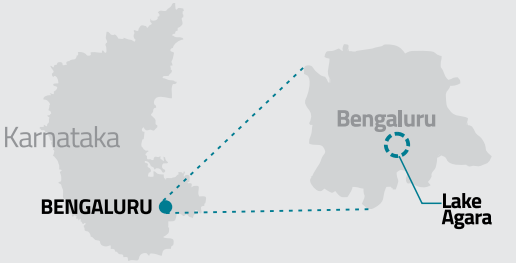
Bengaluru, Karnataka

A lake **thrives** amidst **institutional gridlock**

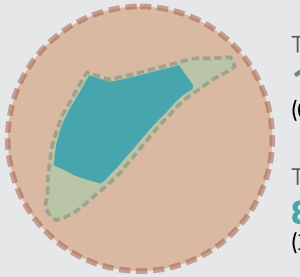
Agara Lake is a part of the Varthur lake series near Hosur Sarjapur Road (HSR) Layout in Bengaluru. The primary source of water is from the surrounding urban catchment and surface discharge from Madivala lake located in the upstream of Agara Lake.

Like majority of the lakes in Bengaluru, this lake was also polluted with sewage and solid waste until recently. The lake was covered with hyacinths that choked the lake and gave it a bad reputation because of the foul smell it emitted. But with the involvement of multiple institutions across the years the lake has been rejuvenated.

Agara Lake is part of the Varthur Lake series. Lakes are linked to each other through drainage networks and thus form a series. These drainage networks were deigned to help water flow from higher to lower elevations.



SALIENT FEATURES



Total **Area**
149.73 acres
(6,05,935.81 sq m)

Total **Water Spread** Area
80 acres
(3,23,749 sq m)

Average Depth of Lake
6.5-9.8 ft
(2-3 m)

Catchment Area
- Surface runoff from **Sarakki, HSR Layout, and Madivala**
- Overflow from **Madivala Lake**

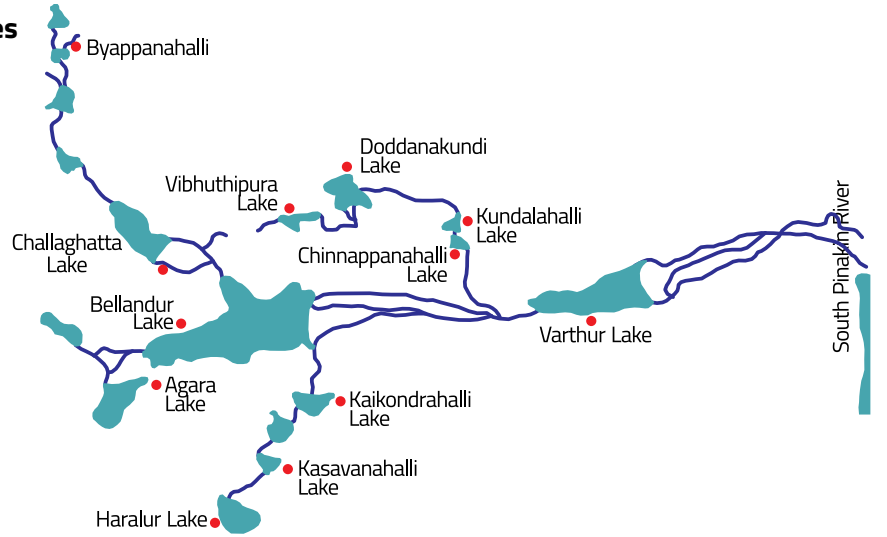
Years of Intervention

2003-04	Lake Rejuvenation works
2019	Wetland improvement
2016-2020	Construction of STP

Cost in INR

2003-04	Cap Ex **80 million**
2017	Cap Ex **170 million**
	Op Ex **1.2–1.8 million p.a.**

Varthur Lake Series



Key Interventions at Agara Lake

Following are the interventions implemented at Agara Lake.

Preparatory Interventions

- Deweeding and desilting
- Fencing of the lake boundary

Biodiversity Enhancement Interventions

- Plantation of native varieties along the revetment

Lake recharge & **wastewater treatment** Interventions

- Construction of silt trap and installation of sluice gate
- Remodelling of the natural wetland into an improved wetland
- Diversion arrangement of treated wastewater into the lake through a 35 MLD STP (Sequential Batch Reactor Technology) (up-coming)

Allied Interventions

- Creation of walking and cycling tract
- Construction of toilets

Box 17

Improved Constructed Wetland System

An integral and unique constituent of the Agara Lake is the 9 acres Wetland which acts as a buffer zone and aids the process of self-purification of water before it enters the main waterbody. Initial rejuvenation measures were supposed to fill the sluice gate portion with alum blocks for settling of the suspended impurities of the receiving water into the wetland.

At present the entire wetland portion has been bifurcated into multiple sections which allow the process of settling of silt and fine solid matter. Permeable bunds act as the bifurcating infrastructure to treat the incoming water. This engineered system uses natural functions like soil micro-organisms, vegetation to treat wastewater and acts as bio filter.

Below is the satellite image and a close shot image of the wetland arrangement

1. Storm Water Drain bringing in the runoff into the Agara Lake. There is silt trap/sedimentation basin along with a fencing arrangement that prevents the entry of solid waste into the Agara Lake
2. Dense Algal growth in the sedimentation basin
3. Sedimentation basin along with a manually operated sluice gate to regulate the entry of water into the lake. This arrangement was installed by BDA during the earlier rejuvenation efforts
4. The figure shows the arrangement of 5 partitioned wetlands designed by ALCON Consulting Engineers and implemented by Souharda Infratech Pvt Ltd. They help in providing retention time to the polluted water so that it gets cleaned naturally before entering the lake

5. The final retention area for water before it enters the main body of Agara Lake
6. Artificial Island created for birds and animals
7. Other end of the storm water drain that further leads to the Bellandur Lake
8. Floral Species within the lake premises

Agara Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Agara Lake

Parameter	P1 Inlet	P2 After sedimentation basin	P3 Lake near the Wetland end	P4 Lake (near island)	P5 Lake periphery	P6 Lake periphery
pH	7.1	7.7	8.9	8.5	9.1	8.5
Temperature (°C)	25.9	25.8	25.9	25.8	25.9	25.9
Electrical Conductivity (µS/cm)	1356	977	548	680	650	679
Total dissolved solids (ppm)	900	700	400	500	500	500
Suspended solids (mg/l)	488	278	252	43	54	43
Turbidity (NTU)	256	93.1	116	23.2	53.1	26.6
Biological oxygen demand (mg/l)	400	58	25	3	2	2
Chemical oxygen demand (mg/l)	733	223	183	47	46	54
Phosphates as PO_4 (mg/l)	17.4	7.0	1.7	BDL	BDL	0.1
Ammonia as NH_3-N (mg/l)	44.0	16.8	0.1	0.5	0.2	0.3
E. coli (MPN/100 ml)	9200	9200	230	23	23	<0.03

Date of sample collection – 21/02/2019[12]

