Sengupta, M. and Dalwani, R. (Editors). 2008
Proceedings of Taal2007: The 12th World Lake Conference: 1699-1706

Bangalore Lakes – Issues and Perspectives on Pollution, Restoration and Management

Aboud S. Jumbe, N. Nandini, Sucharita Tandon, Sunitha N.
Department of Environmental Science, Bangalore University, Jnanabharathi Campus, Bangalore 560056
Email: aboud.jumbe@gmail.com, *Nandini.sai@rediffmail.com, sucharita_apr11@yahoo.com*

ABSTRACT

The environmental conditions of any lake system depend upon the nature of that wetland and its exposure to various environmental factors. These fragile ecosystems must maintain the state of environmental equilibrium with the existing surroundings – particularly from a special perspective of human encroachment and pollution. Even though various efforts are now being undertaken in checking the level of environmental degradation facing these urban lake systems as a result of encroachment, reclamation, sedimentation, weed infestation, land reclamation, untreated sewage and industrial effluent discharges, sand mining, and deforestation around them, still the picture looks gloomy for many of these water bodies in the Bangalore city. Pollution of lake systems in Bangalore has been largely attributed to the rapid and uncontrolled expansion of the built-up areas for many years now. Also, the increasing demand on land for development has resulted in many surface water catchments areas of urban Bangalore to be dried out and reclaimed. Some lakes have been heavily affected by farming activities including pesticides and fertilizers. The environmental pressure on our aquatic systems will only be properly tackled if the main issues of encroachment and management of domestic and industrial discharges were addressed. Solving the problem at end point is a temporary measure with more serious repercussions. The solution is to tackle this problem at source points with strict enforcement of our environmental laws and regulations. But until that happens, the "City of Lake" will soon be history.

Keywords: *Eutrophication; Encroachment; Nitrate toxicity; Algal blooms; Lake Development Authority; Bioremediation; Ecological engineering*

INTRODUCTION

Lakes and tanks are known to be the ecological barometers of the health of a city. They regulate the microclimate of any urban center. The presence of a lake, in any region, greatly influences the life of people living adjacent to it. Lakes are considered to be important with reference to climate, fisheries, trade, traveling, irrigation, and recreation. The naturally undulating terrain of Bangalore city, with its hills and valleys, lends itself perfectly to the development of lakes that can capture and store rainwater. Each valley at the ridge top gives birth to small streams. These cascade down to form three major watershed systems, namely the: The Hebbal valley; the Koramangala-Challaghatta valley; and the Vrishabhavati valley. This peculiar trend form chains of small and medium size reservoirs that play a very important role in urban ground water recharging network. Urban aquaculture and agricultural activities solely depend on the availability of these water impoundments and their tributaries.

The environmental conditions of any lake system depend upon the nature of that wetland and its exposure to various environmental factors. Their fragile ecosystem must maintain the state of environmental equilibrium with the existing surroundings – particularly from a special perspective of human encroachment and pollution. Even though various efforts are now being undertaken in checking the level of environmental degradation facing these urban lake systems as a result of encroachment, reclamation, sedimentation, weed infestation, land reclamation, untreated sewage and industrial effluent discharges, sand mining, and deforestation around them, still the picture looks gloomy for many of these water bodies in the city.

However, the city's population has already touched 6.5 million, with a daily floating population of 15 lakh, at present Bangalore spreads over 500 sq km. If current projections are correct, Bangalore will spread over 1,000 sq km by 2011 and cross 1,500 sq km area by 2025 to accommodate a 10 million-plus population. This is the ever rising concern in the race to save existing lakes of the city.

History of Formation of Bangalore Lakes:

The earliest record of construction of artificial surface water catchments areas of metropolitan Bangalore dates back to the latter part of the 16th century, when the founder of Bangalore, Kempegowda built the Ulsoor tank covering a huge area of 125 acres for the sustenance of Petta. The British administration then maintained and improved the lake which met the water needs of the city for as long as 200 years. Water from other lakes such as

Sankey, Miller's, Sampangi was also used by the people for their water requirements.

