Implementing the Ecosystem Approach to Preserve the Ecological Integrity of Urban Lakes

The Case of Lake Hussainsagar, Hyderabad, India

Mohan Kodarkar

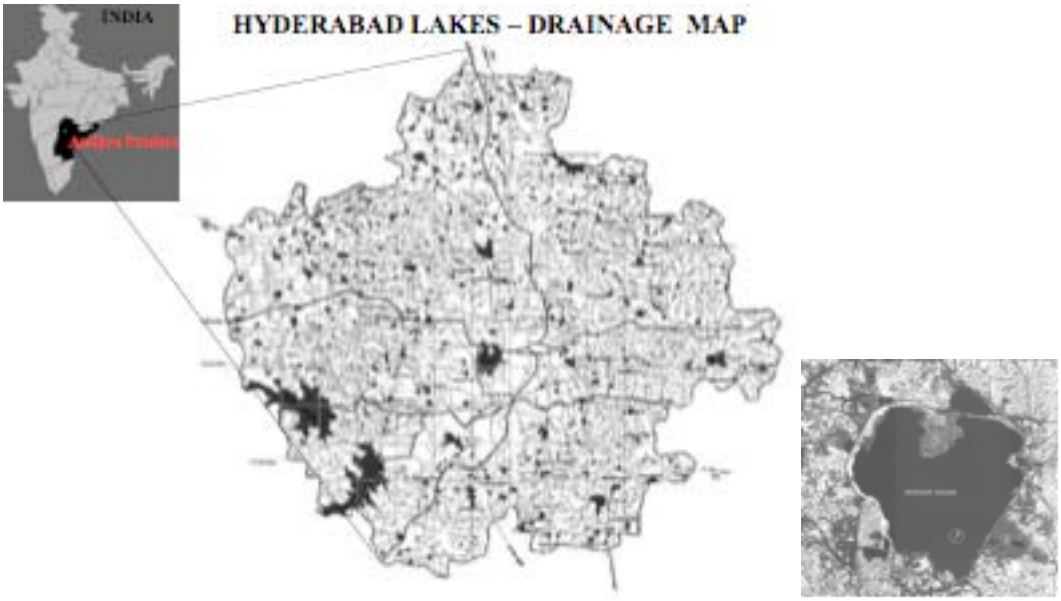
1. Abstract

Constructed in 1562 and situated between the twin cities of Hyderabad and Secunderabad in Andhra Pradesh, India, the almost 450 years old lake Hussainsagar is an engineering marvel and a symbol of traditional wisdom of water conservation in this semi-arid region of peninsular India. The lake with a 275 sq km highly urbanized and industrialized basin receives water from four major feeding channels and is an example of a water body created by taking the advantage of characteristic topography of the *Deccan* plateau of peninsular India. In recent years the lake has emerged as the major recreational centre and ecological land mark on the map of the country.

In the conservation history of India, last half of 20th Century was witness to unprecedented urbanization and industrialization as a result of which natural resources in general and water resources in particular faced the most adverse impacts. It is during this phase that the lake Hussainsagar underwent extensive environmental degradation due to pollution from untreated domestic sewage and toxic industrial effluents. The degradation was evident in the form of shrinkage of lake area due to encroachments, hyper-eutrophication, extensive groundwater pollution, loss of biodiversity, breeding of vectors and recurrent fish kills. The worst sufferers of lake pollution were the lake dependent communities like fishermen, small dairy farmers and washer-men communities belonging to weaker sections of the society.