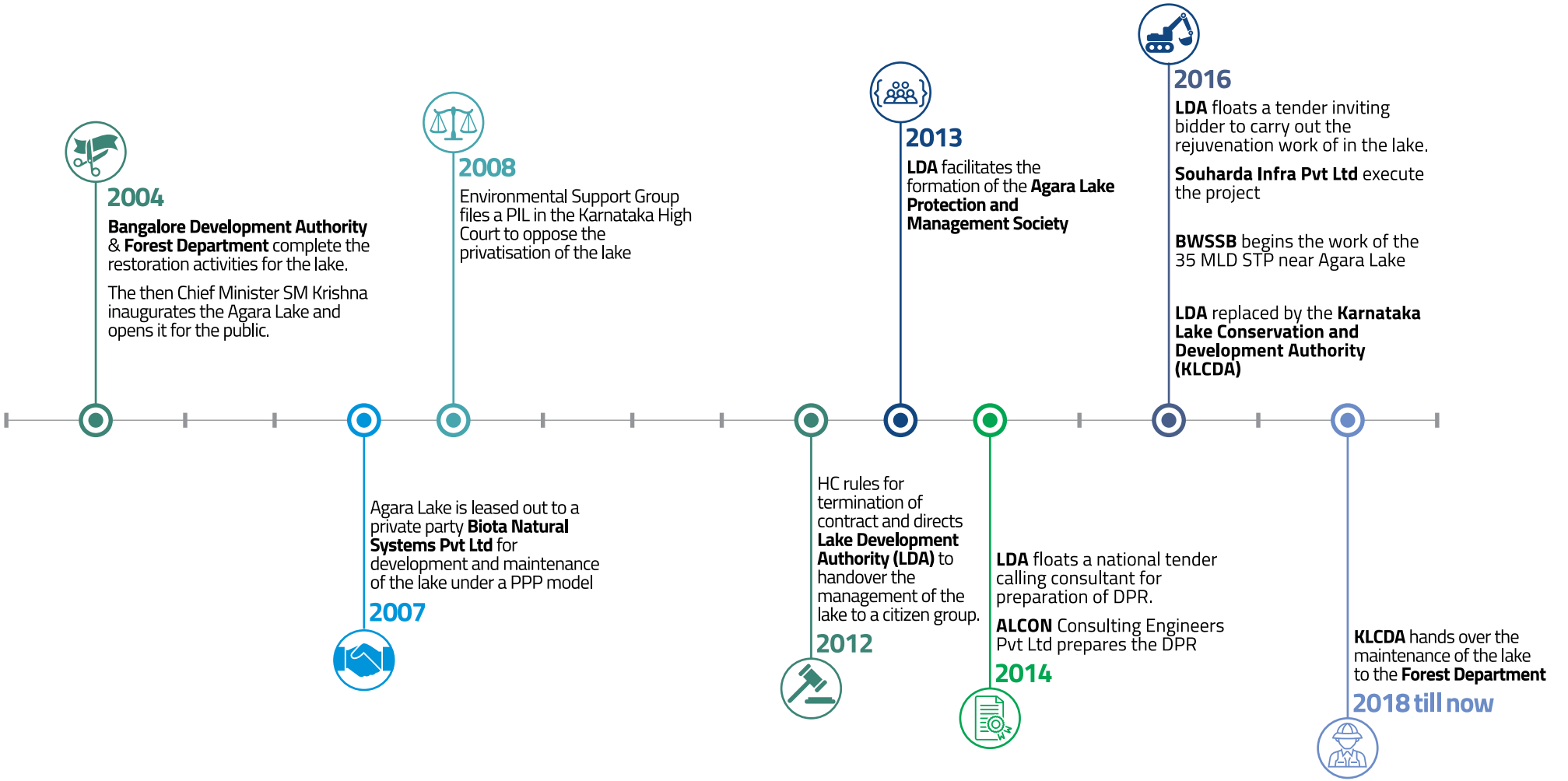
Inference

1. The analysis results show that the existing series of wetland systems in the lake is performing well in terms of removal of both organic and nutrients levels. There is a 99% reduction in the organic as well as nutrient content of the lake after passing through the improved wetland.
2. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS B of the designated best use classification system which makes it fit for the purpose of outdoor bathing.

12 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

Institutions Involved

Multiple institutions have been involved in the process of Agara Lake rejuvenation. Following is a timeline that illustrates the same.



Future Plans

Agara Lake is in the midst of a legal battle. But despite that, the current custodians i.e., the Forest Department are working towards devising the long-term working plan to maintain the lake. This includes collecting user fee to create a corpus fund dedicated for lake maintenance. Once the court case comes to a conclusion, there is a possibility for certain plans to gain traction.

Insights

Agara Lake is one of the few cases in this compendium that has consistently maintained high-water quality level. A key reason that emerges from this case study is the two-way management of wastewater; one being the measures taken in the catchment to divert all the wastewater to the STP and secondly the improved wetland with control arrangements that provides increased retention time to the incoming storm water to naturally bring about the nutrient and organic matter reduction. Moving forward this two-fold approach can prove extremely beneficial in rejuvenating urban lakes with dense catchment areas.

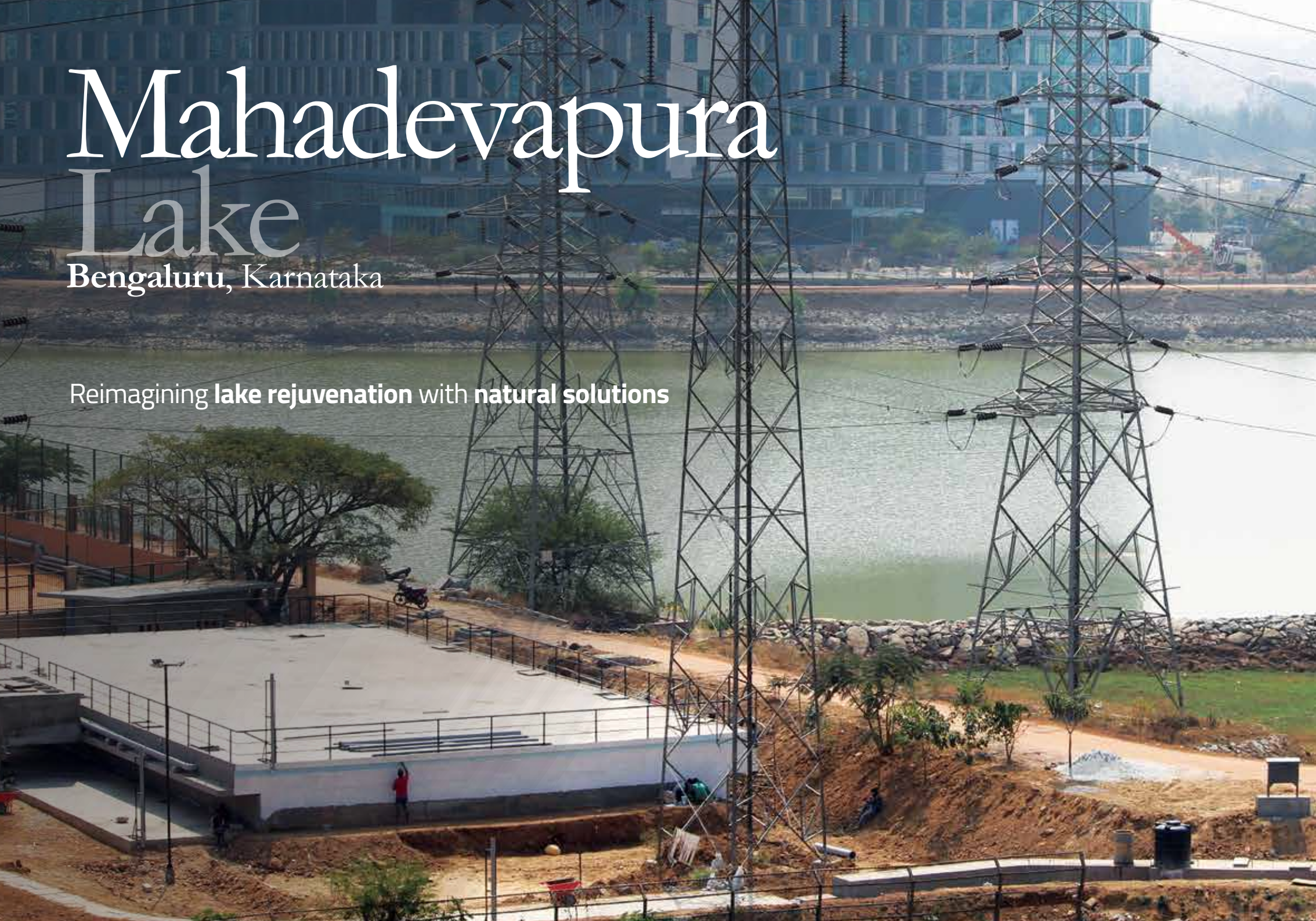
Through the course of rejuvenation, multiple institutions have been given its responsibility to rejuvenate and manage the lake, both public and private. These institutions have their own mandates and therefore view the lake through a different lens. When multiple institutions take care of a single entity then conflict becomes unavoidable which deters the rejuvenation of the lake. A way forward could be to have **clear bifurcation of roles and responsibilities among the institutions involved that will ensure holistic management of water bodies**.

