Bhoj Wetland

Experience and Lessons Learned Brief

*Mohan S. Kodarkar**, Indian Association of Aquatic Biologists, Hyderabad, India, kodarkar_mohan@yahoo.com
Aniruddhe Mukerjee, Madhya Pradesh Lake Conservation Authority, Bhopal, India

* Corresponding author

1. Introduction

South Asia, home to over one-fifth of the world's population, is facing a growing water crisis. This region is in the grip of continuing flood and drought cycles, dictating the need for a long-term strategy for management of its water resources. Big and small water bodies, in the form of lakes and reservoirs, dot the landscape of South Asia. These ecosystems impound precious freshwater, and are the most easily-accessible source for human use. Historically, major cities in this region flourished in geographical regions with assured water supplies that sustained civilization for centuries. Unfortunately, the last half of the 20th century has witnessed large-scale degradation of the environment in general, and water resources in particular, due to multiple anthropogenic factors such as unprecedented population growth, and consequent urbanization, industrialization and chemical intensive agriculture. Among the first victims of this degradation process were the lakes and reservoirs in the vicinity of urban areas that underwent large-scale pollution due to sewage and industrial effluents and toxic chemicals. In most cases, nutrient enrichment led to eutrophication of water bodies (Edmondson 1991), exhibiting negative manifestations such as:

- Loss of water-spread area because of siltation and construction activities;
- Continuous algal blooms;
- Excessive growth of macro-phytes (e.g, water hyacinth) and loss of biodiversity; and,
- Water quality degradation.

There also are drastic alterations in the morphometry and water-holding capacity of lakes and reservoirs, due to inflow of silt, dumping of garbage and reclamation activities. The process has been further aggravated by encroachments and unauthorized construction activities in the catchment and on the lakebed. Compared to rural areas, the impact of this degradation is more severe in urban areas due to their high population densities. Because of the ecological, economical and recreational potential of lakes, there is an urgent need to protect, rehabilitate and conserve them as precious natural resources. This brief examines how these issues have been addressed for the Upper and Lower Lakes of Bhopal, collectively know as the Bhoj Wetland (Figure 1).

2. The Bhopal Lakes

In India, construction of storage reservoirs is an age-old practice. Former rulers contributed significantly by constructing large numbers of impoundments for providing drinking water to the people in their cities. This was particularly necessary in arid, semi-arid and other regions with highly erratic rainfall. The Upper Lake of Bhopal, arguably the oldest among the large man-made lakes in the central part of India, falls in this category. This lake was created in the early-11th century by King Bhoj by construction of an earthen dam across the Kolans River, a rain-fed tributary of the Betwa River.

Figure 1. The Bhoj Wetland Basin.

In the late-18th century, another lake downstream of the earthen dam of the Upper Lake was constructed by Nawab Chhote Khan (a Minister of Nawab Hayat Mohammed Khan's regime) to enhance the beauty of the city.

With the passage of time, the administration of Bhopal City changed hands several times and, in the year 1956, it became the capital of the State of Madhya Pradesh. Since then, it has witnessed a tremendous influx of people and consequent urban development, especially on the northeast fringe of the Upper Lake, as well as around the Lower Lake. This resulted in an increased demand for potable water and subsequent pressure on the Upper Lake resources. Consequently, the storage capacity of the Upper Lake was increased by raising the height of the spillway. Although this has resulted in an increased water supply, the increased anthropogenic activities in the catchment also have caused an increased inflow of silt, untreated sewage, nutrients and pesticides from urban and rural areas, and an overall deterioration of the lakes' water quality. The basic features of the twin lakes are illustrated in Table 1.

The Upper Lake is a source of potable water and meets 40% of the drinking water demand (29 million gallons per day) for the city's growing population. Its fishing rights have been allocated on a long-term lease by the Bhopal Municipal Corporation (BMC) to a fishermen's cooperative, consisting of some 500 fishermen families. The Lower Lake is mainly a recreational site. The livelihood of 250 washer-men families belonging to socio-economically weaker sections of the society is dependent on the Lower Lake.

The BMC is the custodian of the lakes, and also has the authority to control the land use in the fringe area of the lakes since it issues building permission sanctions. The various regulatory provisions for the protection of the Bhopal lakes, as well as other waterbodies, are described below.

Table 1. Basic Features of Upper and Lower Lakes of the Bhoj Wetland.

	Upper Lake	Lower Lake
Riparian countries	India	
Lake origin	Man-made (11th century)	Man-made (Late-18th century)
Climatic region	Warmer humid (humid subtropical)	
Drainage basin type	Open	
Salinity type	Fresh	
Altitude	503.5 m	500 m
Surface area	36 km²	1.29 km²
Drainage basin area	361 km²	9.6 km²
Volume	0.117 km³	0.004 km³
Maximum depth	11.7 m	9.5 m
Average depth	6 m	
Population	0.5 million	
Population density	1,350 persons/km²	

The Bhopal Development Plan 2005, prepared by the Directorate of Town and Country of Madhya Pradesh, provides for the following regulatory measures for the protection and management of lakes:

- Fringe areas of the lakes have been declared as sensitive zones. No construction and development activities in 50 m space from the Full Tank Level (FTL) of the Upper Lake and 33 m space from the edge of the Lower Lake is allowed. The space is to be kept open. The lake fringe of the Upper Lake is to be kept free from any further construction except passive recreation;
- The areas of the Upper Lake, including slopes, are to be planted to the extent of 50-100 m from the maximum tank level with appropriate indigenous trees and shrubs to arrest the pollution and silt entering into the lake;
- The Upper Lake water, which is basically used for drinking purposes, shall not be allowed to be used for such water-based recreational activities that adversely affect the water quality; and
- The practice of agriculture right along the lake fringe areas is to be discouraged so that water is not polluted due to the addition of chemical fertilizer, pesticide and insecticides.

Provisions in other national-level acts include the following:

- The Water (Prevention and Control of Pollution) Act, 1974, amended in 1994 empowers the Madhya Pradesh Pollution Control Board to take action against the polluters of the water resources;
- The Environmental Protection Act, 1986 also empowers the Madhya Pradesh Pollution Control Board to take action against the polluters of the water resources; and
- The Madhya Pradesh Municipal Corporation Act, 1956 (as Amended in 1995) empowers the Municipal Corporation to take appropriate measures to prevent pollution of the water resources.

However, as far as implementation of these provisions is concerned, much is still desired.