Historically, the lakes of Bangalore were a result of a great work of genius from our ancestors. The earliest instance of tank construction in Bangalore dates back to 16th century, when Kempegowda started impounding water catchment areas – a cradle of origin for today's Bangalore. For Kempegowda, the monsoon rains became the natural asset for sustaining his people and kingdom with what we know today as the municipal water supply system. Moreover, these impoundments helped in checking floods, recharging and maintaining the ground water table, and establishing agricultural activities. A century later the British, impressed by the pristine local climate and a great work of indigenous municipal water supply engineering, made this man-made oasis into an all-season military garrison for their own empire. Thus we see how Bangalore was born out of a rain water harvesting. Over the centuries, Bangalore continued to maintain its unique status as the city of gardens and lakes. Tourists from all over the world flocked in to appreciate a rare wonder of mutual co-existence between human and nature. Even after Independence, Bangalore enjoyed a special status as a zone of tranquility and environmental peace. But it was only a matter of time before the urban wetlands of Bangalore were to start off on a long and a painful journey towards the most horrifying form of environmental degradation and pollution ever witnessed by the local standards.

Causes of Pollution in Bangalore Lakes

Pollution of lake systems in Bangalore has been largely attributed to the rapid and uncontrolled expansion of the built-up areas for many years now. Also, the increasing demand on land for development has resulted in many surface water catchments areas of urban Bangalore to be dried out and reclaimed. Some lakes have been heavily affected by farming activities including pesticides and fertilizers.

Major Drainage Patterns of Bangalore Lakes:

The lakes in Bangalore form a chain of hydrological connection through them. The flow of water runs from North to South-east as well as South-west along the natural gradient of the land. During monsoons, the surplus water from the upstream lake flows down into the next lake in the chain and from there further down. This connectivity did not allow an overflow of water out of the lake into the surroundings area as additional quantity of seasonal water was transferred to other lakes. The lakes thus form a chain of reservoirs in each of the three valley systems of Koramangla, Vrishabhavathy, and Hebbal. Each valley at the ridge top gives birth to small streams. These channels then cascade down to form major stream systems in three valleys. Each of the city's three valleys — Hebbal in the north, Koramangala in the east and Vrishabavathi in the southwestern zone is broken up into two series, which in turn comprise several lakes. These lake series have intra and inter-valley links too. The entire network facilitates the downward flow of excess water from lakes in the upper ridges. In this manner, water is distributed evenly and the water bodies are kept alive perennially.

Bangalore Lakes Census:

According to Karnataka State Pollution Control Board, records show that till 1960 there were 262 major water bodies in Bangalore. Today the figures have declined to about 81 of which 34 are recognized as live lakes. These figures denote a reduction of water bodies as high as 35.09%, while in terms of water spread area it shows a decrease of 8.66 percent. Satellite data collected by the Bangalore Metropolitan Region Development Authority in 2001 reveals that the city has as many as 2,789 lakes in various stages of decay. They vary in size from 2 hectares (ha) to 50 ha, and have a total water spread area of 18260.48 ha.

MAJOR CAUSES OF DEGRADATION OF LAKE SYSTEMS IN BANGALORE

The Rapid growth of human population, proliferation of buildings, roads and vehicular traffic congestion in Bangalore has taken a heavy toll of wetlands including lakes. Further, encroachment and illegal waste disposal activities and bad management have threatened the very existence of many of the valuable and productive wetland habitats in the city. As a result the lakes are polluted from two major sources: the point source pollutants and non point source pollutants. Pollution coming from the point source contaminants include excessive nutrients from wastewater coming from municipal and domestic effluents; organic and toxic pollution from industrial effluents; and storm water runoff. Pollutants entering from non- point sources include nutrients through fertilizers, toxic pesticides and other chemicals, mainly from agriculture runoff; organic matter pollution from human settlements spread over areas along the periphery of the lakes and reservoirs

Degradation of lakes forms another major part of the environmental problem. For example, the silting of lakes on account of increased erosion as a result of expansion of urban and agricultural areas, deforestation, road construction and such other land disturbances taking place in the drainage basin; diversion of streams and channels feeding the lakes reducing their sizes; competition arising for using lake water such as for irrigation, degradation of catchment areas, immersion of cultural idols; and growth of invasive species such as water hyacinth.