Agara is part of a larger lake series. Bypass of wastewater to downstream lakes cannot be an option for rejuvenation of a lake. It merely indicates the lack of understanding about the interconnected nature of lakes. **Compromising one ecosystem for the sake of rejuvenating another has its own economic and environmental repercussions.** Lake rejuvenation in the long run cannot be considered as an isolated effort.

Mahadevapura Lake

Bengaluru, Karnataka

Reimagining **lake rejuvenation** with **natural solutions**



Mahadevapura Lake

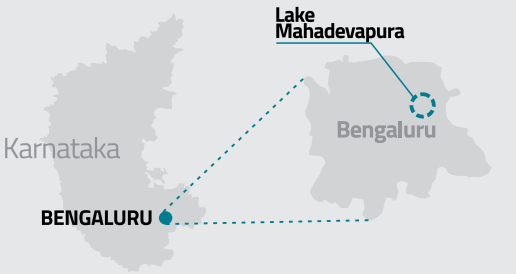
Bengaluru, Karnataka

Reimagining **lake rejuvenation** with **natural solutions**

The Mahadevapura lake, located next to Outer Ring road and adjacent to Bagmane Tech Park is under the custody of BBMP. This lake is a part of the Varthur lake series that drains southward to its downstream Doddanekundi lake.

According to water quality report released by Karnataka State Pollution Control Board (KSPCB) in the year 2011, the lake was listed under Category D which made it conducive only for the propagation of wildlife and fisheries. As the area around it developed the water is the lake completely dried up and much later became a natural sewage deposition node for the area.

Mahadevapura Lake has been rejuvenated jointly by the government, corporates, community and national and international not for profits. This multi-stakeholder group ensured that the solutions proposed were contextual and close to nature's way of functioning. The choice of solution has also been made keeping sustainability in focus. The treatment system, a 1 MLD DEWATS coupled with a well designed diversion structure has introduced a fresh perspective to the whole space of lake rejuvenation.



SALIENT FEATURES

Total **Area**
26 acres
(1,05,218 sq m)

Total **Water Spread** Area
19 acres
(76,890.3 sq m)

Average Depth of Lake
11.4 ft
(3.5 m)

Catchment Area
Domestic wastewater and stormwater runoff from **Mahadevapura, Garudacharpalya area**

Years of Intervention
2016 Interventions implemented by BBMP
2017 1 MLD Nature based treatment system and diversionary structure

Cost in INR
Cap Ex **20 million**
Op Ex **0.36 million p.a.**

Key Interventions at Mahadevapura Lake

Preparatory Interventions

- Desilting the lake area
- Construction of primary wastewater diversion channel
- Creation and restoration of bund
- Creation of silt basin
- Construction of box culvert at inlets
- Waste weir construction
- Walking path created
- Island construction

Lake recharge & **wastewater treatment** Interventions

- Construction of an 85 m long earthen drain for channelizing water from inlet-3 into the STP
- A 1 MLD STP of DEWATS approach
- Gabions for distribution of water flow
- Floating wetlands

Biodiversity Enhancement Interventions

- Plantation of native varieties

Allied Interventions

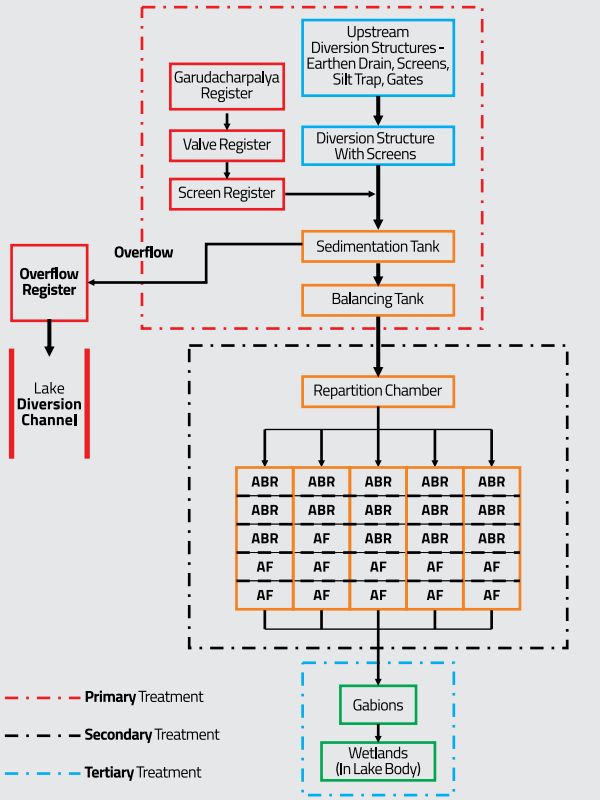
- Creation of walking pathway
- Placement of seating structures and dustbins for disposal of solid waste