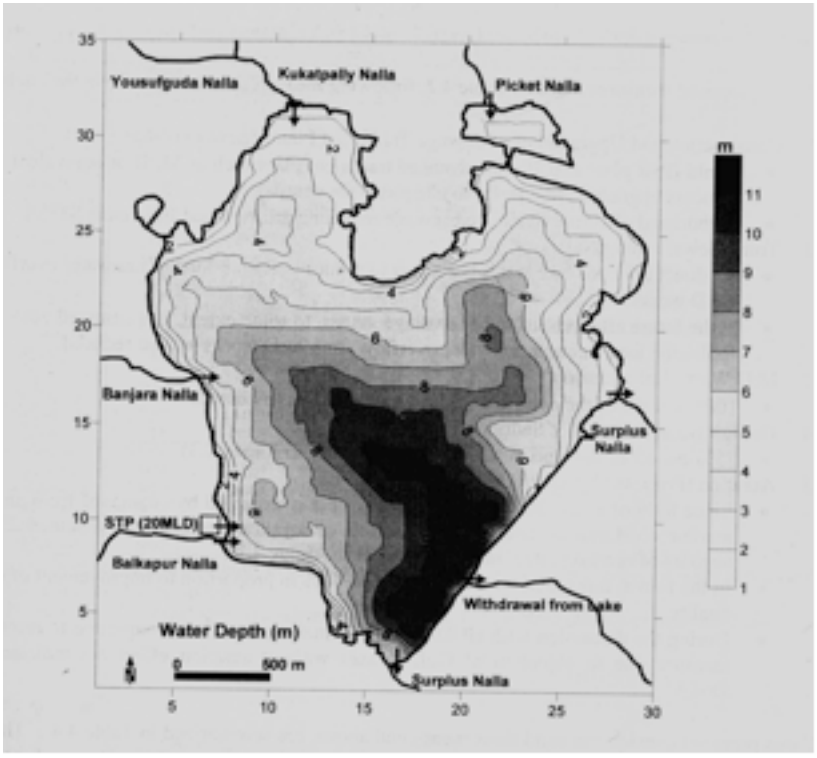
In response to 'Save the lake campaign', a civil society initiative in 1990 and subsequent judicial interventions, the State Government initiated a comprehensive programme for protection and conservation of the lake. The remedial measures under these initiatives have transformed once highly degraded lake into a recreational zone and lung space for otherwise congested urban agglomeration. Some of the important conservation measures included (1) Development of parks, green belts and recreational zones around the lake; (2) Construction of the necklace road to prevent further encroachments along the lake shore line; (3) Downstream diversion of industrial wastes; (4) Setting up of an STP with 20 mld capacity to sustain hydrology of the lake, (5) Establishment of Common Effluent Treatment Plant (CETP) to treat industrial effluents, (6) Solid waste management in the catchment and (7) involvement of stake holders in the lake management.

Fig. 1. Lake Hussainsagar: Drainage basin of Hyderabad and Satellite imagery of the lake



Further, under Japan Bank for International Cooperation (JBIC) funded Hussainsagar lake and catchment area improvement project, following actions are proposed to improve the environmental status of the lake ecosystem. They include (1) Interception and diversion of sewage at five points and establishment of second 50 mld Sewage Treatment Plant (STP); (2) Dredging five in-let zones to remove accumulated nutrients and toxic waste; (3) Lake shore improvement, (4) Nalla (In-let streams) improvement, (5) Strengthening the community based solid waste management in the lake basin and (6) Public participation in water quality monitoring.

Fig. 2. In-lets and depth profile of Hussansagar lake, Hyderabad, India.



To address basic problems of lake basin and water quality management, an integrated ecosystem approach as advocated by the Convention on Biodiversity (CBD) is proposed for conservation and sustainable management of the lake ecosystem. The approach needs synergy between technological interventions like Interception & Diversion (I & D) of sewage, setting of Sewage Plants (STP) and Common Effluent Treatment Plant (CETP) to treat industrial effluents and actions based on cost effective and eco-friendly eco-technologies like wetland developments, 'in situ' conservation measures, habitat regeneration through shore line development, restabilization of food chain/web through phyto-remediation and community participation in the management of the lake.

Key words: Urban lake, Ecosystem approach, Eutrophication, Conservation, Management interventions, Bioremediation.

2. Introduction

Hussainsagar, the picturesque lake situated between the twin cities of Hyderabad and Secunderabad, is an ecological and cultural landmark on the map of state of Andhra Pradesh, India (Fig.1). It was constructed in 1562 mainly to store drinking water brought from the river Musi, a tributary of Krishna, one of the major rivers of South India. The lake represents one of the thousands of impoundments on Deccan plateau in peninsular India, developed for storage of surface water run off in this semi-arid region with an average of 800 mm annual rainfall (Table 1).