THE LAKE EUTROPHICATION

Eutrophication is caused by the enrichment of a lake with chemical nutrients, typically compounds containing nitrogen or phosphorus. Eutrophication is a major form of lake pollution because it promotes excessive plant growth and decay, favoring certain weedy species over others, and causes severe water quality problems and depletion of dissolved oxygen. In the lakes, the enhanced growth of choking aquatic vegetation or phytoplankton (that is, an algal bloom) disrupts normal functioning of the lake ecosystem, causing a variety of problems. Consequently, eutrophication decreases the resource value of the lakes affecting water quality, aquaculture, and even aesthetic activities. Health-related problems can occur where eutrophic conditions interfere with drinking water treatment

Sources of Lake Eutrophication:

Sewage is the major source of nutrients worldwide. This can be treated by establishment of sewage treatment plants. Moreover, fertilizer leachates of largely Nitrogen and Phosphorous which are designed to boost plant productivity end up destroying the water quality and biodiversity of a lake system. The general urban run-offs carrying detergents accelerate eutrophication and hence the death of a lake biodiversity. Urban Monsoon floods increase the water levels in various waterways and drains. The flushing and scooping phenomenon of the storm water take with it highly enriched organic matter.

Effects of Eutrophication:

The effects of eutrophication include changes in algal blooms and species composition. This increases water turbidity, supersaturation with Dissolved Oxygen in the daytime. Some algal species produce toxins, notably the blue green algae which become dominant eutrophication proceeds. Excessive nutrient inputs also alter the macrophyte composition. Initially, some tolerant species may flourish, but after the dissolved has been used up for decomposition of organic matter, the species begin to die out. Severe macrophyte loss with only a few emergent species, or none at all, characterize badly eutrophic habitats. Eutrophication also causes sediment changes. Death of phytoplankton blooms and macrophyte decay all add up to the consequences of eutrophication.

Eutrophication Causes Decreased biodiversity:

When an ecosystem experiences an increase in nutrients, primary producers reap the benefits first. In lake ecosystems, species such as algae experience a population increase (called an algal bloom). Algal blooms limit the sunlight available to bottom-dwelling organisms and cause wide swings in the amount of dissolved oxygen in the water. Oxygen is required by all respiring plants and animals and it is replenished in daylight by photosynthesizing plants and algae. Under eutrophic conditions, dissolved oxygen greatly increases during the day, but is greatly reduced after dark by the respiring algae and by microorganisms that feed on the increasing mass of dead algae. When dissolved oxygen levels decline to hypoxic levels, fish and other aquatic organisms (zooplanktons) suffocate. As a result, fish and other bottom dwellers die off.

Eutrophication accelerates invasion of new species:

Eutrophication may cause competitive release by making abundant a normally limiting nutrient. This process causes shifts in the species composition of ecosystems. For instance, an increase in nitrogen might allow new, competitive species to invade and out compete original inhabitant species.

Eutrophication and Algal Bloom Toxicity

Some algal blooms, otherwise called "nuisance algae" or "harmful algal blooms," are toxic to plants and animals. Toxic compounds they produce can make their way up the food chain, resulting in animal mortality. Freshwater algal blooms can pose a threat to livestock. When the algae die or are eaten, neuro- and hepatotoxins are released which can kill animals and may pose a threat to humans.

