Ecological Changes in Dal Lake Kashmir and its Restoration

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ABSTRACT

Dal Lake (Lat. 340 – 6' N, 740-45' E, alt. 1583m) situated in the heart of Srinagar city, the summer capital of Jammu & Kashmir State is under tremendous anthropogenic pressure. The myriad ways in which people use the lake along with the numerous pollutant-generating activities have stressed the lake ecosystem in diverse ways. Despite the fact that a number of restoration and conservation plans prepared by National and International agencies and being abortedly implemented by state authorities, there is no significant improvement in Dal lake environment; the lake conditions as a whole continue to deteriorate at an alarming rate. The present paper attempts to record the changes in the hydrochemistry and biodiversity of the lake during the last three decades besides giving the current ecological status of the lake; summarizing the reasons for failure of lake restoration; suggesting measures for lake restoration based on ecosystem perspective and signifying the use of wetland mediated technology for the removal of biologically important nutrients.

INTRODUCTION

Aquatic ecosystem worldwide are being severely altered or destroyed at a rate greater than that at any other times in human history and far faster than they are being restored. Dal Lake ecosystem (Lat. 340 – 6' N, 740-45' E, alt. 1583m) situated in the heart of Srinagar, the summer capital of Jammu & Kashmir State is under tremendous anthropogenic pressure since more than three decades. More than 50,000 people live within the lake itself in various islands (hamlets) besides houseboats. The myriad ways in which people use lake, along with the numerous pollutant-generating activities have stressed the lake ecosystem in diverse ways. These stresses have caused significant impairment to lake quality. Three major classes of stress have been identified that has degraded its quality:

i. excessive inputs of nutrients and organic matter, from point and non-point sources, leading to eutrophication.
ii. hydrological and physical changes
iii. siltation from inadequate erosion control

Of these three categories, stress problems related to nutrient over enrichment and excessive plant production is probably the most common. An estimated load of 12.30x106 m3 of liquid waste with 18.17tons and 25 tons of Phosphorus and inorganic nitrogen is enriching lake annually.

Despite the fact, number of restoration plans by National and International agencies viz., Srinagar Master plan of 1971, Lake Area Master Plan by Stein (1972), Enex Consortium Report (Enex,1978), Dal lake Development Report by Riddle(1985), ODA(1989) Project Report under NLCP (1997) and Project Report of AHEC Roorke(2000), there has been no significant improvement in Dal lake environment but the lake conditions as a whole continue to deteriorate at an alarming rate thereby threatening the very existence of the lake beside posing serious health hazard to the people within and around the lake.

The present paper attempts to record the changes in the hydrochemistry and biodiversity of the lake during the last three decades by comparing the earlier available data (Kachroo & suri, 1987, NIAE, 2000) besides giving the current ecological status of the lake; summarizing the reasons for failure of lake restoration; suggesting measures for lake restoration based on ecosystem perspective and signifying use of wetland mediated technology for removal of biologically important nutrients.

METHODOLOGY

The sampling was done on monthly basis during forenoon (900-1200hrs.) and usually composite samples were considered for physico-chemical analysis and plankton enumerations. Oxygen concentration was determined by Winkler's modified method. Pre- fixation of the samples was done in the field. For rest of the parameters methods given in APHA (1997), and Mackereth (1963) were followed using DR4000 UV-spectrophotometer (HATCH, USA).Phytoplankton enumeration were done by filtering 1 litre of lake water through plankton net (mesh size 64mμ) while for zooplankton 10 liters of water were sieved keeping in view the low density of zooplankton population. The filtered plankton samples were preserved with 1% acidified Lugol's solution and enumerations were done in 1ml Sedgwick rafter counting cell. Identification of plankton was done after consulting Smith (1950), Desikachary (1959), Ward and Whipple (1959), Subba Raju (1963), Phillipose (1967) and Weber (1971).