Located 15°N 78°E, the lake is 510 mt. above the mean sea level (MSL) and bounded on west by Banjara hills. The 275 km^2 watershed of Hussainsagar is divided into four sub basins viz. Kukatpally, Dullapally, Bowanpally and Yusufguda. The highest peak in the catchment is at 642 m north and lowest contour near tank bund at 500 meters, the effective north south drop being 142 m covering a distance of 17 km.

The lake hydrology is sustained by four feeding channels (nullahs); Kukatpally (70 mld), Picket (5.7), Banjara (6) and Balkapur (13.3 mld). Of the four in-lets, Kukatpally with total catchment of 168 km^2 passes through two major industrial areas viz. Kukatpally and Balanagar and is the main feeding channel of the lake (Table 2).

Table 1. Physio-graphic features of lake Hussainsagar.

Year of construction	1562	Average depth	5.2 m
Basin area	240 km^2	Depth variable	1 to 12 m
Direct Catchment area	67 km^2	Storage volume (spill)	28.6 million m^3
Shoreline length	14 km	Maximum operating level	514.93 m
Maximum water area	5.7 km^2	Normal operating level	513.43 m
Capacity	27.1 million m^3	Road bund level	5.18.16 m

In the last few years intensive efforts have been initiated to restore the lake environment including management of lake basin and water quality. Further, protection of lake Hussainsagar in terms of improved water quality, control of pollution and beautification of its environment has assumed greater significance in view of its socio-cultural and tourism potential. In this context Asia's biggest monolithic Buddha statue standing majestically on the rock of Gibraltar in the center of the lake, has emerged as the major attraction like the Statue of Liberty in USA. The extensive development of lake environment with the help of National and International funding has bought Hyderabad on the tourism map of the world and the lake has emerged as the landmark representing socio-cultural ethos of the historical city and the region.

3. Issues and problems

3.1 Reclamation and encroachments: With phenomenal urbanization, once peripheral lake finds itself in the densely populated zone of the mega-city and in the last 50 years there has been drastic reduction in its morphometry due to encroachments and large scale reclamation for developmental activities around the lake ecosystem (Table 3). What stands today as the lake area is hardly 2/3rd of its original in the middle of last century.

In view of its ecological, economical and recreational importance conservation of lake Hussainsagar is high on the agenda of the State Government and to achieve the same, a special Buddha Purnima Project Authority (BPPA) was established in 2000 to look after the lake and its environment covering special development area of 902 hectares.

3.2. Pollution from sewage and industrial effluents: One of the major impacts of urbanization and industrialization on the lake was in the form of poor water quality due to pollution. Since beginning of the last century when lake basin was undergoing rapid change very little attention was paid to this vital issue. Thus, failure of lake basin management in terms of proper sewerage system and industrial waste disposal infrastructure was responsible for rapid degradation of lake environment.

Two sub-basins, Kukatpally and Dullapally, of the lake are highly industrialized zones. The Kukatpally sub-basin has three industrial areas viz, Kukatpally, Balanagar and Sanathnagar while in Dullapally one sub-basin, Jeedimetla, are developed as industrial hubs under a planned programme of industrialization. The range of products manufactured by 300 odd industrial units include chemical reagents, organics, pharmaceuticals, drugs, bio-chemicals, synthetic chemicals, detergents, aircraft

Table 2. Dry weather flows in to lake Hussainsagar.

Channel	Flow in mld			Remarks
	Sewage	Industrial effluents	Total	
Picket	05.7	-	05.7	Interception and diversion after pumping Proposed STP (30 mld capacity)
Kukatpally	55.0	15.0	70.0	Interception and diversion (I&D)
Banjara	06.0	-	06.0	Interception and diversion (I&D)
Balkapur	13.3	-	13.3	STP (20 mld capacity),
Total	80.0	15.0	95.0	50 mld treatment by 2 STPs