3. Status of the Lakes

The Upper Lake has both rural and urban catchments. With a well-protected catchment, its water quality was of potable standard until recently (Singh and Anandh 1996). In the last few decades of the 20th century, however, many sections of the lake became surrounded by habitations as the city grew. These developments have generated anthropogenic pressures on the lake, thus accelerating its eutrophication and microbial contamination, and making the water unfit for human consumption without proper treatment (Table 2 and 3).

The lake is rich in biodiversity, however, with the principal components being phytoplankton, zooplankton, macrophytes, aquatic insects and avifauna (both resident and migratory). The biodiversity characteristics of the lake are as follows:

- Macrophytes: 106 species (belonging to 87 genera of 46 families), including 14 rare species;
- Phytoplankton: 208 species, comprised of 106 species of Chlorophyceae, 37 species of Cyanophyceae, 34 species of Euglenophyceae, 27 species of Bacilariophyceae and 4 species of Dinophyceae;
- Zooplankton: 115 species (Rotifera 41, Protozoa 10, Cladocera 14, Copepoda 5, Ostracoda 9, Coleoptera 11, Diptera 25);
- Fish fauna: 43 species (natural and cultured species);
- Avifauna: 179 species (52 migratory, 28 locally migratory and 99 local);
- Insects: 98 species of 10 families; and,
- Reptiles and Amphibians: ›10 species (including 5 species of tortoise).

Because the Lower Lake, located within a completely urban catchment, has been subjected to many negative anthropogenic stresses, its water quality degradation has been much more pronounced than for the Upper Lake (Table 2).

Considering the ecological importance of these lakes, the Government of India declared the twin lakes as lakes of national importance, and efforts to improve their environmental status began in 1989. Later implementation of an integrated conservation and management plan for the lakes was started

Table 2. Water Quality of Upper and Lower Lakes of the Bhoj Wetland (1991-92).

Parameter	Range	
	Upper Lake	Lower Lake
pH	8.8–9.2	7.15–9.7
Transparency (cm)	NA	14–98
Conductivity (μS/cm @ 25°C)	213–228	259–374
Total dissolved solids (TDS; mg/l)	121–252	86–169
Hardness (mg/l)	60–146	68–154
Chloride (mg/l)	16–30	14.9–88.9
Total phosphorus (mg/l)	0.003–0.07	0.106–1.02
Total nitrogen (mg/l)	0.1–0.9	1.08–1.46
Biochemical oxygen demand (BOD; mg/l)	1.8–6	2.2–11.5
Chemical oxygen demand (COD; mg/l)	8.8–26.4	8–112
Class	B	D

Table 3. Water Quality Criteria for Water Uses.

Class of water	Designated best use	Criteria
A	Drinking water source without conventional treatment, but after disinfection	1. Total coliform MPN/100 ml: 50 or less 2. pH: between 6.5 and 8.5 3. Dissolved oxygen (DO): 6 mg/L or more 4. BOD (5 days @ 20°C): 2 mg/L or less
B	Outdoor bathing (organized)	1. Total coliform MPN/100 ml: 500 or less 2. pH: between 6.5 to 8.5 3. DO: 5 mg/L or more 4. BOD (5 days @ 20°C): 3 mg/L or less
C	Drinking water source with conventional treatment, followed by disinfection	1. Total coliform MPN/100 ml: 5000 or less 2. pH: between 6.0 and 9.0 3. DO: 4 mg/L or more 4. BOD (5 days @ 20°C): 3 mg/L or less
D	Propagation of wildlife and fisheries	1. - 2. pH: between 6.5 and 8.5 3. DO: 4.0 mg/L or more 4. - 5. Free ammonia (as N): 1.2 mg/L or less
E	Irrigation, Industrial cooling, Controlled waste disposal	1. - 2. pH: between 5.89 to 6.00 3. DO: 4.0 mg/L or more 4. - 5. - 6. Sodium absorption ratio maximum: 26 7. Boron (maximum): 2 mg/L

in 1995. In recognition of its rich biodiversity (especially avifauna), and for adopting an integrated management plan, this wetland was declared a Ramsar site (a wetland of international importance) in 2002.

4. Environmental Issues Affecting the Lakes

The major issues concerning the environment of the lakes are described below in Table 4.

5. Conservation and Management of the Lakes

Efforts to manage the lakes have been implemented in a piecemeal manner since 1988. The State Government initiated a public awareness generation program of manual weed removal called 'Sarovar Hamari Dharohar' (Lakes are Our Heritage) in 1989. Because of the water quality resulting from aggravated pollution loads and environmental degradation of the lakes, the Government of Madhya Pradesh prepared an integrated plan for the Conservation and Management of both lakes, and requested financial assistance from the Government of India (GOI) in 1989. The GOI provided grants-in-aid of Rs. 16.5 million for conservation works during 1989-1992. Because of the high project costs, the GOI proposed the plan for external financial assistance to the Government of Japan in 1991. The Environmental Clearance from the Ministry of Environment and Forests (MOEF), and the concurrence of the Planning Commission, was obtained for the implementation of the project through foreign funding.

The Japan Bank for International Cooperation (JBIC) dispatched a study team, under Special Assistance for Project Formation (SAPROF), to India in 1993 to assess the project feasibility. Upon its recommendations, JBIC agreed to provide financial assistance, in the form of a soft loan of 7.055 billion yen, out of the total project cost of 8.033 billion yen. It was decided that the 978 million yen balance (i.e., 15 % of the project cost) would be shared equally by the GOI and the State Government. An agreement between the JBIC and the Government of India (Ministry of Finance, Government of India being the signatory) was executed for implementation of the "Lake Bhopal Conservation and Management Project" (also known as Bhoj Wetland Project), to be executed over a period of 5 years, beginning in April 1995.

The project was to be coordinated with JBIC by a government-controlled society, called the Environmental Planning and Coordination Organization (EPCO), and implemented by the Bhopal Municipal Corporation (BMC), State Public Health Engineering Department (PHED), Capital Project Administration (CPA) and MP Fisheries Development Corporation (MPFDC). EPCO was the executive and advisory arm of the Environment Department on statewide environmental issues.

A Japanese-Indian joint venture firm formed for this project was appointed as Project Management Consultant (PMC), as per the terms of the agreement, with a mandate to advise the project for project implementation in May 1996. The project envisaged tackling various conservation and management issues of the Upper and Lower Lakes of Bhopal in an integrated manner. Although the issues are interrelated and interlinked, for ease of operation and management, these issues were divided into various sub-projects, albeit with the understanding of the related issues and their interconnectivity with each other. The project initially envisaged 14 sub-projects under the major topics of:

- Desilting and Dredging (desilting and dredging of the lakes; deepening and widening of the spill channel, and restoration of the island);

Table 4. Summary of Environmental Issues facing the Bhoj Wetland.