WATER QUALITY CHANGES

Assessment by parameters

The average secchi transparency of Dal Lake was 1.2 m during the study period against an average value of 2.5 - 3.6m during 1965-1966 by Zutshi (1968). Kachroo and Suri (1987) reported 77.1% decrease in transparency during 1976 and 70.3 % during 1985 while Zutshi (1987) recorded decrease in visibility by one metre in Nigeen basin of

Dal lake. The 100% decrease in average secchi transparency by Kundangar and Zutshi (1985) and Zutshi (1987) is attributed to increased suspended material present in the lake.

The average dissolved oxygen content during 2005-2006 is recorded to be 6.8 mg/l against 10.2 mg/l during 1974-1976 (Kachroo and Suri 1987), thereby indicating a major shift in oxygen regime. According to Wanganeo and Wanganeo (1997) the oxygen concentration in water depends on temperature, plankton population and the degree of sewage pollution. In the present studies the depletion of oxygen content could be attributed to the contamination of water due to incoming sewage and also to increased density of phytoplankton population, recorded in various polluted basins of Dal Lake. Table(1) depicts the significant increase in total alkalinity, nitrate-nitrogen, ammonical-nitrogen, phosphate content and that of the total dissolved solids which may be taken as indication of deteriorating water quality. Average total alkalinity values recorded during the study period (2005-2006) is 93mg/l which is indicative of moderately hard waters. The alkalinity was of bicarbonate type which is in conformity with those of Freiser and Fernande (1966), who stated that when total alkalinity is higher the carbonate system persists and pH usually remains on alkaline side.

The average nitrate-nitrogen content and ammonical-nitrogen content was recorded to be 539 and438 µgl-1 respectively during 2005-2006 which is much higher than those of earlier records of Kachroo and Suri (1974-1976, 1985) NIAE report (1996-1997) and Kundangar et al (2003).

The average phosphate content was also high (768 and 515µgl-1) during 1996-1997 and 2005-2006 as compared to earlier records. The higher concentration of phosphorus and nitrogen in the lake waters is yet another indication of higher trophic level. According to Mc Caull and Crossland (1974) the most important factors responsible for eutrophication of freshwater lakes are phosphorus (Po4-P) and nitrogen (NO3-N). Smil (2000) reports human activities have intensified release of nutrients. By the year 2000 the global mobilization of the nutrient has roughly tripled compared to its natural flows; increased soil erosion and runoff from fields, recycling of crop residues and manures, discharge of urban and industrial wastes and above all, application of inorganic fertilizers (15 million tones / year) are the major causes of this increase which holds good for Dal lake too.

The average value of total dissolved solids during 1966-1997 was 119.8 mg/l while during 2005-2006 it was 201 mg/l. These values are very high when compared to earlier records of 30.2 mg/l by Kachroo and Suri during 1974-1976. The high values of TDS is clear indication of continued siltation, failure of retention of silt by partially commissioned settling basin, also due to high ingress of sewage into the lake and mineralization process of organic matter.

Table 1 : Water quality changes in Dal lake during three decades

Parameters	Unit	1974-1976 [1]	1985 [2]	1996-1997 [3]	2005-2006 [4]
Dissolved oxygen	mg/l	10.25	8.7	8.6	7.9
Total alkalinity	mg/l	69.5	85.6	104	93
Nitrate nitrogen	µg/l	481	483	272	539
Ammonical nitrogen	µg/l	23.6	37.0	362	438
Ortho phosphate	µg/l	65.5	80.5	135	93
Total phosphorus	µg/l	187.8	211.5	768	515
Total dissolved solids	mg/l	30.2	32.2	119.8	201

CHANGES IN BIODIVERSITY

Bacteriological studies

The coliform group of bacterial density is significant criteria of degree of pollution or sanitary quality, therefore, monitoring microbial response has been recommended as an early working indicator of stress in aquatic ecosystems (Adnan and Kundangar 2005). Enex (1978) reported that the waters of the Dal lake were contaminated by the faeces of warm blooded animals. The increase in total fecal coliform from the Boulevard (House boat area) indicated that some of the material is coming from human sources due to discharge of night soil from the houseboats. The report further adds that at the houseboat site the total coliform counts exceeded 2400(MPN/100ml). Adnan and Kundangar (2005) reported average total coliform count of 415 CFU/100ml and faecal coliform count of 228 CFU/100 ml at Hazratbal basin of Dal lake while, at Nishat basin recorded mean counts of 75 FU/100ml and 32 CFU/100ml respectively. The house boat and settlement area near Boulevard and Gagribal recorded mean total and faecal coliform counts of 454 and 180 CFU/100ml and 19283 and 3876 CFC/100ml respectively (Table 2). It is quite clear that during last three decades human activities have resulted in elevated levels of total and faecal counts besides inadequate sanitary system, poor land use practices in the immediate catchment and the discharge of grey water continues to jeopardize the water quality of Dal Lake.