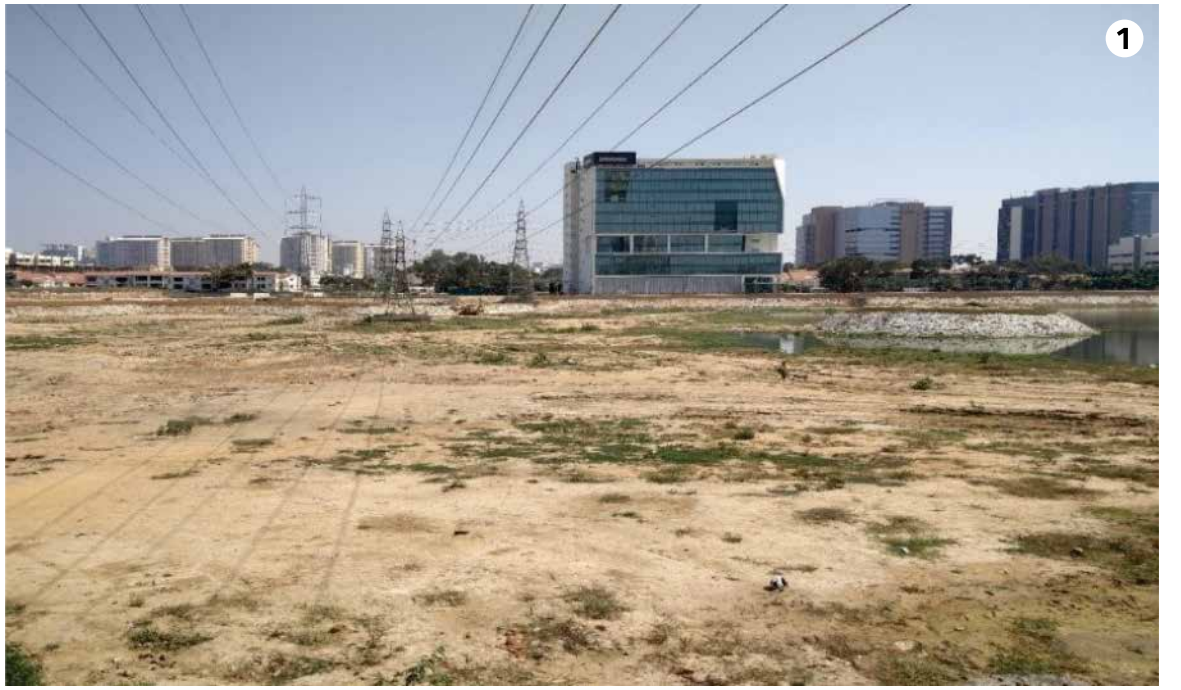
Box 18:

1 MLD DEWATS Sewage Treatment Plant

A 1 MLD DEWATS based wastewater treatment plant has been constructed to treat the incoming wastewater. Tertiary treated wastewater is used to fill the lake. The following schematic shows the primary, secondary & tertiary treatment modules.

- Intake Structure -
  Upstream Diversion Structure with 2 stages of screening
- Primary treatment -
  Diversion Channel with 2 stages of screening, Sedimentation tank and Balancing tank with pump arrangements. (allows for equalisation of wastewater flow and characteristics)
- Secondary treatment -
  DEWATS (ABR + AF)
- Tertiary treatment -
  Gabions followed by floating wetlands





1. Mahadevapura lake during its intervention period by BBMP in the year 2016-17

2. Earthen drain to channelize wastewater into the treatment plant
   a. (Before)
   b. (After)

3. Upstream diversion structures including silt trap, screen and gates

4. Intake and diversion structure for controlling the quantity of wastewater flow into the treatment system

5. Sedimentation Tank (under construction pictures)
6. Construction of Secondary module (top view)
7. Gabions for distribution of secondary treated water inflow into the tertiary module
8. Rejuvenated Mahadevapura Lake
9. Floating wetlands

Mahadevapura Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Mahadevapura Lake

Parameter	**P1** Upstream drain	**P2** Garudachar-palya Inlet	**P3** Anaerobic Filter Outlet	**P4** Anaerobic Filter Outlet	**P5** Gabions Outlet	**P6** Lake sample
pH	7.1	7.6	7.2	7.4	7.6	9.1
Temperature (° C)	25.4	25.3	25.2	25	25	24.8
EC (µS/cm)	1499	1161	1492	1427	1416	972
TDS (mg/L)	692	525	673	650	644	429
TSS (mg/L)	385	294	395	105	61	60
BOD3 (mg/L)	470	270	460	70	50	15
COD (mg/L)	737	476	709	175	130	122
PO_4-3 (mg/L)	14	12	12.7	19.8	16.3	7.7
NH_4-N (mg/L)	20.3	30.4	22.4	41.2	36.6	2

Date of sample collection – 10/09/2019[13]

Inference

1. The wastewater and stormwater runoff entering the system is first getting mixed in the sedimentation tank inlet. Hence considering that as the starting point we see that there is a 85% reduction in organics after the secondary treatment (P3 to P4). Post the tertiary treatment the water in the lake shows 97% reduction in organics.
2. There is an increase in nutrients post the treatment in DEWATS. DEWATS being an anaerobic process does not help in cutting down the nutrient load of wastewater. However, as it passes through the gabions and floating wetlands the nutrient concentration in water undergoes a sharp decrease.
3. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS

13 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

E of the designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.

Institutions Involved

The lake is located in a technology hub sparking the interest of corporates for making an investment towards the rejuvenation of the lake. United Way of Bengaluru along with several corporates like Amazon, Dell, HTC, Mphasis approached BBMP with the proposal. The rejuvenation work was co-funded by a German not-for-profit BORDA and the CSR wing of the companies mentioned. This led to the initiation of work on the lake in the year 2016 with the support of wastewater management and implementation consultants Consortium for DEWATS Dissemination Society and REVLON Buildtech. Additionally, the fisheries department has tendered out the fishing contracts for the lake.

Future Plans

The O&M of STP has been taken up of by CDD Society until the mid of 2021. The remaining area of the lake has been taken up for operation and maintenance by United Way of Bengaluru and is part of a separate contract.

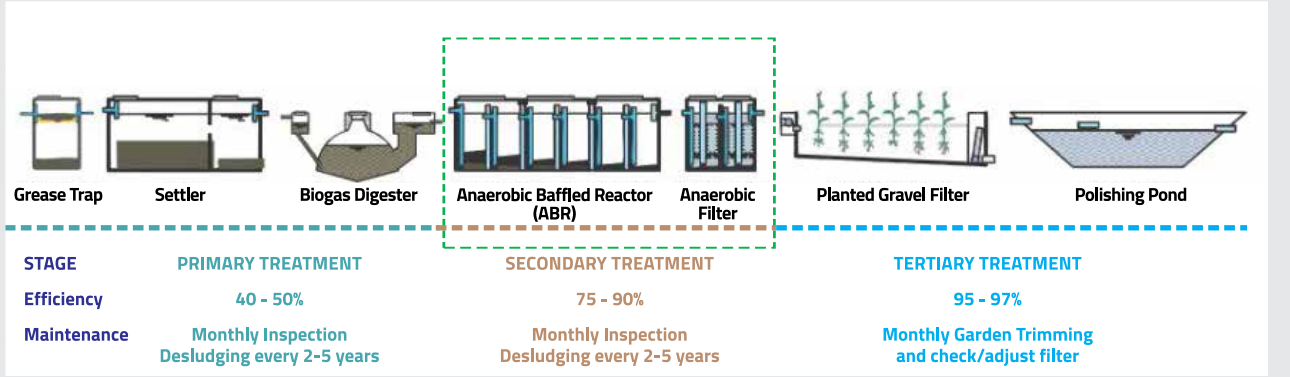
Insights

Mahadevapura Lake is an example of **holistic rejuvenation process where multiple agencies joined together and brought their own set of expertise to revive the lake**. All critical dimensions of rejuvenation such as adequate funds, design & implementation of treatment systems, community mobilization for ownership and lastly key operations

Box 19:

Decentralised Wastewater Treatment System (DEWATS)

The primary focus for DEWATS is a decentralised approach i.e., building many smaller systems to treat wastewater close to the point of generation, enabling water to be effectively reused. It makes use of natural bacteria, plants and gravity instead of electricity and chemicals, is easy to integrate aesthetically into built environments and is adaptable to a variety of wastewater characteristics.