Problems	Causes
Reduction of water storage capacity of the lakes	Inflow of silt and organic materials from urban and rural catchments, along with monsoon runoff and dry weather flows; Addition of clay and non-biodegradable materials through immersion of idols
Obstructions to smooth waterflow through the Upper Lake's spill channel, resulting in a threat to the stability of the earthen dam	Constriction of the spill channel, due to deposition of silt
Deterioration of water quality	Inflow of untreated sewage from habitations; Dumping of municipal wastes not collected by the Municipal Corporation; Dissolving of paints in water during immersion of idols; Chemical fertilizer runoff from the catchment; Activity of washing of clothes by washermen, resulting in release of detergents; Leakage of oil during motor boating
Flourishing growth of invasive aquatic plants	High nutrient load to lakes from inflow of sewage and agricultural wastes
Reduction of water spread area	Encroachment on the lake fringe area, which becomes exposed when the lake water level drops after rains end

- Catchment Area Treatment (afforestation, creation of buffer zones, construction of check dams, silt traps, toe walls and cascading and garland drains);

- Prevention of Pollution (Sewerage schemes);

- Shoreline and Fringe Area Management (construction of link road from Retghat to Lalghati, solid waste management, prevention of pollution from Dhobi ghats); and,

- Improvement and Management of Water Quality (deweeding, biological control of weeds through aquaculture, installation of floating fountains, water quality monitoring).

Considering the importance of public awareness in successful project implementation, public participation and environmental awareness activities were added as the 15th sub-project. Additional works, including a lakeview promenade and protection of lake fringes (both for shoreline management), a bridge across the Bhadbada spill channel, establishing an Interpretation Center for increasing environmental awareness, and control of seepage from the earthen dam of the Upper Lake, were subsequently included as additional sub-projects during 2002-2004.

6. Project Implementation

Implementation of the projects began in April 1995 under the Housing and Environment Department of the State Government, with the Environmental Planning and Coordination Organisation (EPCO) playing the role of coordinating agency among various implementing agencies of the State Government. Being a large investment project, sanction of the major works fell under the purview of the State Cabinet. To ensure speedy disposal, the State Cabinet delegated its financial powers to an Empowered Committee under the chairmanship of the Chief Secretary of the State Government, which was constituted in February 1996. The Committee had the secretaries of all concerned state government departments with a stake in the project implementation, as well as the MOEF, GOI, as members.

A project cell was set up within EPCO, with the role of coordinating the activities of various implementing agencies (IA) and the PMC. At times, the IA showed an indifferent attitude toward completing the project on schedule. The project progress was tardy for the first two-and-a-half years because of a lack of coordination between the implementing and coordinating agencies, as well as the PMC. None of the Detailed Project Reports (DPRs) of the various sub-projects were cleared for implementation during this period, with the three parties blaming each other for the delay. Two of the DPRs ultimately had to be given to private consultants for preparation. The project remained headless for a period of 6 months (March - September, 1997).

However, upon a Project Officer joining the project in September 1997, the activities began taking shape, with many DPRs cleared between then and mid-1998. The speed of project execution further improved in May 1998, when the state government decided to bring most of the sub-projects (except for the ones being executed by the Bhopal Municipal Corporation and the CPA) under a single umbrella called the Bhoj Wetland Project Directorate, by upgrading the project cell within EPCO. Being under the same administrative department, the CPA was left independent. Thus, two executive divisions were formed as the IA under the Project Director (new designation of the Project Officer). To assist the IAs in preparing the DPRs of each sub-project, and for monitoring their implementation, a Project Coordination and Monitoring cell within the project was created, reporting to the Project Director, with the induction of experts of various disciplines (environmental engineering, urban planning, geo-hydrology, limnology, ecology, etc.) from various government departments. Since EPCO was going to execute such major works for the first time, an operational system that delineated the responsibilities of the executing and monitoring divisions was prepared and implemented.

In May 1998, another major decision was taken to accelerate the tendering and sanctioning of the project works. In the government system, authority for sanctioning works depends on the magnitude of the estimated costs. The time required for such sanction are often long, having to pass through several levels and thereby creating a bottleneck constraining smooth progress for time-bound projects. It was necessary that such departmental delays be avoided if the project was to be completed within the remaining 2 years. A project Technical Evaluation and Tender Approval Committee (TE and TAC) was constituted in May 1998, under the chairmanship of the Secretary of the Environment Department, including Chief Engineers of the Public Health Engineering, Water Resources, and Public Works, as well as a representative of the Finance departments, as members. It was the competent authority for according approval to the Detailed Project Reports of the various works under the project, evaluating tenders and technical matters, and sanctioning works up to Rs. 15 million for all IAs.

Regarding financial issues, as per the loan agreement with the JBIC, the release of funds to the State Government was done via a reimbursement process (i.e., the JBIC would reimburse the expenditure made by the IAs). The Project Authority previously got the funds from the government in the form of budgetary allocations in its annual budget, with its release from the Finance Department having to be periodically obtained. There often was a delay in getting the budget released from the Finance Department, thereby also delaying payments to contractors. This problem was ultimately overcome with the EC giving the go-ahead in 2000, with the concurrence of JBIC, to shift from a reimbursement mode to a transfer mode of payment. Under this new system, the bills were passed by the IAS, and payment to contractors made directly by the JBIC to their account, thereby bypassing the state budgetary system.

This change both accelerated project execution and made the payment system completely transparent. In addition, to prevent the transfer of IA or EPCO personnel involved in project execution, the Empowered Committee decided that nobody would be transferred or relieved from his duty without the concurrence of the Empowered Committee.

With this new system in place, the project implementation became much smoother, with the TE and TAC regularly convening to make necessary technical decisions. Further, the time for sanctioning DPRs, calling tenders and tenders evaluation, was considerably shortened. In July 2000, however, the Project Director was transferred, with the next director lasting only 4 months, followed by a short period in which the project was headless, resulting in delaying the progress at a crucial implementation stage. Since December 2002, two Project Directors have had reasonable terms of more than a year, heading the project almost continuously.

7. Project Progress

Although implementation of the project is still underway, its positive impacts are perceptible, including the following areas.

- **Fringe area protection**. The Bhopal Development Plan 2005 prohibits construction within 50 m of the Full Tank Level (FTL) of the Upper Lake and within 33 m of the Lower Lake. Accordingly, a "No Construction Zone," located up to 50 m from the FTL of the Upper Lake, has been demarcated with boundary stones. A physical barrier, in the form of arches along the Lower Lake, has been constructed to prevent direct access to the lake.