Table 2 : Bacterial population at four sites of Dal Lake

Site	Total Coliform [1] (MPN/100ml)	fecal Coliform [1] (MPN/100ml)	Total Coliform [2] (CFU/100ml)	fecal Coliform [2] (CFU/100ml)
Boulevard	2400+	2400+	454	180
Hazratbal	1500	460	415	228
Gagribal	750	240	19283	3876
Bod Dal	640	0	75	32

Plankton

The phytoplankton species are qualitatively and quantitatively better represented

in the polluted zones. The most important forms which were predominating include Cyclotella operculata, Melosira granulata, M.varians, Synedra ulna, Achnanthes sps, Gomphonema accuminatum, G. constrictum, G. gracilis, Navicula radiosa, Nitzchia sps., (Diatoms) . Pandorina morum, Pleodorina calfornica, Eudorina elgans, Volvox globator, Chlorella vulgaris, Ankistrodesmus sps., Selenastrum sp., Pediastrum sp., Scnedesmus bijugatus, S.quadricauda (Green algae) Microcystis aeruginosa, M. robusta, Merismopedia sp., Aphanocapsa biformis, Oscillatoria sps; Anabaena constricta, A. circinalis, Aphanizomenon flosaquae (Blue green algae) and Euglenoids like Phacus accuminata, Euglena acus, Euglena sp.

A significant relationship was reported between the dominance of a particular algal classes and the proximity of wastewater disposal sites in Dal Lake by Zutshi and Vass (1982). Wanganeo and Wanganeo (2006) in their studies on plankton diversity in Kashmir Himalayan lakes observed that during the summer when the temperature conditions are favorable and the nutrient influx is more due to human pressure the most sensitive species get eliminated and large population of more tolerant species replace them such as Euglena, Oscillatoria and Microcystis. Stockner and Benson (1967), Richardson (1968), Williams (1969), Holland and Beeton (1972) and Sommerfeld et al (1975) regard Fragillaria and Nitzchia as indicator of sewage pollution and eutrophy. According to Munawar (1970) the rise in nitrates and phosphate may accelerate the growth of algal forms other than Cyanophyceae, particularly diatoms and green algal forms. Munawar (1972) attributed the abundance of euglenaceae to higher concentration of organic matter (15-16ppm). The author suggests that euglnoids are closely associated with the oxygen-iron complex in view of the fact that sewage pond exhibits higher concentration of carbon dioxide and phosphate, with a persistent deficiency of oxygen. Since all these elements are readily available in the Dal lake basins thus could be responsible for predominance of euglenoids. Kundangar et al (2003) while recording the Microcystis bloom in Nishat basin of Dal lake as a result of massive deweeding ,the area depicted depletion in oxygen content in the bottom waters coupled with high range of ammonical-nitrogen, nitrate-nitrogen and total phosphorus. According to authors Mirocystis is dependent on NH4-N supplied by animal and bacterial excretion in the water sediment. The dominance of Chlorophycean species with particular reference to Volvocales is attributed to enriched waters due to urea superphosphates and Potash by Subla et al (1986).

Among the zooplankton communities rotifera were the predominant group and their population was comparatively much higher in polluted zones of Dal lake. The species which have dominated include Cyclops sp; Bryocamptus minutes, Diatopomus (copepoda), Bosmina longirostris, (cladocera), Pompholyx sp; Polyartha qudricornis, Trichcerca sp. Keratella cochlearis and Brachinous sps.(rotifera).