Table 3. Developments around the lake

Name	Area in hectares (acres)	Characteristics
NTR Garden	13.736 hectares (34 acres)	Greenery, Party zone, Recreation
NTR Memorial	0.81 ha. (2 acres)	Greenery and memorial of former Chief Minister Dr N.T.Rama Rao
Lumbini Park	2.025 ha (5 acres)	Floral clock, Fountain, Toy train, Recreation, Jetty for boating on the lake, Laser show
Sanjeevaiah Park	36.45 ha (90 acres)	Lung space, Sprawling garden, Palm garden, Recreational centre
P.V. Memorial	1.1745 ha (2.9 acres)	Memorial of former Prime Minister of India, P.V.Narsimha Rao
Necklace road	1.1458 ha (3.6 acres)	Garlanding road on rear side of the lake, recreational zone
People's plaza	1.4175 ha (3.5 acres)	Promenades and areas for exhibitions
Wetland eco-conservation zone	5.0615 ha (12.5 acres)	Great floral diversity, 'in situ' conservation, greenery

batteries, distillation products, alloys and rubber products and effluents generated bring in a cocktail of toxic waste in to the lake. Though interception, diversion and treatment of industrial effluents was undertaken as a part of management intervention, the volume of waste generated exceeds treatment capacity of CETP in the Jeedimetla area and toxic effluents continue entering the lake through Kukatpally stream, the main feeding channel.

3.3. Siltation from natural and cultural factors: Soil erosion due to construction activities in the catchment generates a lot of silt which along with the surface runoff ultimately ends up into the lake. Similarly, traditional festivals like *Ganesh* and *Durga Puja* conclude by immersion of massive idols of the deities in the lake. These events apart from addition of tons of silt also pollute the lake by floral offerings, paints, pigments, wooden and iron frames that go into making of idols, year after year.

3.4. Eutrophication: Lake Hussainsagar has been a subject of extensive research for the last 50 years and earlier reports on its limnology clearly indicate that up to 1950 it was virtually pollution free. Subsequent degradation of the ecosystem is directly linked to nutrient loading from domestic sewage, the magnitude of which could be assessed from a study that has estimated daily influx of 1041 kg of Phosphates and 1204 kg Nitrates in to the lake (Kodarkar *et al.,* 1991; Reddy *et al.,* 2002). Of the enormous amounts of nutrients entering the lake most are trapped in the sediment, while a fraction enters the food chain and webs sustaining eutrophic state of the water body (Zafar, 1959, 1966; Associated Industrial Consultant Pvt. Ltd., 1993).

Some of the perceptible manifestations of eutrophication are (a) Algal blooms and wild growth of aquatic macrophytes like water hyacinth, (b) Breeding of vectors, (c) Foul smells and (d) Fish kills (Kodarkar *et. al.,* 1991). The Pollution has also an adverse effect on the biodiversity of the lake and consequent disruptions in bio-geo-chemical cycling of organic load on the lake.

3.5. Ground water pollution: Due to inadequate treatment and disposal facilities, ground water pollution from seepage of effluents let out in open drains is a common phenomenon (Kodarkar *et al.,* 1991). For example, ground water along seepage zone of Kukatpally stream, the main feeding channel of lake Hussainsagar, is heavily polluted with all physico-chemical parameters exceeding the WHO and IS standards (Table 4).

3.5. Breeding of vectors: The nutrient-rich lake supports wild growth of aquatic weeds like water hyacinth and, in turn, provide ideal breeding sites for vectors (mosquitoes and snails) of diseases like Malaria, Dengue fever and Fileriasis. Lake pollution thus has a very heavy cost in terms of expenditure on public health.

3.6. Loss to lake dependent communities: Fishermen, washer-men and small dairy farmers are traditional lake dependent socio-economically backward communities and degradation of the lake has direct effect on their livelihood. Since studies in 1980s that indicated contaminated nature of fish, fishing activities in the lake are banned and once flourishing fishermen community has almost disappeared. Historically, the lake is a great community asset, particularly for floating population with no access to water and its pollution has deprived people at large ecological, economical and recreational benefits bestowed by a healthy lake ecosystem.

4. Strategies and Actions

In the South Asian context, lake management is relatively a young subject and unique by virtue of its highly interdisciplinary and cross-sectoral nature. Since 1990 after pollution of Hussainsagar reached an alarming proportion, culminating in to massive fish kills of 1993, otherwise complacent State Government was forced in to action. Credit for this turn around also should go to civil society movements and Judicial interventions in response to Public Interest Litigation (PIL).