DEWATS consists of Settler, Anaerobic Baffled Reactors (ABR), Anaerobic Filters (AF) and Planted Gravel Filter (PGF).

- Settler - The Settler acts as a Sedimentation tank that retains most of the Settleable organic matter and scum and decomposes some of it through anaerobic digestion.
- Anaerobic Baffle reactor (ABR) – ABR degrades suspended and dissolved solids anaerobically through a naturally occurring active sludge blanket.
- Anaerobic Filter (AF) – AF acts as a fixed bed filter where wastewater is brought into close contact with active bacteria for removal of dissolved organic matter.
- Planted Gravel Filter (PGF) - PGF is a shallow tank with plantation that can be used to treat remaining pollutants by biological conversion, mechanical filtration and chemical adsorption.

& maintenance were streamlined to complete the work in specified time.

A major focus of this rejuvenation has been implementation of Decentralized Wastewater Treatment System. This low-cost treatment system uses biological processes to break down the pollutants without using any external energy source. Considering the limited financial resources within which governments operate, it is imperative to consider such eco-friendly solutions. Though the DEWATS requires more area as compared to other systems, the benefits of low cost, nature based, low energy and low O&M outweighs the area factor quite significantly.

Incoming wastewater can vary both in terms of quantity and quality. **Process control** in the form of minimum pumping arrangements and equalisation have been introduced to facilitate DEWATS to handle this variation.

This case also elicits the principle of **Co-funding** where multiple CSR companies jointly funded the complete rejuvenation project. This requires a lot of coordination effort and has worked out well here.

Significant amount of thinking has gone into designing the intake and diversion structure for the treatment system. It simplifies the operation by trapping wastewater for treatment in alignment with the requirement of the lake which is 1 MLD. This aids in maintaining the integrity of the treatment plant by not overloading it. Additionally, it also reduces the wastewater load on the downstream lakes. Moving forward, such **context specific thinking** can be encouraged to increase the longevity of treatment infrastructure that caters to lake recharge.

Dasarahalli Lake

Bengaluru, Karnataka

Perils of unmonitored **industrial effluents**

Dasarahalli Lake

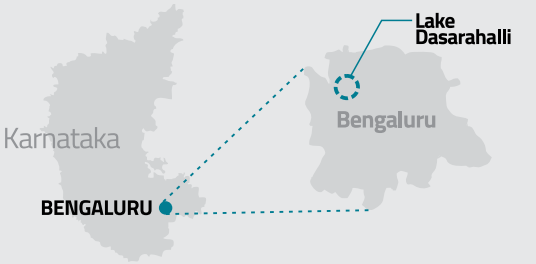
Bengaluru, Karnataka

Perils of unmonitored **industrial effluents**

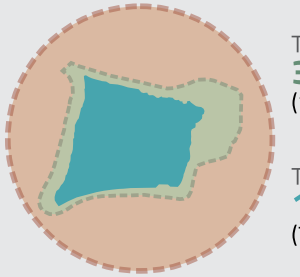
In the process of expansion of industrial belts, water bodies are often subjected to becoming a liability rather than an asset. An important question to ask is whether Bengaluru as a growing urban space is capable of supporting the ecological recovery of lakes in a rapidly expanding economy.

Peenya, located in north-west of Bangalore is synonymous with the bustle of manufacturing industries, the smells of fuel burning and chemicals used in factories of all scales. Peenya industrial belt includes major industrial areas like Peenya, Yashwanthpur, Rajajinagar, Jalahalli, Goraguntepalya and Dasarahalli. Amidst this industrial zone lies 34 acres of serenity in the form of Dasarahalli Lake.

The source of water for Dasarahalli Lake other than rainfall is an inlet carrying wastewater. The inlet on the east is used to divert about 1 MLD of wastewater to the STP near the lake, which then enters the lake after treatment. If the sewage is beyond the capacity of the STP it is bypassed along with another sewage channel from Kammagondanahalli area to Doddabidarukallu Lake. The sewage from households and effluents from the industries were a big reason this lake was more an eyesore than an asset.



SALIENT FEATURES



Total **Area**
34 acres
(1,37,593 sq m)

Total **Water Spread** Area
18 acres
(72,843.4 sq m)

Average Depth of Lake
n/a

Catchment Area
Domestic wastewater and industrial effluent from **Peenya Industrial Area**

Year of Intervention
2009-13

Cost in INR
Cap Ex **80 million + 42.7 million** for the STP
Op Ex **n/a**

Key Interventions at Dasarahalli Lake

Preparatory Interventions

- Dewatering, deweeding and desilting of the lake
- Creation of bunds and installation of grit separators

Lake Recharge & **Wastewater Treatment** Interventions

- Diversion structures
- Sewage Treatment Plant of 1 MLD Capacity (Technology - Activated Sludge Process)

Biodiversity Enhancement Interventions

- Creation of artificial island

Allied Interventions

- Walkways

Satellite images of Dasarahalli Lake over the years

1. Walkway along the Dasarahalli Lake
2. Sedimentation Basin for the Lake
3. Eastern inlet carring wastewater from the Peenya industrial area
4. Plantation done by the Forest Department within Dasarahalli Lake Premises
5. Dasarahalli Lake

Dasarahalli Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Dasarahalli Lake

Parameter	P1 East Inlet	P2 STP Outlet	P3 Lake Middle	P4 Lake Outlet
pH	6.9	7.6	9.3	10.1
Temperature (˚C)	27.3	26.7	26.4	26.4
Electrical Conductivity (µS/cm)	1668	1585	1112	1038
Total dissolved solids (ppm)	1200	1100	1000	1000
Suspended solids (mg/l)	383	34	238	234
Turbidity (NTU)	65.9	21.3	277	303
Biological oxygen demand (mg/l)	220	4	30	35
Chemical oxygen demand (mg/l)	408	29	201	259
Phosphates as PO_4 (mg/l)	5.0	8.2	1.6	1.6
Ammonia as NH_3-N (mg/l)	42	6.3	0.3	1.1
E. coli (MPN/100ml)	23000	150	2300	120

Since industrial effluent discharge was a concern for this lake, the samples were additionally tested for the following parameters :

Parameter	Permissible Limits[14]	P1 Inside Sedimentation Basin	P2 Outside Sedimentation Basin
Total Iron as Fe (mg/l)	3	0.03	11.6
Chromium as Cr (mg/l)	2	BDL	0.18
Cadmium as Cd (mg/l)	2	0.01	0.07
Copper as Cu (mg/l)	3	0.03	0.18
Nickel as Ni (mg/l)	3	0.20	1.51
Lead as Pb (mg/l)	0.1	0.12	1.64

Date of sample collection - 20/02/2019[15]

14 The Environment (Protection) Rules, 1986 – Standards for Inland Surface Water

15 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

Inference

1. The analysis of metals indicates the presence of Iron and lead in the wastewater conveyed to the STP through the east inlet that carries a mix of domestic and industrial wastewater. This is likely to lower the treatment efficiency of the STP.
2. There is a 98% removal in organics by the STP. There is also 85% removal of ammonia.
3. The analysis results of STP effluents show that the STP is able to treat both organic and heavy metal pollutant and release good quality water into the lake.
4. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water resembles CLASS E of the designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.