Wanganeo and Wangneo (2006) regard the dominance of rotifers in the lakes due to influence of eutrophication. Micheal (1964), Sampath et al (1979) attributes the

dominance of rotifers to higher total alkalinity values and hardness of water which is in conformity with the present studies where the total alkalinity values and hardness in Dal lake basins have increased significantly during the past three decades. Zutshi and Vass (1982) observed low population density of zooplankters in open waters in comparison to sites close to human settlements. However, the scenario has changed as no significant change is recorded in population density of zooplankton densities between the open waters and that of the shores because of ingress of raw sewage, of which the impacts are now extending to the open waters despite dilutions.

Algal blooms

Although the algal blooms are natural to freshwater lakes but the Dal lake waters with the advent of time and due to increased and unabated human incursions within and lake peripheries have witnessed frequent algal blooms. Recurrence of such blooms have become a regular phenomenon in the various basins of the lake.In1991 the reddening of the lake waters due to Euglenoid bloom was first of its kind. According to Kundangar and Sarwar (1997) a close relationship was observed between chloride and nitrates which almost coincided with those of euglenoid population. The authors opined that the lack of water flushing, nutrient enrichment and accumulation of free carbon dioxide were the possible causes of the euglenoid bloom in Dal lake. In April 1998 a bloom of cladophora was recorded in the Pokhribal zone of Nigeen basin of Dal lake which smelled like untreated sewage and chocked the waterways near the exit point of Nallha Amir Khan (Kundangar 1999).The author attributed the appearance of this ' blanket weed' to the chemical enrichment due to incoming sewage. In 1999 the two algal blooms one of Volvocales and that of Microcystis aeruginosa appeared in Hazratbal and Nehrupark basin respectively giving waters a lush green colour. The Microcystis bloom since then has remained perpetual in the lake basin and has engulfed the entire basin. Besides these, Spirogyra bloom is of common occurrence in the Nigeen lake particularly when the exit gate at Nallah Amir Khan remains closed.

Macrophytes

Although many workers have carried extensive studies on macrophytic vegetation of Dal lake in the past but later studies by Zutshi (1968,1975), Zutshi and Vass(1971,1973,1982) and Kaul et al(1972) recorded significant changes in macrophytes vegetation in Dal lake where under Ceratophyllum had colonized large tracks of the lake forming mono-specific meadows. Zutshi and Wanganeo (1980) reported Salvinia invading open water areas of the lake. Kachroo et al (1987) also reported increase in abundance of some eutrophic macrophytes like Ceratophyllum demersum, Myriophyllum spicatum, Hydrilla verticellata, Potamogeton crispus, P. lucens, Najas flexilis, Lemna trisulca and Salvinia natans. Zutshi (1987) reported Eurayle ferox almost disappeared from the lake and number of Chara species reduced in their coverage. Kundangar (1996) reported radical changes in the macrophytic associations in Dal lake. According to the author the

luxuriant growth of Hydrocharis dubia mixed with Salvinia natans and Lemna sps. at the inshore sites, describing it a significant change; as this type of vegetation had never been observed on this side of the lake basin. The author further reported luxuriant growth of Potamogeton natans, Trapa bispinosa, Nymphoides peltata and dense forests of submerged species like Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton sp. and Hydrilla verticellata associations in the Nishat basin. Presently Hazratbal basin of Dal lake depicts Myriophyllum-Ceratophyllum associations with thick patches of P. pectinatus. The Nigeen basin is mostly infested with Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton. sps and Nymphoides sps.

Peculiar changes have occurred in this basin over a period of time arising out of human incursions. Not only the floating gardens are being expanded unabatedly but 1/3 of the lake area towards Saderbal side has been turned in to marsh supported by thick mats of Typha and Phragmites and subsequently into land mass.