Apart from earlier actions for conservation of the lake, presently Hyderabad Urban Development Authority (HUDA) with support from Japan Bank of International Cooperation (JBIC) has initiated an ambitious project titled Hussainsagar

Table 4. Ground water quality in the Kukatpally Industrial area in the catchment.

Parameter	WHO	IS	Average	Range
pH	7.5	8.5	8.06	7.3 - 9.0
TDS	500	500	827	435 - 1531
Alkalinity	-	-	313	200 - 475
Hardness	150	300	249	160 - 440
Sulphates	400	250	618	242 - 985
Nitrates	45	20	57	40 - 90
Nitrites	-	-	2.3	0.12 - 5.8
Phosphates	0.1	0.1	0.48	0.11 - 0.68
Chlorides	250	25	358	10 - 760

All values except pH in mg/L.

lake and the catchment area improvement initiative in 2006. The 3700 milloin US $ (370 crores :1 Crore = 10 millions) project has following important components:

A. Interception and down stream diversion of sewage and industrial effluents:

At six locations along the main in-flow channels I & D weirs are proposed to prevent pollution of the lake from sewage and industrial effluents.A.

B. Establishment of a proposed and up-gradation of existing Sewage Treatment Plants (STP):

To sustain hydrology of the lake in 1998 an STP of 20 mld capacity was commissioned, treated water from which is let in to the lake to sustain its hydrology (Table 5).

Further, a second STP of 30 mld capacity is planned at the entry point of Picket stream. With this total 50 mld of treated water will be let in to the lake for sustaining its hydrology (Table 5). This measure is also expected to improve the lake water quality to the level of SW-II; suitable for bathing, contact water sports and commercial fishing (Table 6).

C. Lake shoreline improvement:

1.2 km stretch will be developed by beautification of lake front through development of paved walk ways, railings, fountains, pavilions.

D. Dredging of 1,000,000m^3 silt:

Massive removal of sediment in the 500 m radius from 4 nalla confluence is proposed to reduce nutrient and toxic waste load on the lake.

E. Solid waste management:

A comprehensive programme of collection and disposal of solid waste from catchment localities and lake environment will be implemented with the help of community participation to rid the lake of solid waste pollution.

F. Environmental awareness and community participation:

The lake environ has been promoted as people's plaza for socio-cultural events. Annual lake festival and establishment of Lake Interpretation Centre (LIC) for spreading awareness about benefits from the lake and it's role in the over all water economy of the city. A lake information centre will be established to propagate the environmental awareness among visitors and communities around the lake.

5. Ecosystem Approach

Ecosystem approach underlines the idea of facilitating the nature to sustain structural and functional integrity of natural ecosystems. Too much anthropogenic pressure beyond carrying capacity of natural ecosystems is identified as the basic cause for their constant and sometimes irreversible degradation. Internationally, Convention on Biological Diversity (CBD) was perhaps the first effort to integrate ecology with management of natural and man-made ecosystems on the earth. Article 2 of the Convention, while elaborating on Ecosystem Approach has defined "Ecosystem" as a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use

Table 5. The water quality before and after treatment by the STP.

No.	Parameter	Influents	Effluents	% reduction	Limits
1.	pH	7.15	7.51	-	7 - 8
2.	Suspended Solids	252	20	92	30
3.	BOD	250	8	96.8	20
4.	COD	540	46	91	250
5.	Phosphate	5.9	2.5	58	5
6.	TKN	48	5	90	100

Table 6. Central Pollution Control Board (CPCB) water quality standards/norms.

Parameter	Surface wetter quality of Hussainsagar lake, Hyderabad	Water use SW-II (Bathing)	CPCB revised criteria		
			A Excellent	B Desirable	C Acceptable
pH	7.6	6.5-8.5	-	-	-
BOD	30-48	<3	<2	<3	<6
DO	0.99	>4	>90%	>80%	>60%
Turbidity	High	<30	-	-	-
Coliform count	>1600	<100	<20	<200	<2000

in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems.

The ecosystem approach underscores the importance of basic principles on which ecosystems function and emphasizes the socio-economic dimensions of nature management when implementing the CBD. It further advocates that human life, activities and well-being must be included as basic factors in the wider geographical application of the ecosystem approach. Biodiversity has to be integrated into the economy of the relevant communities, and the various values of biodiversity should be captured and realized at the local level to give the right incentives to those that are nearest to guard it.