Institutions Involved

The lake was rejuvenated by BBMP during the period 2009 – 13. BBMP continued with the maintenance of the lake until the year 2018, post which the maintenance of the lake was handed over to the United Way Bengaluru.

Future Plans

United Way Bengaluru, the primary maintaining agency for the lake plans to plant wetland plants for in-situ wastewater treatment and fruit bearing trees to enhance the biodiversity of the lake. Incoming industrial effluent is a major challenge during the monsoons.

Insights

Dasarahalli Lake in the midst of an ever-growing industrial space is an example worthy of attention. It is a challenging task to keep a water body thriving with limited control on the nature of wastewater entering the treatment system. **STP's are primarily meant for domestic sewage and not designed to handle industrial loads.** Industrial waste causes accelerated deterioration of sewer lines and STPs. They also interfere with the removal and digestion of sewage and the entire biological oxidation process. In the long run it creates operational challenges in the functioning of the system along with an increase in the cost of sewage treatment.

Considering the competing demands on already scarce water resources, a **lack of regulation and monitoring of industrial effluent discharge wreaks havoc on the existing infrastructure**. The need of the hour for lakes situated in industrial belts is to **involve the corporate entities beyond volunteering and fundraising to taking responsibility for maintaining the lake and its surroundings**. There is no one industry that can be blamed, however collectively creating avenues for their dialogue and contribution of ideas can help in reviving these urban spaces.

Neknampur Lake

Hyderabad, Telangana

Initiating rejuvenation with **simple interventions**

Neknampur Lake

Hyderabad, Telangana

Initiating rejuvenation with **simple interventions**

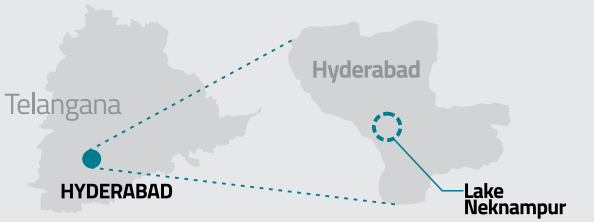
Ibrahim Cheruvu or Neknampur Lake is a man-made lake in Hyderabad commissioned by Ibrahim Shah, the emperor of Golconda more than 440 years ago. The lake is also called Neknampur after Neknam Khan, a nobleman who constructed a channel that brought water from the upstream lakes of Durgam Cheruvu and Malakam Cheruvu.

These lakes were built to store water in summers. The subsurface rocky strata of the Deccan region did not allow recharge of groundwater aquifers, which made the lakes created in Hyderabad the only source of water in the dry season.

These lakes, once rich in biodiversity, had become a dump yard for solid waste, construction debris and wastewater from the multiple residential complexes around it. It emitted a foul smell and froth formation was a regular occurrence that indicated the presence of toxic sewage in the lake.

Neknampur lake has originally two inlets, both carrying wastewater from nearby residential areas. The inlet near the lake entrance has been closed. The other inlet gets wastewater from Alkapur township and upstream areas, which amounts to around 13 MLD (*Dhruvansh - NGO*).

Water from the upstream lake, Durgam Cheruvu is channelized to overflow into Neknampur Lake. Water from these sources and rainfall has ensured that the lake is always full, but choked with hyacinth which thrives on the sewage laced water in the



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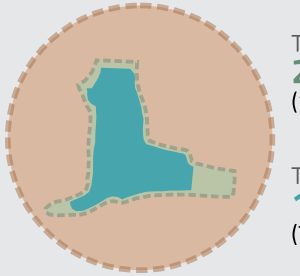

Total **Area**
25 acres
(1,01,171 sq m)

Total **Water Spread** Area
19 acres
(76,890.3 sq m)

Average Depth of Lake
20 ft
(6 m)

Catchment Area

- Domestic wastewater from **Alkapur Township** area
- Surface overflow from **Durgam Cheruvu**

Year of Intervention
2016 and ongoing

Cost in INR
Cap Ex **0.68 million** for deweeding and construction of the floating wetland
Op Ex **0.6 million p.a.**

lake. As a result of the severe eutrophication and waste getting dumped in the vicinity, the lake prior to rejuvenation had been smelling and festering vectors.

In 2016 an attempt was made to revive it by a group of individuals with support from the Hyderabad Metropolitan Development Authority (HMDA). A section of the lake as highlighted in the adjacent figure, which was naturally separated from the rest of the lake was attended to by Dhruvansh, an NGO dedicated to improving the lake's condition. All the efforts are directed towards the improvement of lake water quality and quantity.

Key Interventions at Neknampur Lake

In a 19-acre enclosure which is a part of the larger Ibrahim Cheruvu, the following interventions have been implemented.

Preparatory Interventions

- Removal of accumulated solid waste on walkway
- Partial fencing of the lake boundary
- Awareness drive coupled with regular vigilance activities
- Conversion of garbage dump into an idol immersion tank

Biodiversity Enhancement Interventions

- Plantation of saplings under the Haritaharam Programme

Lake Recharge & **Wastewater Treatment** Interventions

- Mechanical Deweeding
- Slope stabilisation using fruit and flower trees
- Floating treatment island
- Installation of aerators

Allied Interventions

- Corporate volunteering for regular upkeep of the lake
- Conversion of abandoned sewer pipes into art works for lake beautification

1. Neknampur Lake
2. Floating Wetlands at Neknampur Lake
3. Discarded sewerage pipes that had earlier become a spot for nuisance creation have been converted to art works and placed along the entrance of the lake adding aesthetic value to the Neknampur Lake
4. Plantation of fruit and flower trees on the revetment of the lake for stabilisation under the the Haritaharam Program on the slope for stabilisation
5. Canna Indica plantation for in-situ treatment of polluted water

6. Dried up portion of the wetland in Neknampur Lake due to closure of the wastewater inlet on its side
7. 3000 sq ft (30 platforms of 10*10 sq ft dimensions) floating treatment wetland with plants like vettiver, Canna Indica, cattail, bulrush, citronella, hibiscus, tulsi and ashwagandha to absorb nutrients from the wastewater
8. Aerators in operation that aid in increasing the dissolved oxygen level in water
9. Kalyani for idol immersion has been constructed by converting a legacy garbage dump area

Neknampur Lake **satellite map**

Lake Water Quality

Following is the water quality analysis for Neknampur Lake

Parameter	**P1** Inlet	**P2** Outside Sedimentation Basin	**P3** Waste Weir	**P4** End Stagnation Point
Total suspended solids (mg/l)	370	44	140	190
Biochemical oxygen demand (mg/l)	304	28	70	100
Chemical oxygen demand (mg/l)	880	100	200	280
Phosphates as PO_4 (mg/l)	17.37	4.1	19.08	21.2
Ammonia as NH_3 (mg/l)	7.8	3.96	32.4	140
Dissolved oxygen (mg/l)	<1.0	4.4	3.2	3.0
E. coli (MPN/100ml)	3400	260	1100	790

Date of sample collection – 29/03/2019[16]

Inference

1. Over all the quality of water in the lake is not good. This is evident from the fact that both the concentration of organics and nutrients is high. This indicates that there is stagnation and dead zones in the lake.
2. But the area close to the floating treatment wetlands and aerators shows low organic and nutrient concentration and hence is comparatively better that the rest of the lake. Treatment systems are functioning well but the effect is limited to a certain area.
3. All parameters have not been analysed hence a conclusive remark on the water quality cannot be made. But based on the few parameters that were analysed, the lake water close to the aerators and floating wetlands resembles CLASS E of the designated best use classification system which makes it suitable for irrigation, industrial cooling and controlled waste disposal.