Euryale ferox, an abundantly found macrophytes has almost vanished and hardly scattered plants could be seen interspersed with Nelumbo plants. Chara an alga of which eleven (11) species were recorded by Mukerjee (1934) is on the verge of extinction and hardly few plants could be recorded in undisturbed pockets of the lake. Eichornia crassipes(water hyacinth), Azolla sp. the exotic species are now the new invaders to the lake and assumed the greater dimensions. Zutshi (1987), Kundangar et al (2000) presumed that the different growth pattern of macrophytes was mainly controlled by the mineral grain depositions and the slope orientations of the lake basins. Kundangar (1996) attributed the significant changes in the vegetational pattern of the Dal lake and their prolific growth in the open areas to unabated inflow of effluents channels, drains and raw sewage and enrichment of the lake sediments particularly due to heavy load of organic nitrogen and phosphates.

Fish and Fisheries

The fish population of Kashmir has been introduced from the Central Asian Highlands during the second inter glacial period, (Hora, 1975, Das and Subla, 1968, Jayaram, 1974). The fish species include the members of Schizothoracine, Sisordiae and Cobitidae. The notable fish species common in Dal lake were Schizothorax esocinus, S.niger, S.curvifons, S. micropogon, Labeo dera, Carassius carassius but during the last three decades their number has declined sharply. The schizothoracides have been since out numbered by Carpiodes. The two fish species viz; Cyprinus carpio specularis and C. carpio communis, introduced in 1956 have got well established as they thrive in waters rich in nutrients and organic matter. The present day fish catch of Dal lake comprises more than 80% of the carp. The decline in fish diversity and yield is attributed to the changes in hydrological regime and lost of critical habitats. The changes in the species richness can be attributed to heavy loads of incoming sewage thereby leading to increased eutrophication which has adverse impact on the growth and development of sensitive

fish species like Schizothorax. The increased pollution levels are favourable for the prolific growth of aquatic vegetation, which seem to be more favourable for hardy species thereby altering the balance of species richness.

RESTORATION OF DAL LAKE

On the basis of recommendations of the various consultants from time to time, the measures taken by the concerned authorities include partial commissioning of settling basin at the mouth of lake to arrest the tremendous silt load form Telbal nallah (a perennial source of water), marginal dredging along the lake shore, retrieving of land masses including that of sediment and slush, improving of the water circulation by way of cut and conduit at Brarinambal, revamping of the exit gates, removal of illegal floating gardens and some hamlets within the lake, deweeding along the specified lake areas, aeration of the lake water at selected places, laying of sewers around the lake and setting up of few Sewage treatment plants. Yet the lake does not show any sign of improvement either in its water quality or overall lake ecology. The fact remains that the condition of the lake is deteriorating at an alarming rate and creating hue and cry among the people of all walks of life.

The reasons for the failure of restoration programme of Dal lake are summarized as under:

a) Changing of the consultancies from time to time and non-availability of required funds in time.
b) Politicization of the issue of Dal lake conservation and diversion of funds.
c) Predominance and preferences on engineering works.
d) Winding up of an established Research and Development wing to reduce the scope of scientific surveillance and to avoid any sort of scientific contempt.
e) Adopting of such energy dependant wastewater treatment (FAB) technology, proven to be failure under Kashmir conditions.

Kundangar (2003) while monitoring the FAB based STP of one of the hotels in the immediate vicinity of Dal lake recorded reversed trend i.e., instead of expected decrease in nutrients, a significant increased was observed in the treated sewage. According to the author 90-98% increase was recorded in ortho-phosphate and total phosphorus respectively while 32% increase was recorded in nitrate-nitrogen during winter months. The author had cautioned about the adoption of this technology for Dal lake prior to its installation. Table(3) reveals the malfunctioning of the FAB based STP installed and commissioned by the Dal lake Authority and in the opinion of the author the situation will not only aggravate the problem of pollution of Dal lake but shall have catastrophic consequences; as the non-point sources of pollution are becoming the point source of pollution. This is manifested by the massive and unmanageable weed infestations in all the basins of Dal lake, further enrichment of the lake sediment, anoxic conditions in

Table 3 : efficiency of nutrients removal through FAB-STP (April 2008)

Parameters	*Raw sewage	*Treated Sewage	*% removal	**Raw sewage	**Treated Sewage	**% removal
COD (mg/l)	116	36	69	190	108	43.1
Po_4-p (µg/l)	658	282	57	620	390	37
T.P (µg/l)	1660	342	79	1320	805	39
NH_4-N (µg/l)	2283	999	56	2810	1392	50
No_3-N (µg/l)	-	-	-	680	1232	**44**