- **Creation of buffer zones between the lake and the human settlements**. A 5.4 km Link Road on the northeast and a 2.5 km long Lake View Promenade on the southeast fringe of the lake, were constructed, serving the dual purpose of preventing encroachment of the lake fringe area and reducing the traffic pressure throughout the city. The promenade also has become a recreational site for city dwellers. In order to prevent encroachment by human settlements, cultivation and grazing within the lake area, and siltation, plantation buffer zones have been created, particularly in the western, southern and northern fringes of the Upper Lake. In addition, intensive planting activities have been carried out in the lake's watershed area to control soil erosion. The species selected (51 in total) either produce biomass or have medicinal properties; they are also tolerant of both flooding and drought conditions. About 1.7 million plants have been planted in over 10 km^2 of land over a period of 12 years. In the social forestry program, farmers were encouraged to raise fruit yielding trees along their crop fields and marginal lands, with the results being encouraging to date.

- **Catchment area treatment**. The catchment area of the Upper Lake covers about 361 km^2, with agricultural practices being undertaken in most of the area. During the rainy season, runoff from the catchment carries much silt and organic debris to the lake. The urban catchment runoff and sewage enters the lakes through various drains, causing both siltation and water pollution. To mitigate the inflow of silt, agricultural residues and other wastes into the lakes, 75 check dams of loose boulder/gabion structures, and 2 silt traps having a cumulative silt trapping capacity of 0.36 million m^3, have been constructed across 31 inlet channels.

- **Sewerage system**. Sewage is a major cause of pollution and water quality deterioration of both lakes with 14 drains carrying 15 million liters/day of sewage entering the Upper Lake and 28 drains carrying 50 million liters/day entering the Lower Lake. An infrastructure has been developed that comprises an 86.7 km pipeline through congested human settlements with 8 sewage pump houses and 4 treatment plants for diversion and treatment of domestic sewage. The systems are in a trial stage, expected to be fully operational within a period of 6 months. However, connecting individual households to the main sewage pipeline is a remaining task.

- **Solid waste management**. Due to limited infrastructure before project implementation, the municipal corporation could only collect 96 tons of garbage daily, compared to the generation of 131 tons of garbage from the project area (18 city wards). The infrastructure of the Bhopal Municipal Corporation was strengthened from project funds, by providing dumper placers, refuse compactors, a sewer-cleaning machine and containers. An electronic weigh bridge also was installed at the dump site to monitor the efficiency of each vehicle. These measures resulted in the additional collection and disposal of 70 metric ton of solid waste from the 18 municipal wards located in the urban watershed.

- **Prevention of pollution due to washing activities**. There are unorganized settlements of washermen along the Lower Lake, with the sewage from these settlements previously flowing directly into the lake. Their cloth-washing activities also resulted in discharges directly into the Lower Lake. These sewage inflow and washing activities caused drastic deterioration in the lake's water quality. To ameliorate the situation, the washermen have been shifted outside the catchment of the Lower Lake, with rehabilitation sites for 250 washermen families having all facilities for living and washing, being constructed. Resettlement of the washermen families was completed in February 2004, with the vacated land being developed as a buffer zone with gardens and parks.

- **Dredging and desilting of lakes**. Due to silt deposition from the various drains, mass land formation was occurring at the confluence points, resulting in decreased water storage capacity and spread area. About 85,000 m^3 silt was removed from the Lower Lake via the dredging operation. Silt removal in Upper Lake, however, was undertaken through dry excavation, after constructing earthen coffer dams and dewatering the area. A total of 2.70 million m^3 of silt was removed from 6 peripheral zones of Upper Lake, resulting in a 4% increase in lake storage capacity. The excavated materials were transported to wastelands transforming them into productive agricultural and plantation lands.

- **Deepening and widening of the spill channel**. To maintain the Upper Lake's water level, it has a spillway and approach channel (4.41 km long) for the smooth discharge of excess water during the rainy season through gates. Continued silt deposition over the years within the existing narrow channel section, however, resulted in obstructions to the smooth water flow through the channel. Silt accumulation near the gates also caused high pressure on the gates. An insufficient spillway system discharge capacity would lead to the buildup of water pressure in the Upper Lake, causing a threat to the dam at Kamla Park. The deepening and widening works were carried out in 2.6 km of the spill channel to accommodate a discharge of 566 m^3/sec, with about 0.98 million m^3 of silt being removed. The channel also was given a proper shape to attain the required discharge. As with desilting, the excavated material was given to public and private parties on payment for their soil improvement and landscaping usage, earning the project authority about Rs. 6 million in this manner.

- **Restoration of Takia Island**. Takia Island in the Upper Lake has a Mazar of Shah Ali Shah Rahmatullah Aliah, which is of religious importance. Because of wave action, its periphery has been getting eroded from the western side over the years, posing a threat to the existence of the Mazar, while it was being silted on the eastern side. Two rows of toe walls were constructed around the island as a remedial measure and the area between the walls was filled in with soil excavated from the silted lakebed.

- **Weed removal**. Nutrient enrichment of the lakes due to inflows of untreated sewage, organic waste-containing runoff from urban areas in both lakes, and agricultural residues from rural areas around the Upper Lake have caused excessive aquatic vegetation growth within the lake area. In order to reduce nutrient recycling and prevent accelerated evapotranspiration of lake water, controlled weed removal operations were carried out in about 90% of the submergence area of the Upper Lake, and almost the entire area of the Lower Lake. Removal of different types of weeds, including shoreline (*Ipomea fistulosa*), emergent (*Scirpus roylie, Cyprus rotandus*, *Polygonum glabrum* and *Ipomoea aquatica*), floating (water hyacinth) and an assemblage of submerged weeds, was started in a systematic manner in January 1999. Maintenance operation are still continuing, with the magnitude of weed growth having been considerably reduced.

- **Installation of water oxygenation systems**. Injection of ozone to improve water quality of an urban lake was tried out for the first time in the world in the Lower Lake. For the Upper Lake (a potable water source), however, only fountains with the provision of exposing the hypolimnetic water to the atmosphere, have been installed. A total of 15 aeration units (1 ozonizer, 1 ozonizer cum fountain and 4 fountains in the Lower Lake; 9 fountains in the Upper Lake) have been installed to oxygenate the hypolimnetic water. This activity has not only improved the water quality, but has also become a tourist attraction.