Eutrophication and Nitrate Toxicity:

Nitrate (NO_3) has been shown to be toxic to human babies. This is because bacteria can live in their digestive tract that convert nitrate to nitrite (NO_2). Nitrite reacts with hemoglobin to form methemoglobin, a form that does not carry oxygen. The baby essentially suffocates as its body receives insufficient oxygen.

AN OVERVIEW ON THE STATUS OF WATER QUALITY ON BANGALORE LAKES

While a number of lakes have successfully been restored and maintained on the long run (Ulsoor, Lal Bagh, Sankey, Agara Kere, Hebbal, Venganaih Kere, Mathikere, Madiwala, etc), more other number of lakes have continued to deteriorate. Field observation confirms that even in some of these restored lake systems, there are signs of recurring trend of pollution and degradation. The study by Department of Environmental Science, Bangalore University on water samples collected from selected water bodies in all three valley systems (Hebbal, Koramangla, and Vrishabavarthy) around Bangalore City show that the for more than two thirds of the 70 water samples collected on monthly basis, the pH is above 8;

Turbidity levels vary between 5 and 10 NTU; with all lakes severely affected by total solids and organic matter. Color is at 20 Hazen units for almost all bodies showing highest level of pollution. Total Hardness is above the permissible limit of 300mg/L. Chlorides have also been found to be above the permissible limit. Levels of Phosphates were above permissible levels for more than 40% of the samples. Dissolved Oxygen (DO) levels for the same number of lakes were below 4 mg/L with highly variable degrees of Biochemical Oxygen Demand (BOD) and the Chemical Oxygen Demand COD).

Heavy Metals Contamination:

The presence of heavy metals in the lakes indicate a new threat of environmental pollution caused by heavy metals in the urban surface water systems. For example, preliminary studies carried out by the Department of Environmental Science on heavy metals analysis in these lakes have revealed presence of significant levels of Lead (Pb), Nickel (Ni) and Cobalt (Co), Iron (Fe), Manganese (Mn) and Zinc (Zn) in numerous urban lakes including Yellamallappa Chetty Lake, Bellandur, Hebbal, Karihobanahalli and Madiwala lakes. It is ironic to note here that Madiwala Lake, which recently was a successful case study for lake restoration and ecological engineering as was Hebbal, and Agara Kere, faces a new challenge of sewage pollution from the surrounding layouts from illegal Sewage lines causing a foul smell and multiplication of Water Hyacinth.

Sewage and Water Hyacinth on Urban Lakes:

Similarly, another successful case study of lake restoration in Bangalore, Agara Kere, also faces an impending challenge from the diverted sewage line which runs parallel to the lake on the western side. Here, the rising levels of sewage water are threatening to inundate the northern outlet leading towards Bellandur valley. Hebbal is another case example of the challenges of lake restoration. At the moment, the lake is undergoing a second restoration attempt costing tens of crores of rupees. Just recently, before this restoration phase started, the lake was completely covered with Water Hyacinth causing an indefinite halt in boating activities. The bulk volume of waste water entering the Hebbal lake Wetlands for natural dilution before entering the lake on the western side seems to overwhelm the carrying capacity of the wetland to maintain the ecological balance. In some inflow points of the lake, the water looks greasy. Farmers harvest the grass from these wetlands for fodder. They also let their animals feed on this dangerous wet field. This might cause health risk to both the animal and human beings. Even in the wake of its new restoration attempt, the sub-surface levels of Sulphates are alarmingly higher.

Lakes and Encroachment:

Encroachment has been another biggest crisis facing lakes in Bangalore. Hectares upon hectares of the former agricultural fields that once surrounded Bellandur village on the southern side of the lake are now busy construction sites for new real estates. This is also a similar trend in the western and southern side of Hulimavu lake, once a pristine water system with natural clean quality. Encroachment of Malathalli and Ullal tanks located to the west of the city has already begun to accelerate the degradation of these tanks. Nevertheless, Hosakere Tank in Kengeri Uppanagar faces similar fate. Earlier, villagers used to boast about how clean the lake was to an extent that they would directly drink from the tank. But situation has changed now with falling levels of Dissolved Oxygen and an increasing Biochemical Oxygen Demand.