At the heart and soul of ecosystem approach is the biodiversity which is the life insurance of life itself. The intra-specific diversity is the insurance for the species survival in difficult times, the inter-specific diversity is the guarantee for ecosystem functioning and services, and the variation of functional ecosystems is the life insurance for sustainable development.

6. Ecosystem Approach and Conservation of Hussainsagar Lake

A review of conservation efforts on Hussainsagar undertaken so far with National and International funding clearly bring out the fact that most of the work done is of civil engineering nature and did not comprehensively address two basic issues viz. lake basin and water quality managements.

The basin of Hussainsagar lake is highly urbanized and heavily industrialized. Further, lack of comprehensive management of sewage and toxic industrial liquid and solid waste are the basic reasons for environmental degradation of the lake ecosystem. There is also a historical perspective to this situation; after independence of India, industrialization was considered as the major activity to generate employment and work for millions. Secondly since developments were mainly concentrated in the urban areas, population from impoverished countryside migrated in large numbers to urban centers in search of better livelihood. These developments led to large-scale development of urban centers and when such developments happened in the catchment of rivers and lakes like Hussainsagar, the water bodies were the victims of pollution and environmental degradation.

Actions proposed based on ecosystem approach:

I Lake basin management:

A lake is reflection of its catchment and the developments in the latter has a direct bearing on the status of the former. Such developments in the catchment include urbanization, industrialization, solid and liquid waste generation and topographical alterations affecting the in-lets channels draining the catchment. Lack of proper lake basin management invariably leads to sewage, industrial effluents and solid waste finally ending up in to the water body. Thus eutrophication, toxification of water and siltation are direct results, in turn, leading to reclamation and loss of precious water body. In the last 50 years hundreds of lakes are lost all over the country.

A. Sewage management: Decentralization of sewage management and introduction of septic tank system could reduce sewage related problems of eutrophication. Further, wherever possible emphasis should be on recycle and reuse of sewage as a resource.

B. The catchment topography needs to be protected so that rain water flows in to the lake to sustain its hydrology. Laying of proper sewage network is necessary and separation of sewage lines from storm water drains needs priority.

C. For reducing pressure on water supply system rain water harvesting, recycle and reuse needs to be given priority.

D. Industries should be encouraged to adapt zero discharge policies through effective use of water in its processes.

E. Common Effluent Treatment Plant (CETP) to treat effluents through public-private partnership should be encouraged to minimize effluent load on the lake.

F. Sewage Treatment through STP needs to be complemented through introduction of cost effective eco-technologies for restoration of the lake water quality.

II Water quality:

Restoration of water to the quality to SW-II level so as to use the lake for its intended purpose is at the heart of conservation of Hussainsagar. This needs actions to reduce nutrient load and toxic materials through remedial measures both at catchment and water body levels. Following are suggested actions for improvement of water quality in the lake.

A. Maintenance of bio-conservation zone:

A well de-marked bio-conservation zone around the lake extending between 100 to 1000 meters in width depending on topography, will act as an effective barrier to moderate the negative impacts from developmental activities in the

lake environment. In this eco-sensitive zone only plantation and other eco-friendly activities should be allowed.

B. Treatment of sewage in the course of its flow in to the lake by Green Bridge filtration system:

It can be integrated as a part of nalla (stream) improvement proposed in the JBIC funded project. As effective as STP, the green bridge technology is not only cost effective and eco-friendly but also effectively treat entering sewage to the SW-II grade quality as recommended by the Ministry of Environment & Forests (MOEF), Government of India (GOI) in its revised guidelines for National Lake Conservation Programme (NLCP).

Construction of Green Bridge Filtration System (GBFS): The system consists of an easy four step filtration process involving a green Bridge and linearly arranged three stages of the fine gravel (size 10mm to 40mm), the course gravel (size 40mm to 60mm) and the large sized gravel. The Green Bridge filter consists of layers of Coir over which a bed of floating aquatic weeds (eg. water hyacinth) are compactly woven to form a bridge. All the floatable and suspended solids are trapped in this biological bridge and the turbidity of water is reduced. The aquatic weeds are very efficient at nutrient stripping. The over-flowing sewage passes over three sections of gravels during which microbes and algae remove the nutrients. Finally, the filtered water is sent to a pond where the organic matter will settle down by the process of sedimentation and clear water will flow into the lake.