- **Aquaculture**. Herbivore grass carp, along with Indian Major carp, were introduced in the lakes to control submerged weeds (e.g., Hydrilla, Najas, Vallisnaria), as well as to maintain ecological balance. This has resulted in an up to 50% reduction in the density of aquatic weeds, and an increase in fish production by 130%. Thus, this activity has both improved the lake water quality, and enhanced the economic conditions of fishermen.

- **Construction of high level bridge across Bhadbhada spill channel**. Because of the development on the southeastern part of Upper Lake, and to reduce traffic pressure over the old Bhadbhada Bridge (spillway), a 4-lane bridge across Bhadbhada spill channel was constructed, and is expected to divert the development outside of the catchment of the Upper Lake.

- **Public awareness campaign**. During the implementation of the project, it was concluded that there was a need to educate the public of Bhopal about the need for the project and to make the public aware of the deteriorating lake environment. It was decided, therefore, to organize a well-coordinated public awareness program. As an initial activity, a survey was conducted to assess people's responses regarding the conservation and lake management efforts. Based on this initial study, people of all walks of life were involved through the awareness program. The cooperation of selected NGOs also was solicited for this activity, with various education awareness materials being developed including: gatherings at strategic locations; publication of special bulletin (Tal Sandesh) to create awareness regarding diversion of Idol immersion activities; advertisement in newspapers regarding project actions; communication through TV/radio; T-shirts/caps, showing the message of "Save Bhopal Lakes," used by students/volunteers involved in awareness campaign; and stickers with various lake conservation slogans, used to communicate the message. A major achievement of this awareness campaign was the complete cessation of idol immersions at the traditional site of the Upper Lake. Details of specific the activities carried out under the awareness program are provided in Table 5.

- **Interpretation Center**. To create awareness among people of all walks of life, an Interpretation Center was developed on the shore of the Upper Lake, depicting the origin of the Bhoj Wetland, ecosystem structure and functions, conservation principles, project activities and the future course of action for the wise use of the lake ecosystem. This museum is expected to be a common meeting point for stakeholders, as well as a tourist attraction.

- **Control of seepage through earthen dam of Upper Lake**. The earthen dam of the Upper Lake was constructed in the year 1005, reportedly being constructed between 2 dry masonry wall fields with moorum (small pebbles mixed with red soil) and boulders. A tunnel (gallery) subsequently was constructed to release water from the Upper Lake to the Lower Lake, and to supply potable water to the city. Lacking proper care over the years, the upstream retaining wall of the earthen dam, upstream toe, and the tunnel inside the earthen dam, were damaged. Consequently, water was seeping throughout the length of the body of the dam and through the tunnel. A proposal to stabilize the dam retaining wall, and to prevent water wastage, was included in the project at a later stage. The remedial measures included col-crete construction of existing stone masonry walls, grouting of retaining walls, construction of bell-mouth inlet and outlet structures of the tunnel, and shot-creting in two layers on the tunnel's inner wall. A vertical shaft was provided to facilitate the future inspection and treatment of the tunnel. For inspection purposes, a pathway was laid on the upstream side of the dam. Area beautification also has been done through provision of planters and lighting, with the work being in its last stage of completion.

Table 5. Activities Carried Out Under the Awareness Campaign.

Particular Event/Material	Total number
Workshops	37
Seminars	7
Training	22
Public meetings	54
Recreational program/field visits	20
Open fora	18
Rallies	20
Eco-camps	24
Street theater/puppet shows	20
Lecture (20) and audio-visual shows (50)	103
Competitions	43
Exhibitions	20
Participatory programs	18
Bird watching	4
Science fairs	4
Festival fairs	1
Film festivals	–
Big Events	
Mera Taal Mera Bhopal on World Environment Day (5 June 2001)	1
Public hearing (10 October 2001)	1
Lake Festival (22 - 25 December 2001)	1
Human Chain on World Wetland Day (2nd February 2002)	1
Total	419

8. Project Innovations

In addition to what was conceptualized in the project, a number of other innovations also were done, including the following.

- **Promotion of organic farming**. Intensive cropping with inorganic fertilizers is being done in the rural watershed. A significant part of these nutrients find their way into the lake via monsoon runoff, causing the growth of aquatic vegetation in the lake. With the intention of discouraging farming practices in the watershed based on inorganic fertilizers, a drive to promote the use of organic manure was launched in 15 villages of the catchment, comprising two districts of the State. The manure was produced by the farmers themselves, and was comprised of farm wastes and cow dung. Relevant activities included hands-on training to farmers for making high-quality compost using bacterial inoculums. The farmers found the method acceptable, since their crop yields were higher, compared to the conventional method, and there also was considerable savings because the need to purchase inorganic fertilizers was eliminated.

- **Control of idol immersion activities**. Religious activities have a deep relationship with water resources in India. At the end of religious festivals, the immersion of idols in water is practiced throughout the country. Idol immersion also was practiced in the Upper Lake, which is a potable water source for the people of Bhopal. Since the idols are made of wood, hay, bamboo, clay, and printed with bright (heavy metal laden) colors, the lake was receiving silt, as well as being polluted. Thus, an alternate idol immersion site on the spillway of the Upper Lake was developed, and through constant persuasion and intensive awareness campaigns, idol immersion ceased around the year 2002 at the traditional site, which was located near the potable water intake point. Because the new site was located on the spill channel of the Upper Lake, the impacts of idol immersion on the main waterbody were eliminated.

- **Control of motor boating**. Being a large, urban lake, boating activities, including motor boats, were popular in the Upper Lake, causing pollution problems related to oil and grease spillage. The project authorities were able to convince the BMC to ban motor boating because of the spillage, which was polluting the lake.

9. Importance of Scientific Studies in Decision Making

Analysis of water quality, and monitoring of biodiversity of the two lakes, has been conducted since 1998 on a regular basis. Special studies were conducted to assess the impacts, if any, of anthropogenic activities, as well as developing project activities to facilitate corrective measures, if necessary, on the part of decision-makers. Some of the notable special studies are enumerated below in the following sections.

9.1 Impact of Idol Immersion

The immersion of idols in waterbodies is a religious activity performed by Hindus after the worship of gods and goddesses. Because of the immersions, a considerable quantity of organic and inorganic materials find their way to the waterbodies, resulting in siltation and water pollution. There also is concern related to the toxic materials used in the paint of the idols. In the Upper Lake, Sheetal Das Ki Bagiya was the traditional site for idol immersion, which was located very near the potable water intake points. Thus, shifting idol immersion from the traditional site was necessary. An alternate site at Prempura Ghat was created in the year 1999, and people were requested via an awareness program to stop idol immersion at Sheetal Das Ki Bagiya. Through the cooperation of general public, religious leaders, district administration and local bodies idol immersion at Sheetal Das Ki Bagiya was completely stopped since 2002. The water quality at Shetal Das Ki Bagiya and Prempura Ghat was analyzed during this period, with improved water quality at Shetal Das Ki Bagiya being recorded after 2002 (Table 6).