16 Grab sample test results are not representative in nature, they are just indicative of the water quality of specific parts of the lake on the day of sampling

Insights

Rejuvenation of Neknampur Lake is a work in progress. One of the key interventions to initiate work on the lake was to get the solid waste cleared in the adjoining areas coupled with instilling awareness on good practices in solid waste disposal. This demonstrates the clear **usage of simple interventions to get the attention of the public and administration to issues of waterbody pollution and management**.

The conversion of a legacy solid waste dumping ground into a Kalyani has had a huge effect on the behavior of citizens residing in the vicinity of the lake. Religion in a way can be used as a tool to make public support towards these issues more resolute in the long run.

The NGO conceptualized a floating treatment wetland which was different from the ones that we usually see. The floating wetland is robust and aligns well with Indian conditions. It is home to a variety of species beyond the conventional wetland plants. It is also home to a variety of avian fauna and reptiles. Moving forward this gives way for **developing a deeper research and understanding on the functionality (stability under extreme loading on the wetland and treatment potential of herbs and flowers-based plants) of this floating wetland** and to also gauge its applicability in other lakes.

An additional treatment mechanism in the form of sedimentation basin has been left underutilised. Sedimentation basins are natural, low cost, effective and easy to operate. Leveraging this potential by integrating it with existing treatment infrastructure can go a long way in increasing overall quantity of wastewater treated.

Epilogue

Unplanned urbanisation, the inflow of untreated domestic and industrial wastewater, dumping of solid waste and rampant encroachments continue to threaten the sustenance of our water bodies. The pressure of climate change is an added trigger to the already looming crisis. One way to improve reliance in urban areas is improving the condition of lakes, making them a part of an inclusive urban space and creating effective policies and processes for their health and maintenance.

In the process of curating these case studies, we had an opportunity to reflect on how waterbody rejuvenation interventions have been thought about and implemented in India. Some positive and practical elements have been presented here with the intent to set the path forward for citizen groups, government officials and sector practitioners.

1. **Importance of Stakeholder Involvement** – Stakeholders play a vital role throughout the entire process of rejuvenation. Bringing relevant stakeholders to a common platform at the start of the rejuvenation can help in understanding their aspirations for the waterbody. Other key aspects requiring stakeholder input include different direct and indirect uses of the lake and distribution of the benefits and costs of the rejuvenation. Consensus building at early stages eases conflicts and facilitates buy-in for implementation and maintenance of lakes. Case studies like Puttenahalli and Jakkur illustrate how citizens have led the initiative including intervention in key areas like lake use decisions, contextual interventions like vegetation to be planted in the periphery, facilitation of research, etc. Citizen groups have formed registered entities that implement operation and maintenance and escalate important issues to the government bodies. They have also raised funds and brought together volunteers for lake upkeep. In Mahadevapura Lake we particularly see that multiple CSR wings have been brought together to co-fund the rejuvenation effort.
2. **Catchment Approach** – The catchment is the focal point for rejuvenation as it determines the hydrological regime of the basin. In Rajokri, Mansagar, Pichola and Fatehsagar lakes, wastewater entering the lake from residential areas was intercepted at various locations and diverted to a sewage treatment plant. In case of mountainous catchments, check dams, trenches are often constructed to lower erosion and thus deposition of silt in waterbodies. Smaller decentralised measures at catchment level help in reducing the treatment load closer to the lake.
3. **Incremental interventions** – All case studies illustrate that one-time lake revival efforts are insufficient to ensure their sustained good health. Multiple interventions developed and implemented systematically over time tends to work better than one-time interventions. For example, in Hebbagodi, rejuvenation was initiated with bio enzyme dosing and aeration, and then moved to the installation of floating wetlands with gradual increase in their numbers. Improvements in biodiversity or restoration of the relationship between lakes and people develops over longer timeframes. However, there are quick wins that can be aimed to generate momentum. In the case of Neknampur we can see that rejuvenation began with something as simple as cleaning up the solid waste around the lake which brought a significant change in the appearance of the space. Post this improvement there was monetary infusion for trying out an in-situ treatment system. Other measures like deweeding, desilting, strengthening of bunds using plants can also be done in the earlier stages to gather more support for rejuvenation.
4. **Integration of existing treatment infrastructure** – Integrating existing infrastructure in rejuvenation plans can aid in capacity

augmentation and overall cost reduction. In Mansagar, in the process of revamping the sewage treatment plant, another tertiary treatment plant and vast areas that were earlier covered by constructed wetlands have been left vacant. In lakes like Herohalli, Mahadevapura, Dasarahalli the sedimentation basin has been left unutilised. On the contrary, the existing sedimentation basin in Agara Lake has been redesigned into an improved wetland to aid the treatment of water before it enters the lake.

5. **Hybrid treatment technologies** – The case studies show a mix of active and passive treatment systems that are used for lake rejuvenation. A hybrid version combines these two approaches with an additional layer of process control to better manage the incoming wastewater. They are capable of competing with the conventional ones on cost and quality of treatment. For example, Mahadevapura, Jakkur and Mansagar having a combination of STP and wetlands leading to low energy and human resource requirement.

6. **Conserving native biodiversity** – Native biodiversity is sturdier, adapts better and has higher chances of survival, facilitating development of a stable ecosystem in a very short time. Cases like Jakkur and Puttenahalli have proved this by planting native varieties of plants around the lake. A special mention has to be made about Adyar Poonga where the focus was to plant mangroves that were indigenous to the coastal ecosystem.

7. **Regular Operation and Maintenance** – All treatment solutions have a scientific backing to it which needs to be understood by the ground staff responsible for O&M. Since the actual custodian of a lake is a government body, they can set up processes to determine the eligibility of an O&M service provider. Additionally, service providers should work closely with the developers of the treatment system. Since lake rejuvenation related O&M works are relatively new, the contracts can have a detailed list of tasks to be performed and their frequency. Citizen groups can then take up the responsibility of the less technical aspects of O&M and overseeing implementation.

8. **Education and awareness** - Lakes which are in the process of rejuvenation or have already been rejuvenated can have an element that helps build awareness among citizens. These measures help in developing a sense of ownership with the lake among people. Lakes in Bangalore have regular events like lake festivals, citizen volunteering, visits by school students and researchers to create awareness. Adyar Poonga has created a nature educational centre where people can learn about estuarine ecosystems and their rejuvenation.