**LWDA – Health Bulletin April 2008; ** Adnan & Kundangar (2008)*

various parts of the lake and perpetual occurrence of algal blooms and accelerated deterioration of water quality.

a) The unscientific and erratic deweeding practices have proved a cosmetic and temporary treatment without any relief to the ecology and health of the lake ecosystem.

b) The Houseboat waste management has remained still an unaccomplished job. The so called floating septic tanks installed in some houseboats during early nineties have proved only show pieces to mislead the people.

SUGGESTIVE RESTORATION MEASURES

The restoration measures should lay emphasis on:

a) Catchment conservation whereby already identified and prioritized micro watersheds should be taken for control of soil erosion and regulate flow regimes

b) Integrated water management into restoration whereby measures should be taken for enhancement of water holding capacity based on water and sediment balance; restore area under willow plantation, water lilies, vegetable gardens and other encroachment and take proper measures for improvisation of water quality

c) Biodiversity conservation whereby achieving self sustaining native and endemic fish population through targeted restocking and enhancing diversity and abundance of Schizothorax. Moreover, emphasis should be laid to develop method to reduce the prolific growth of endemic and exotic aquatic plants species like lemna, Salvinia and Azolla.

Frequently people have read reports in the print media about the plight of Dal lake where under the lake has been termed "Dying lake", "Open Sewer". There is no doubt that the lake is facing ecological problems due to superabundance of nutrients particularly that of nitrogen and phosphates yet the lake is quite alive. During the last three decades the phosphorus and inorganic nitrogen has increased tremendously enhancing the production of organic matter on the lake bottom where they are attacked by those decay organisms which generate ammonia. If the entry of raw sewage and its effective treatment are employed to reduce the levels of phosphorus and nitrogen a significant reduction in abundance of aquatic weeds and improvement in water quality is expected.

The long term solution in our opinion to the problem under Kashmir conditions (where there is already energy crisis and severe winters) is the adoption of a proven Root Zone technology (constructed wetlands) for wastewater treatment. Adnan (2004) while studying the role of aquatic macrophytes in treating the wastewater entering into Dal lake has stated that in order to improvise the lake condition it is important to reduce the input of nutrients (biologically important) from both the point as well as non-point sources. The Treatment compartments (constructed wetlands) have been found to be eco-friendly in reducing the nutrients (nitrogen by 70% and phosphorus by 73%) as well as other chemical constituents into the lake that can go a long way in maintaining the present trophic status of the water body. Construction of Treatment wetlands for wastewater treatment in and around Dal Lake including other lakes in Kashmir valley will have several advantages compared to conventional secondary and advanced wastewater treatment systems.

Moreover, the preparation of vegetational maps through latest available techniques seems to be a pre requisite in order to record the existing weed density prior to deweeding practices and that too under close scientific supervision. The desiltation of the settling basin has become inevitable to increase the efficiency of arresting of the incoming silt load. The retrieval and cleansing of chocked peripheral springs all along the lake periphery and diversion of their fresh waters towards lake will certainly increase the required volume of the lake.

The utter failure of the local authorities to restore the lake on scientific lines for last more than two decades and their interest in civil engineering works alone impel the authors to recommend the handing over the entire Dal restoration programme to any international agency well versed with the lake restoration programme.

CONCLUSION

Dal Lake management needs holistic approach that considers lake as component of a landscape and treats their restoration at the watershed scale. The state government should support research and development for watershed –scale restoration that integrate lake component. Various state agencies and university researchers should participate in planning, implementing and evaluating restoration work. Research and development are needed in several areas of applied limnology. Improved techniques for littoral zone and aquatic macrophytes management need to be developed. The relationships between loading of stress-causing substances and response of lake need to be understood more precisely. A well planned rehabilitation programme free of politics for the displaced Dal dwellers is essential. Empowerment of the lake authority to enforce the rules and regulations with proper legislation to curb the lake encroachments and violations is necessary for the success of Dal restoration programme.

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