9.2 Dredging and Desilting

The Upper Lake receives runoff and wastewater from 38 inlet channels in its catchment area, spread from the northern to southern side of the lake. The major part of the catchment area is subject to agriculture activities, and part is devoted to settlements, in a ratio of approximately 70:30. Although part of the southern side of the Upper Lake is protected, due to the Van Vihar (protected area) and Shyamla hills, the northern side of the settlements has spread rapidly over the last two decades. The shallow portion of the Upper Lake extends towards the north. The stormwater inflow deposits silt in the shallow area of the lake, with regular deposition of silt and dead organic matter making the lake shallower. Water to the Upper Lake is supplied as potable water, thereby exposing the shallow area during the summer months because of the receding lake water level. The accrued nutrients support plant and macrophyte growth. After death and decay of the plants, humus is formed, and because of decomposition of the humus, the nutrients are recycled in the lake ecosystem. This phenomenon is repeated at least twice per year, enhancing nutrient enrichment of the lake water. To ameliorate the situation, as well as increase the lake's water storage capacity, a desilting operation was carried out, resulting in removal of considerable quantities of nutrients from the lake bed, including 187.4 tons of nitrogen and 93.7 tons of phosphorus in the total 4.68 million tons of silt removed.

9.3 Impacts of De-weeding

The Upper and Lower Lakes receive untreated sewage though different sewage inlets. The estimated pollution load to the two lakes through this process is presented at Table 7.

Table 6. Comparison of Water Quality Status after Shifting the Idol Immersion Site.

Parameters	Shetal Das Ki Bagiya		Prempura Ghat	
	1998	2003	1998	2003
Turbidity (FAU)	68	17	6	36
Total alkalinity (mg/l)	228	110	74	164
Biochemical oxygen demand (BOD; mg/l)	36.4	12.0	1.6	14.0
Chemical oxygen demand (COD; mg/l)	270	40	20	68
Chloride (mg/l)	50.6	17.98	28.8	24.98
Total hardness (mg/l)	200	104	66	152
Phosphate (mg/l)	2.98	0.37	0.081	3.21
Chromium (mg/l)	0.038	0.009	0.02	0.04
Nickel (mg/l)	0.056	0.038	0.018	0.052
Lead (mg/l)	0.648	0.018	0.023	0.042
Manganese (mg/l)	0.682	0.02	0.043	0.052

Because the lake's nutrient enrichment accelerates the growth of macrophytes, removal of weeds (invasive shoreline and floating weeds, emergent and submerged weeds) was conducted, and nutrient levels in various types of weeds analyzed, as part of the conservation measures (Table 8).

The pattern of nutrient accumulation in major emergent, floating and submerged weeds is illustrated in Table 9.

A revival of indigenous species was also observed as a result of the removal of invasive species. The harvesting of weeds from the lakes, by mechanical or manual means, has demonstrated that the eutrophication of the lake can be controlled to a large extent by this process. Similarly, the heavy metal contamination also can be controlled through harvesting of weeds (e.g., water hyacinth).

9.4 Effects of Mechanized Boating

The Upper Lake attracts many tourists, for which a number of mechanized boats utilize the lake. Accordingly, a study to assess the impacts of mechanized boating on lake water quality was conducted, indicating considerable oil and grease leakage from the boats, due to bad maintenance. This material forms an impervious layer over the water surface, causing anaerobic conditions in the bottom water layer in the lake. Based on these results, action was initiated by the local body and mechanized boating was prohibited in the Upper Lake.

10. Future Action Plan for Sustainability

During the implementation of the Lake Bhopal Conservation and Management Project, it was realized that due to the multiplicity of agencies involved in the development, regulation and maintenance of the lakes and their catchment areas, and the issues thereof, the conservation and management efforts for these lakes were being diluted. Also, environmental conservation and management of lakes cannot be a one-time effort, and project activities must be continued as a catalyst to initiate further action and development activities.
Additionally, the experiences gained and the human resources developed during the project implementation process should be meaningfully utilized for the purpose of conserving lakes and other waterbodies of the entire state of Madhya Pradesh. Finally, although there are a number of laws related to water resources, there is no single agency with responsibility for their conservation and management. Thus, there is a need for a specialized, legally-empowered agency for the integrated conservation and management of lakes and waterbodies.

The Government of Madhya Pradesh has proposed establishing an independent Lake Conservation Authority (LCA) for conservation and management of lakes for the entire state of Madhya Pradesh. In response to this initiative taken by the Government of Madhya Pradesh, JBIC funded a pre-investment study of the institutional and financial framework of such an agency. After discussion with various stakeholders, and several rounds of roundtable meetings with the stakeholders, the pre-investment study consultant recommended an institutional framework for the Lake Conservation Authority, and suggested a mechanism to make the Authority financially viable (it is noted that, there were no attempts during the project implementation to generate revenues except by the Water Quality Monitoring laboratory until now). It is proposed that the Authority function with two-tier administrative set-up (i.e., a State level Lake Conservation Authority), headquartered at Bhopal, with local Lake Management Committees constituted for each conservation area (constituting a specific lake, its catchment and command areas). The responsibilities of the LCA will include the following:

- Preparing an inventory of lakes and other waterbodies in the state;

Table 7. Estimated Annual Pollution Load from Untreated Sewage (million tons).

Parameter	Upper Lake	Lower Lake
Nitrate	22	44
Total phosphorus	97	217
Biochemical oxygen demand (BOD)	270	4590
Chemical oxygen demand (COD)	81	22,952

Table 8. Removal of Weeds from Upper and Lower Lakes during 1999-2000.

Type of weeds	Quantity removed	
	Upper Lake	Lower Lake
Shoreline *(Ipomoea fistulosa)*	4.21 km^2	–
Emergent	6.11 km^2	–
Free floating	21,346 tons	5,807 tons
Submerged	74,078 tons	–

Table 9. Levels of Nutrients in Various Types of Weeds.