9. **Infusion of funds and process streamlining** – Considering the vast number of lakes that need to be rejuvenated, calls for an infusion of funds from governments, corporate social responsibility wings and philanthropists. But for the systematic usage of funds, processes can be set up for the selection of quality design consultants, construction and O&M contractors. Additionally, having a formal understanding with citizen groups can aid in monitoring the flow and usage of funds. We can see this in Delhi where the government plans to rejuvenate more than hundred water bodies for which effort is being made to simplify the administrative processes related to tendering. This will aid the selection of more bidders and at the same time avoid any compromise in the quality of work. In Bangalore lakes we see that the government departments engage in formal MoU's with citizen groups for monitoring of maintenance work and raising funds for small additions like a gate, gazebo etc.

10. **Gradual water quality improvement** – Lakes are ecological systems and interventions take time to yield optimal results. Lakes in our country are not used for domestic purposes so the requirement of high-water quality levels is not an essential requirement. With so many water bodies yet to be rejuvenated, so many sources of wastewater to be managed, there is a limit to how perfectly things can be controlled on the ground. So instead of aiming for a very high-water quality for a few lakes, having an optimal water quality for a majority of them helps in controlling the environmental and public health menace more effectively.

It would only be right to say though, that we are still learning the most efficient methods to carry out these interventions and achieve success. As the cases in this compendium show, various levels of success have been encountered in the different experiences and there is no one solution. Each lake requires some level of contextualisation during rejuvenation planning. What we hope that this compendium enables, is the extraction of lessons and inferences towards feeding the recent momentum across urban communities.

We hope this has been a useful read and we look forward to your feedback and suggestions.

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Technical Definitions

Aerobic Process
Aerobic process is the process that relies on microorganisms that thrive under aerobic conditions

Anaerobic Process
A process that occurs in the absence of free oxygen.

Bund
An embankment used to control the flow of water

Buffer Zone
An area of land designated for lake protection.

Bio enzyme
Bio-enzyme cleaners are organic solutions produced by fermentation of fruits, vegetables, sugar, and water.

Biochemical Oxygen Demand
Biochemical oxygen demand, the amount of dissolved oxygen used by microorganisms in the biological process of metabolizing organic matter in water. The more organic matter there is the greater the BOD; and the greater the BOD, the lower the amount of dissolved oxygen. BOD is therefore a reliable gauge of the organic pollution of a body of water. One of the main reasons for treating wastewater prior to its discharge into a water resource is to lower its BOD – i.e., reduce its need of oxygen and thereby lessen its demand from the streams, lakes, rivers, or estuaries into which it is released.

Berm
A berm is a simple way to add interest and height to a landscape, especially in a dull, flat area

Bioremediation
Bioremediation is the use of microbes to clean up contaminated soil and water. Microbes are very small organisms such as bacteria, that live naturally in the environment. Bioremediation stimulates the growth of certain microbes that uses contaminants as a source of food and energy. Microbes eat and digest contaminants usually changing them into small amounts of water and harmless gases like carbon dioxide and ethene. (USEPA 2012)

Bioswale
Bioswales are storm water runoff conveyance systems that provide an alternative to storm sewers. They can absorb low flows or carry runoff from heavy rains to storm sewer inlets or directly to surface waters. Bioswales improve water quality by infiltrating the first flush of storm water runoff and filtering the large storm flows they convey. (USDA n.d.)

Catchment area
The area from which rainfall flows into a river, lake, or reservoir.

Catchment area treatment
Catchment Area Treatment is a term used to describe the process of implementing land use practices and water management practices to protect and improve the quality of the water and other natural resources within a watershed by managing the use of those land and water resources in a comprehensive manner.

Constructed wetland
A constructed wetland is a shallow basin filled with some sort of substrate, usually soil or gravel, and planted with vegetation tolerant of saturated conditions. Water is introduced at one end and flows over the surface or through the substrate and is discharged at the other end through a weir or other structure which controls the depth of the water in the wetland

Check dam
A check dam is a small, sometimes temporary, dam constructed across a swale, drainage ditch, or waterway to counteract erosion by reducing water flow velocity.

Chemical Oxygen Demand
Chemical oxygen demand is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite.

Dead Zone
Dead zones is a more common term for hypoxic

which refers to a reduced level of oxygen in the water. (Commerce n.d.)

Drain
A channel or pipe carrying off rainwater or liquid waste.

Desilting
Desilting refers to the removal of earthy materials, fine sand etc carried by running water and deposited as a sediment.

Deweeding
Deweeding is the process of removal of water hyacinth and duckweed covering the surface of water bodies. Dense proliferation of weeds cause a depletion in the oxygen level and thereby fish kills.

Dual Piping
Dual Piping is a system of plumbing installations used to supply both potable and reclaimed water. Usage of treated wastewater through dual water distribution and plumbing systems help in providing a secondary source of water for gardening or toilet flushing. The provision of water of lesser quality through a separate distribution system for non-potable purposes from alternative sources of supply can help lower the demand for potable freshwater. (United Nations Environment Programme - Division of Technology n.d.)

Estuary
An estuary is a transitional zone between fresh and marine water bodies, and includes tidal waterways, rivers, streams and creeks that are near sea level and rise and fall with the tides. Estuaries provide two very important ecosystem services which are water filtration and habitat protection. Estuaries and their surrounding wetlands are also buffer zones. They stabilize shorelines and protect coastal areas, inland habitats and human communities from floods and storm surges.

Floating Wetland
Floating treatment wetlands (FTWs) are manmade ecosystems that mimic natural wetlands. Floating wetlands consist of a suspended matrix in which wetland plants are enmeshed. This facilitates microbiological and plant processing of nutrients naturally present in domestic wastewater. Plant roots are believed to play a major role in treatment processes within floating wetland systems as the water passes directly through the extensive root system hanging beneath the floating mat.

Gabions
Gabion is a cage-like structure filled with rocks and gravels and is used for uniform distribution of water which in turn aids aeration.

Intertidal Zone
Intertidal zone is the area of the marine shoreline that is exposed to air at low tide, and covered with seawater when the tide is high.

Pergola
Pergola is an outdoor garden feature forming a shaded walkway, passageway, or sitting area of vertical posts or pillars that usually support cross-beams and a sturdy open lattice, often upon which woody vines are trained.

Revetment
A retaining wall or facing of masonry or other material, supporting or protecting a rampart, wall, etc.

Rejuvenation
The action of restoring a river or stream to a condition characteristic of a younger landscape.

Sedimentation Tank
A sedimentation tank allows suspended particles to settle out of water or wastewater as it flows slowly through the tank, thereby providing some degree of purification

Sedimentation Basin
A sedimentation basin is a temporary pond built on a construction site to capture eroded or disturbed soil that is washed off during rain storms, and protect the water quality of a nearby stream, river, lake, or bay.

Silt Trap
A silt trap is a basin device that is set upstream of a lake and its purpose is to prevent any kind of silt, soil, sediment, metals or pesticides from entering your water storage system by containing water in the trap for some time and allowing these unwanted materials to settle to the bottom of the bucket and separate from the wat

Soil bioengineering
Soil bioengineering refers to low-impact techniques for soil stabilization and environmental restoration by employing living plant material (or wood) coupled with inert materials (rocks, earth, mulch mat, metallic nets, geotextiles, etc).

Sludge
Thick, soft, wet mud or a similar viscous mixture of liquid and solid components,

Waterbody
Waterbody is any significant accumulation of water, generally on a earth surface.

Wetland
Land consisting of marshes or swamps; saturated land.


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