Vatur Lake and Nitrates Toxicity:

Vartur lake is an exceptionally clear example of excessive use of Nitrates as agricultural fertilizers. Although Nitrates can be caused by other leaching effects of septic tanks and sewage, here in Vartur, the major problem is the use of fertilizers especially for Horticultural activities. Samples collected from various sampling points of the agricultural area on the banks of the tank reveal excessive presence of Nitrates above its permissible 50mg/L level. The situation is more alarming in the ground water. Here, further studies are needed to assess the levels and effects of Nitrates found in Ground Water on the people living around the Vartur Lake. Nitrates can cause a “Blue-Baby Syndrome” for infants 6 months old.

Contamination of Yellamallappa Lake with Sewage:

Yellamallappa Chetty lake symbolizes another environmental hazards emanating from the lake. The lake is largely used for fishing purposes but also home to a number of industrial units in the neighborhood. The visual quality of this lake is enough to conclude that this lake is now hazardous for any economic activities related to human consumption such as fishing, bathing, and for other domestic use. Industrial effluents are discharged here along with the waste coming from the fish market. Sewage pipes from undisclosed locations have been located in some points of the lake. People in this area have been complaining of food poisoning cases.

But it is in Peenya Industrial Area where effects of chemical pollution manifest themselves in greater proportions. Studies carried out recently on Karihobanahalli tank reveals the effects of excessive dumping of industrial waste and discharge. Here the samples collected show higher levels of Sodium

crossing 500 mg/L at some points. Total Hardness at three times its permissible level, Chlorides and Fluorides above the limits, with Fluorides reaching 2.0 in some instances. With higher levels of Sulphates, Total Dissolved Solids and Bicarbonates, Karihobanahalli has the poorest conductivity value of all lakes in Bangalore.

THE TRENDS TOWARD RESTORATION OF BANGALORE LAKES

In 1995, the National Lake Conservation Authority (NLCA) came up with National Lakes Conservation Plan for Bangalore, specifically aimed at raising the highest state of environmental alarm for dwindling quality of the remnants of the city's lakes. The report called for the implementation of the recommendations of the N. Lakshman Rao Commission which was set up by the Karnataka State Government in 1986. The N. Lakshman Rao Commission conducted a rapid survey and listed the general status of the existing lakes and the problems they faced. The commission, alarmed at what it saw as the unimaginable destruction of Bangalore urban wetlands, recommended that the city' lakes be handed over to the Karnataka State Forest Department for immediate protection and preservation. In addition, the Commission also recommended that the Principles of Ramsar Convention on Wetlands should be effected to Bangalore lakes at once. Census on various species of migratory birds was made the principal environmental indicator tool for rapid assessment of the health of the urban lake systems. The first census was carried out in 1989 and repeated in January 1995. Since then Bird's census on the city's wetlands has been ingrained in several areas of the Bangalore conservation community. This people involvement in efforts for conservation and restoration of city's lakes was gazetted for the first time in Bangalore in February 11, 1988 as per the N. Lashman Rao's recommendations.

The Forest Department was handed over a total of 81 lakes around the city. This handing over was officially effected in 1991. The process of handing over was completed in 1994. Out of this 81 lakes, fencing work was done for only 34 (42.5% of the total lakes handed over); and out of this 34, only 8 lakes were selected for extensive ecological engineering works such as desilting, afforestation, and recreation facilities. This was done between 1994 and 1995.