C. Micro habitat and feeding ground along shore line:

Shore line along margins of a lake generates feeding habitats and help in reducing nutrients due to development of benthic food chain/web. In the case of lake Hussainsagar such habitats can be created along shore line; particularly the zone from where watermen community is relocated down stream. Such sand-gravel shore line provides habitats for development of micro and macro-benthos and create feeding ground for resident and migratory birds visiting the lake.

D. Phyto-remediation:

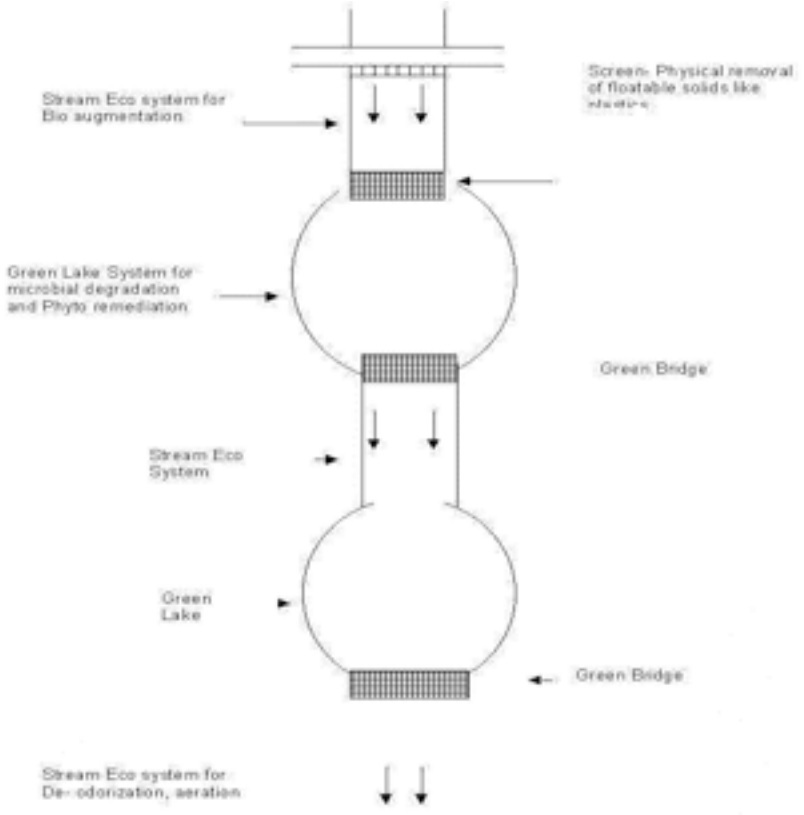
Macrophytes in the lake are important components of biotic community and should not be viewed as a menace. These species basically absorb nutrients and toxicants from the water thus improving its quality. If allowed to grow in controlled manner and regularly harvested and composted, there is a great possibility of utilizing this natural resource for improvement of lake water quality. Allowing towable flotillas of weeds like water hyacinth and other floating species will not only enhance beauty but also rid the lake of excess of nutrients and toxic materials.

E. Introduction of composite fish culture:

Fishes constitute very important biotic community in a lake. They not only harvest nutrients and live biomass but also provide much needed proteins. Hussainsagar lake once used to harbour 27 species of fishes. However, recent survey has reported existence of only few species of hardy cat fish belonging to the genera *Channa, Clarias, Mystus, and Heteropneustes.* Another cause of great concern for future of fishery in the lake is clandestine introduction of the invasive species of African catfish, ***Clarias gariepinus***

Once the lake use to support flourishing fishermen community but with on-set of pollution and reports of contaminated fish, the fishery was banned. There is a need to reassess the situation and introduction of large scale composite fish culture. To begin with some controlled cage culture can be introduced to begin with and based on the results fisheries should be introduced on large scale.

Figure 3. Green Bridge sewage filtration system



F. Aeration:

Low levels of Dissolved Oxygen (DO) often lead to anaerobic conditions, interruption of normal bio-geo-chemical cycling of energy and matter and reduction of biodiversity. Aeration in such situation can improve DO levels and thereby reduction of BOD of water.