Type of weed	Name	Nutrient level (mg/kg)	
		Nitrate	Phosphorus
Emergent	*Scirpur royli*	58.0	0.008
	Jussia repens	1.28	0.0025
	Polygonum glabrum	8.28	0.0014
Free floating	*Eichornia crassipes*	70.60	0.028
Submerged	*Potamogeton crispus*	8.28	0.004
	Mysiophyllum spathullatum	1.31	0.0015
	Ceratophyllum derriursum	8.284	0.0018
	Najas minor	1.28	0.007
	Vallisnaria	38.0	0.018

- Identifying critical water sources and formulating conservation and management plans to prevent anthropogenic activities;

- Regulating and controlling incompatible activities which adversely affect the water sources;

- Formulating policy guidelines for managing water resources;

- Preparing basin management plans;

- Identifying and facilitating declaration of conservation areas; and,

- Preparing status reports of water resources.

The conceptual framework of the Authority is provided in Figure 2. The LCA will have four functional divisions (Research, Development and Monitoring, Engineering, Outreach and Administration and Finance). While Outreach Cell will be responsible for implementation of awareness program involving NGOs, the Research, Development and Monitoring and Engineering divisions will focus on development of conservation plans of the lakes of the state, and monitoring implementation of such plans by the Field level agencies in the Conservation Areas. The day-to-day function of the LCA will be under the control of a Chief Executive Officer.

The State Government has approached JBIC to provide a core fund for the functioning of the Authority which, through proper investment of the corpus fund, and generating resources through project grants and consultancy services to other agencies involved in lake management within and outside the state, would generate additional funds to make the Authority a self-sustaining organization. This issue is presently being negotiated between the State Government and JBIC.

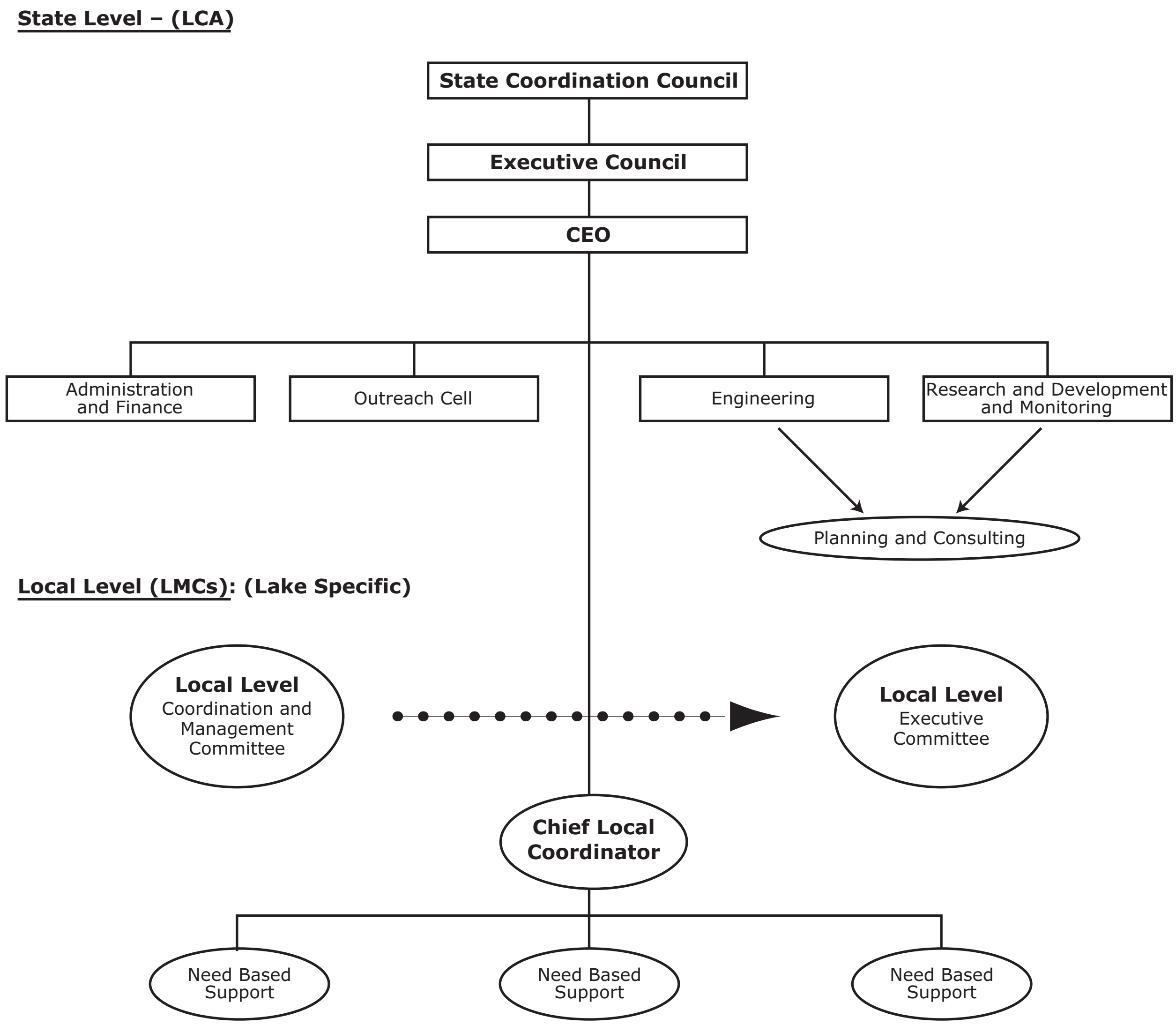

Figure 2. Conceptual Framework of the Lake Conservation Authority.

11. Lessons Learned

11.1 An Integrated Project Planning Approach is Required

Lake management is a very complex issue, involving different disciplines, multi-dimensional activities and an integrative approach. Unfortunately, the mind set of experts available for such work is quite different; technocrats consider lakes as a physical entity and apply stereotypic technology-based solutions, while scientists consider lakes as 'living systems' requiring specific solutions based on prevailing biological and physicochemical circumstances. This differing perception sometimes leads to a conflicting situation in regard to project implementation. The best solution to this problem lies in imparting common core training to all project staff, covering diverse areas and interdisciplinary topics.

Staff training should be arranged at the beginning, rather than in between implementation phases. Staff selection should be according to the work requirements, and their qualifications, experience and expertise should be elaborated in the project proposal itself. The processing of a project should be simple and easy so as to avoid delays. Post-project infrastructure maintenance for specific periods should be a part of the project proposal, including the necessary funding allocations.