The National Lake Conservation Plan for Bangalore came with the new theme of "*Integrated Lake Ecology with Water Quality.* This plan aimed at improving urban sanitation and health conditions, especially for the weaker sections of the society living within the lake catchment area. The plan also called for eco-friendly, low-cost, waste management bio-systems like "engineered wetlands". A total of 4 sub-systems comprising of around 20 lakes were selected for the first phase of the NCLP. These four sub-systems included Agara Lake System (Hulimavu, Doddabegur, Madiwala, Puttenahalli; Agara Kere); Hebbal System (Narasipura I and II; Dodda Bomassandra, Hebbal Kere, and Nagavara); Bellandur Lake System (Ulsoor, Bellandur, Vartur); and Dorekere System (Vasanthapura, Janardhana, Dorekere, Moggekere).

The proposal specified the following tasks for restoration: desilting of lakes, fencing around the lakes, afforestation and gardening, sewage water treatment, interception chambers, diversion channels, oxidation ponds, deweeding of lakes, community sanitation, solid waste and garbage disposal, recreational facilities. This was to be a five-year phasing project (1995 – 2000) divided into Catchment Area Development (CAD); Sewage Diversion Channels; Desilting and Weed Control; Facelifting of a Lake; Biological studies and public awareness program; land acquisition, and others. The total cost was estimated at Rupees Twenty-One Crores, Twenty Lakhs, and Thirty-Five Thousands (21, 20, 35,000)

RESEARCH AND MONITORING BY KARNATAKA STATE POLLUTION CONTROL BOARD (KSPCB)

In late 2000, the Research and Development Wing of the Karnataka State Pollution Control Board (KSPCB) published its report on comprehensive monitoring of lakes and tanks in and around Bangalore Metropolitan Area to assess the state of the water quality. This was an interesting report given the weight of the output carried after the first phase of the city's lakes restoration process. KSPCB's results as a result of water quality monitoring on 44 selected lakes (including all but 2 in the NLCP list) revealed that most lakes still remained highly polluted.

Untreated sewage coming from missing sewage links from these new layouts had begun to reach the watershed lines of these lake systems and diffusely but cumulatively causing pollution havoc. It was also revealed in the report that the city was undergoing a sewage management crisis. The missing links were forming bypasses and such bypasses of effluents generated from within the catchment area were not reaching the sewage treatment plants. The Bangalore Water Sewerage and Supply Board (BWSSB) were overwhelmed with mushrooming layouts without proper planning.

KSPCB's report also called for a multi-stake holder concerted approach to tackle the new wave of lake pollution. It called on the BWSSB, the Bangalore Development Authority (BDA); Bangalore Metropolitan Regional Development Authority (BMRDA); Bangalore Mahanagara Palike (BMP); Zilla Panchayat; and the Forest Department

to invest equal efforts in protection, preservation, and conservation of the city's lakes. Finally in July 2002, a new authority, unique by Indian standards was established to pioneer a multi-stake holder coordination between the above agencies in a new wave of tackling the lake degradation and pollution.

THE ESTABLISHMENT OF LAKE DEVELOPMENT AUTHORITY

The Lake Development Authority, (LDA), an autonomous body instituted in July 2002, took charge of the existing reinvigoration plan that was earlier recommended by N. Lakshamn Rao Commission and partly implemented by the NLCA and the Central and State Pollution Control Boards. Its task was to play as an important axis in the drive for lake restoration and management program by acting as a nodal point for convergence of all responsible agencies such as the BWSSB, the Bangalore Development Authority (BDA); Bangalore Metropolitan Regional Development Authority (BMRDA); Bangalore Mahanagara Palike (BMP); Zilla Panchayat; and the Forest Department.

The LDA identified about 60 lakes for immediate restoration soon after it was established. This program , like the NCLP one previously was proposed to be a five year phasing project costing Rs. 250 Crores, almost ten times the estimated cost proposed by the NLCA in 1995. These selected lakes included Ulsoor lake, Sankey tank, Agara lake, Narasipura lake, Lal Bagh lake, Dodda Bamasandra lake, Hebbal lake, Nagavara lake and Bellandur lake. The LDA's main objectives were: Resuscitation of lakes to boost aquifers, Diversion and treatment of sewage to generate alternative sources of raw water; improving sanitation and health conditions; and Preserving the habitat of aquatic life.