G. Establishment of lake conservation society *(Hussainsagar Sarovar Samvardhini)* to ensure peoples participation:

It is envisioned as a common platform to bring together diverse stake holders on a common platform to develop common action plan, sectoral conflict resolution and a mechanism to create environmental awareness.

7. Lessons Learned

In India a number of initiatives with the help of National, International and private funding are being undertaken for conservation of lakes. A look at the actions implemented under these programmes brings out a common pattern in which funds are mainly utilized for beatification of lake environment which includes a number of civil engineering actions like strengthening of bund, laying of ring roads, developments of gardens, pathways, promenades etc. and other recreational facilitates. The two key aspects as outlined by International Lake Environment Committee (ILEC) Foundation, Japan, viz. lake basin management and water quality issues are not adequately addressed. Further, these actions lead to transformation of a lake in to tank with loss of self-sustaining capacity of the ecosystem. Unlike a lake, tanks need maintenance and finances are seldom allocated for such activity. Thus, key to successful lake management lies on approaching conservation based on an integrated ecosystem approach.

Traditionally in India water sector is dominated by the people with engineering and technological backgrounds who often have very less knowledge about the ecological functions that sustain structural and functional integrity of ecosystems like lakes, reservoirs and wetlands. Further, in conservation and management actions cost intensive technological solutions are often over emphasized. This imbalance at decision making and execution levels comes in the way of integrating alternate approaches. The difficulty with ecological solutions is, they are cost effective and benefits generated are invisible in a system where big (budgeted work) is beautiful and politically attractive (for getting votes in the elections). On this backdrop an integrated ecosystem approach advocated by CBD has a potential to generate a synergy between technological solutions and solutions based on ecological principles. An emphasis on such an integrated approach by National Government and International funding agencies can make a difference.

8. Reference

Anitha, G., Chandrasekhar, S.V.A. and Kodarkar, M.S. (2005) Hydrography in relation to benthic macro-invertebrates in Mir Alam lake, Hyderabad, Andhra Pradesh. Rec. Zool.Surv. India. Occ. Paper No.235 : 1 - 148.

Associated Industrial Consultants Pvt. Ltd. (1993) Hussainsagarlake, Hyderabad. The profile of a highly eutrophic lake. Vol.7,No:10.

Hyderabad Urban Development Authority (HUDA) (2005) National seminar on Management of urban lakes - 1-2nd December, 205. Proceedings. PP : 28.

ILEC (2005) Managing lakes and their basins for sustainable use: A report for lake basin managers and stakeholders. International Lake Environment Committee Foundation. Kusatsu, Japan.

Kodarkar, M.S. (1995) Conservation of lakes, case study of five lakes in and around Hyderabad, Andhra Pradesh, India. Publ. 3. Indian Association of Aquatic Biologists (IAAB), Hyderabad. PP : 85.

Kodarkar, M.S. and Sandeep Joshi (2006) Conservation and management of lakes in urban environment; bioremediation a new frontier in the control of eutrophication in urban lakes. Proceedings. Vol. II, World Lake Conference Nairobi, Kenya. PP : 79 - 82.

Kodarkar, M.S., Sandeep Joshi and Bhatnagar, Manu (2005) conservation and management of lakes in urban environment: bioremediation, a new frontier in the control of Eutrophication of urban lakes. 11th World lake conference, Nairobi, Kenya : 31st Oct to 4th Nov. 2005. Abstract. P- 24.

Reddy, R.C., P.S.Kelkar, R.R.Rao and S.P.Pande (2002) Eutrophic status of Hussainsagar lake in Hyderabad. Insitutte of Engineers (IE) Journal EN. , 83 : 14 - 19.

World Bank (2005) Lessons for managing lake basins for sustainable use. Environment Department Report No. 32877. Washington, DC: World Bank.

World Lake Vision Committee (2003) World lake vision. Kasatsu, Japan. International Lake Environment Committee and International Environment Technology Centre (IETC), United Nations Environment Programme (UNEP).

Zafar, A.R. (1959) Taxonomy of lakes. Hydrobiologia, 13(3): 187 - 299.