11.2 A Lake and Its Catchment Must be Managed as a Composite Whole

Management of lakes and reservoirs for their sustainable use is directly linked to their catchment. In other words, a lake is a reflection of its catchment, and a number of measures must be taken to protect the catchment, including:

- Developmental activity that affects its green cover and landscape should be prohibited, and developmental activities associated with human settlements in the catchment should be restricted;
- Nonpoint source runoff (i.e., from the drains) must be trapped; and,
- Agriculture activities in the catchment require an awareness generation, conducted via the government extension services machinery, especially to facilitate a change in fertilizer consumption patterns, from chemical to organic fertilizers.

11.3 Awareness Raising, Education and Stakeholder Participation are Essential

Stakeholder involvement, including lake-dependent communities and common people, should be an integral part of any management program. Their interest in the lake needs to be sustained through awareness campaigns and other eco-friendly activities.

11.4 Lakefront Protection is a Must

The lakefront is always prone to encroachments and pollution, thereby requiring protection as a major management action. This could be achieved by declaring a buffer zone from the full tank level of the lakes as a "No Construction Zone," by developing and demarcating the area as a bio-physical zone. Nevertheless, protecting the lakefront and water-spread area from abusers is a continuing battle.

11.5 Administrative and Financial Mechanisms for Expeditious Decision-Making are Needed

Project implementation in a government mechanism is usually handicapped because of a maze of red tape and delays in the decision-making process. For special projects, however, there is a need for administrative and financial innovations in project execution, as has been demonstrated by various state government decisions which helped expedite the decision-making process.

11.6 Continuity of Project Staff is Essential

This lesson is of utmost importance when executing a time-bound conservation project. In the project, the technical staff involved in project preparation and execution remained with the project for long periods of time, thereby facilitating project continuity. However, frequent changes of the project head during the period when its execution was in full swing affected the project implementation progress.

11.7 Need to Sustain Measures

By their very nature, conservation measures are never one-time activities. The sustainability of the measures must be ensured for a long period, in order to achieve fruitful results.

12. References and Further Reading

Agarker, M.S. *et al*. 1994. *Biology, Conservation and Management of Bhoj Wetland*. Bionature.

Annual Report of Environmental Research Laboratory. 2000-2003. Bhoj Wetland Project.

Bajpai, A., S. Pani, R.K. Jain and S.M. Misra. 2002. "Heavy metal contamination through idol immersion in a tropical lake." *Eco. Env. and Cons*. 8(2): 157-159.

Chandrasekhar, S.N.A. 1996. *Ecological studies on Saroornagar lake, Hyderabad, India*. Ph.D. Thesis, Osmania University: Hyderabad, India.

Detailed Project Report of Deweeding of lakes. 1997. Bhoj Wetland Project.

Detailed Project Report of Control of Weeds through Aquaculture. 1997. Bhoj Wetland Project.

Detailed Project Report of Dredging and Desilting of lakes. 1998. Bhoj Wetland Project.

Detailed Project Report on Deepening and Widening of Spill Channel. 1998. Bhoj Wetland Project.

Edmondson, W.T. 1991. *The Uses of Ecology, Lake Washington and Beyond*. University of Washington Press: Seattle, WA, USA.

Kodarkar, M.S. 1995. "Conservation of lakes, with special reference to five waterbodies in and around Hyderabad." Publication 3, Indian Association of Aquatic Biologists (IAAB): Hyderabad, India.

Mukerjee A. 1999. "Conservation and Management of Bhoj Wetland, India." In the *Proceedings of the 8th International Conference on the Conservation and Management of Lakes* in Copenhagen, Denmark.

Mukerjee, A. 1999. "Fringe Area Management in the Context of Urban Lakes." In the *Proceedings of the 2nd National Consultation on Framework For Action (FFA) for the Indian Water Vision* in New Delhi, India.

Mukerjee, A. 2000. "Religious Activities and Water Pollution: Case Study of Idol Immersion in Upper and Lower Lakes of Bhopal." Paper presented in *World Lakes Session, 2nd World Water Forum* in The Hague, Netherlands.

Mukerjee, A., P.K. Nandi and A.K. Bajpai. 2000. "Dynamics in Bhoj Wetland, Bhopal." Paper presented at the *20th Annual International Symposium of the North American Lake Management Society*, Madison, USA.

Mukerjee, A. and P.K. Nandi. 2000. "Impact of religious practices, boating and trapa cultivation on Upper Lake, Bhopal." In the *Proceedings of the 10th World Water Congress*, Melbourne, Australia.

Mukerjee, A. 2001. "Religious Activities and Water Pollution." Paper presented at *Asian Wetland Symposium*, Penang, Malaysia.

Muromoto, S. and Y. Oki. 1983. "Removal of some heavy metals from polluted water by water hyacinth (*Eichornia crassipes*)." *Bull. Environ. Contain. Toxicol*. 30: 170-177.

Nandi P.K. and S. Pani. 2002. "Impact of nutrient enrichment on biodiversity of a tropical wetland." In the *Proceedings of the Conference on Reservoir Limnology*, Czech Republic.

Nandi P.K. 2002. "Control of *Ipomoea fistulosa*, an invader species in Upper Lake, Bhopal, India." In the *Proceedings of the 23rd Meeting of the Society of Wetland Science*, Lake Placid, USA.

Pani, S., B.J. Khan and P.K. Nandi. 2002. "An analysis of effectiveness of restoration measures in the improvement of water quality of Bhoj Wetland." In the *Proceedings of the International Conference on Hydrology and Watershed Management*, Hyderabad, India.

Pani, S. and S.M. Misra. 2003. "Impacts of artificial aeration/ ozonization on algal community structure of a tropical eutrophic lake." *Eco. Env. and Cons*. 9(1): 31-34.

Pani S., S.M. Misra and P.K. Nandi. 2000. "Bio-monitoring of two tropical water bodies of contrasting trophic status using macrobenthos." In the *Proceedings of INTECOL 2000*.

Postel, S. 1984. "Water: Rethinking management in an age of scarcity." *World Watch Paper* 62.

Singh, R.K. and H. Anandh. 1996. "Water quality index of some Indian rivers." *Indian J. Environ. Health* 38 (1 and 2): 21-34.

Subrata, P. and S.M. Misra. 1993. "Impact of hydraulic detention on the water quality characteristics of a tropical wetland (Lower lake)." In Pankaj Srivastava (ed.). *Environmental pollution and its management*.

Tekale, N.S. 2003. "Idol immersion: A critical analysis of environmental impact on urban lakes and remedial measures." In the *Proceedings of the UGC-sponsored National Conference on Urban lakes: Environmental status economics and management options*, Hyderabad, India.

World Commission on Environment and Development. 1990. *Our Common Future*. Oxford University Press: Oxford, U.K.

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

Disclaimer