Restoration and Management of Lakes:

Source control is the most important aspect in protection of lake watershed zones. This practice includes soil conservation measures, bank/slope erosion control measures, afforestation, drainage improvements, control of sewage and solid wastes, sewage interceptions and diversions and participation of people in watershed management measures. In-Lake treatment measures to remove eutrophication and improve quality of lake water. These include Lake dredging and desilting; De-weeding/Hyacinth Control; and Bioremediation controls. There are further number of methods which include:

a) Establishment of protected parks and sanctuaries around the lakes
b) Shoreline management through controlled entry and demarcation of lake boundaries
c) Public or neighbourhood participation in protection and conservation of the lakes.
d) Establishment of resource and information centers for scientific and social studies related to the lakes.
e) Environmental education and awareness
f) Production of guidelines for protection measures, watershed management, restoration measures, hydrological measures, pollution control measures, socio-economic development through community participation, monitoring and evaluation, public awareness and education, and legislative and administrative measures.

Restoration of Eutrophic Waters

As a general principle, restoration of eutrophic waters can be achieved by cutting the supply of nutrients into the system. This can be done by cutting down diffuse sources in the fields; water treatment of a point source before discharge; and stripping of the nutrients and then releasing the water back into the system. Also isolation of water bodies from nutrient rich sediments are critical.

Restoration and Management of Lakes in Bangalore City:

The Lake Development Authority, an autonomous body instituted in July 2002, has formulated the reinvigoration plan which it is implementing along with agencies such as the National River Conservation Authority (NRCA); Department of Ecology of GoK; Indo-Norwegian Environment Program (INEP); Bangalore Mahanagara Palike (BMP), Karnataka Forest Department (KFD), Bangalore Development Authority (BDA), and Bangalore Water Supply and Sewerage Board (BWSSB). The multi-pronged programme primarily involves desiltation of the lakes, sewage diversion from storm water drains that connect them and biological treatment of sewerage entering the water bodies.

Since 2002, the Lake Development Authority (LDA) has been working with these agencies on restoration programs of about 60 lakes. The principal objectives include eco-engineering of the lake shorelines and immediate catchments peripheries; resuscitation of lakes to boost aquifers; diversion and treatment of sewage lines; improving sanitation and health conditions of areas within the lake catchments systems; preserving the habitat of aquatic life; removal of water hyacinth, etc.

Lake Restoration and Eco-Engineering:

Lake restoration is a complex process, especially when attempting to modify the physical structures of the lake system. Any such process must strictly focus upon the role of restoration on the local biodiversity. Eco-engineering is the means of using a specific eco-

friendly technology for the purpose of restoration and conservation of a specific ecosystem such as the lake. The methods involved depend upon the aim of that particular restoration project. Some of the in-lake eco-engineering methods include:

a) Deep dredging of the lake
b) Desiltation of the lake bed
c) Cleaning up of the marshes and wetlands
d) Construction of artificial lake islands and planting of native plant species
e) Construction of flood control gates and outflow weirs
f) Concrete embankment of deep and steep slope shore lines to control wave force on and avoid lake inundation or landslides
g) Trimming of reeds and grasses; and control of weeds

The out-of-lake Eco-engineering methods include:

a) Fencing of the immediate catchment periphery of the lake
b) Treatment and channelization of waste water before it enters the marshes of the lake
c) Diversion of sewer lines towards the treatment plants
d) Creation of buffer zones with native plant species.
e) Creation of eco-park areas for human aesthetic activities.

CONCLUSION

It should be noted here that despite several efforts being made to find a lasting solution for the status of the Lakes in Bangalore; and despite some form of success in a number of lakes such as mentioned above, Bangalore aquatic map continues to be threatened by encroachment and effluent discharge. Most lakes in Bangalore are rain fed directly by rains or through a series of cascading effects of flow and recharge channels. These channels have now been severely disintegrated thanks to the rising demand for land, housing and other economic activities, thus causing a slow but gradual suffocation of these unique urban aquatic systems. Even in restoration can cause a slow death of a lake. Blockage of storm drains into the lake has often been used and seen as the most convenient way of stopping pollution at end point. But these storm drains have been the life line of these fragile urban tanks, and by solving the problem at end point, one has not solved the issue of environmental pollution at source point.

A classic example of diversion and dilution of waste water before it reaches the lake is at Venganaiah Kere lake located along the K R Puram Road. The diverted sewer line mixes with the waste water that has been treated from a nearby treatment plant before the new flow enters the lake. Recent studies have shown that despite being completely restored and protected, the Salinity of the water is at higher levels along with its pH. Although Nitrates and Phosphates levels have been greatly reduced to lower limits since its restoration program began, the lake is still severely colored and highly turbid. This still indicates the presence of disease causing micro-organisms in water which can cause symptoms such as nausea, diarrhea, headaches, etc. Sodium and Sulphate levels are still significantly and comparatively higher. Fish catch has dropped significantly as has the fish diversity. It appears that raw sewage running parallel to the lake continues to seep in - causing reduced dissolved oxygen and increase in BOD.

The environmental pressure on our aquatic systems will only be properly tackled if the main issues of encroachment and management of domestic and industrial discharges were addressed. Solving the problem at end point is a temporary measure with more serious repercussions. The solution is to tackle this problem at source points with strict enforcement of our environmental laws and regulations. But until that happens, the “City of Lake” will soon be history.

REFERENCES

Arora P. Mohan; (2004); Ecology ; Himalaya Publishing House

Chandel P. S. and Shukla R. S.; (2000); Plant Ecology and Soil Science; S. Chand Co.

Clapham, W. B.; (1973); Natural Ecosystem; McMillan Publishing Co.

E. Somanathan; (2005); Biodiversity in India; Oxford Companions to Economics in India; Planning Unit – Indian Statistical Institute, Delhi.

J.P. Pascal; (1996); Wild and Fragile; Down To Earth; Society for Science and Environmental Communications; Vol 5; No. 6; August 15, 1996.

Jack R. Vallentyne; (2002); Principles of Modern Limnology; In: Proceedings of the Lake 2002 Symposium on Conservation, Restoration, and Management of Auqatic Ecosystems; December 9 th – 13th 2002; Indian Institute of Science.

Karnataka State Pollution Control Board – Research and Development Wing (2001); Monitoring and Analysis of Tanks and Lakes of Bangalore; KSPCB Publication.

Rao, Y.R; Murthy C.R. (2002); Physical Limnology of Lakes and Reservoirs; In: Proceedings of the Lake 2002 Symposium on Conservation, Restoration, and Management of Auqatic Ecosystems; December 9 th – 13th 2002; Indian Institute of Science.

Robert G. Wetzel; (1995); Limnology – Lake and River Ecosystems; Third Edition; AP Publishers

S. Sridhar; B.K. Chaprani; A.K. Chakravarthy; (2000); An Overview of Conservation Strategies and Sudggestions for Restoration of Wetlands of Karnataka; in the Abstracts of Symposium on Restoration of Lakes and Wetlands; 27th – 29th November 2000; Indian Institute of Science, Bangalore.

SACON - Inland Wetlands of India: Conservation Priorities and Inland Wetlands of India – Conservation Atlas (2005); Drained India’s

Wetlands; Down To Earth; Society for Science and Environmental Communications; Vol 13; No 20. March 7, 2005

Tripathy A.K., Pnadey S.N.; (1990) Water Pollution, Ashish Publishing House.

V.G. Ranjani; T.V. Ramachandra (2000); Bathymetric Analysis and Characterization of the Hebbal Lake to Explore Restoration and Management Options; in the Abstracts of Symposium on Restoration of Lakes and Wetlands; 27th – 29th November 2000; Indian Institute of Science, Bangalore.