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Mansagar Lake: Past, Present & Future

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ABSTRACT

Mansagar is spread over in about 130 ha with a maximum depth (>7m) at the dam's outflow point is a man-made lake polluted with municipal and industrial sewage since 1962 through 2 main wastewater drains namely Brahampuri and Nagtalai. Water-hyacinth infestation in 1975 suppressed algal growth whereas addition of its organic produce catalyzed water quality deterioration. This lake suffered maximum when unprecedented down pour for 2days in August 1981 deposited enormous amount of sand and silt through wastewater drains.

After 45 years of neglect, Ministry of Environment and Forest, New Delhi and State Government of Rajasthan have ventured into its restoration which is being executed by Jaipur Development Authority (JDA). This includes revamping of existing 27MLD Sewage Treatment Plant near Bhrampuri from which 7MLD treated water will be diverted to lake for compensating evaporation losses, lake front promenade along Amber road, road construction along south – east bank, desilting of lake, islands for bird nesting, check dam (about 5ha) for storing rainy season hill run off to forest wild life and manual removal of water-hyacinth. JDA has funded to State Forest Department for conserving soil and water on the forested hills surrounding lake from three sides.

During Limnological studies of the lake (JDA sponsored), we found very low Secchi disk transparency (<10.0cm) but higher values for EC, free CO2, BOD, COD, TKN and TP, especially during summer season. Phytoplankton were the most noticeable primary producers represented by 16species belonging to Bacillariophyceae (4), Chlorophyceae (8species) and Cyanophyceae (4) forming blooms during warmer period of the year (April-October). Among the ten zooplankton species, *Moina*, *Euglena* and *Paramecium* were dominant during warmer period while *Daphnia* and *Mesocyclops* in the winter. Most of the arthropods (9species) found were dominant during rainy and post-rainy season. *Clarius batrachus* (African tiger) was the only fish noted in the lake.

Our team is also executing JDA sponsored lake bank stabilization program since May 2005 and planted 35 species of trees and 28 of shrubs and undershrubs on the upper (relatively drier) reach of the bank slope (45^0). Among the 11 marshy species planted, only *Arundo donax*, *Cyperus alopecuroides*, *Phragmites karka*, *Scirpus* sp. and *Saccharum spontaeneum* are surviving, *Arundo* being the most successful one. Introduction of free floating and submerged species was however, unsuccessful in the lake. Beside landscape improving, plant species are providing shelter and food to both native and migratory birds.

Rajasthan Tourism Development Corporation (RTDC) joined hand with Jalmahal Resort Pvt. Ltd. Jaipur to develop infrastructure for tourism outside the lake under public-private partnership agreement. However, the latter is unofficial master of the lake and pursuing unscientific management practices derogatory to the lake ecosystem as well as monument therein and vicinal areas.

Key Words: Catchment, Algal bloom, aquatic flora & fauna, bank stabilization, desilting, lake mis-management

INTRODUCTION

Freshwater bodies commanding greater respect of Indian society even today had beginning of their pollution in the early 20th century, with the onset of urbanization (potable water supply through pipes and disposal of municipal waste in the drains) and industrialization in the country since these activities were not accompanied by establishment of wastewater treatment facility. Even today, most of the cities except for metros have minimal/no wastewater treatment facility. As a result, the water bodies located in/nearby urban areas were the first choice of civic authorities for waste disposal. Detail information of pollution rood. Similar data for lentic water bodies is not available though they are worst affected due to lesser dilution of pollutants and relatively slower self purification capacity in comparison to lotic system due to standing water. Deforestation and agricultural run off contributed further to water pollution. The rapid pace of urbanization and industrialization in the post-independence era has brought several water bodies either within or nearby urban settlements, and so, they are suffering from pollution caused by anthropogenic activities.

Rajasthan state situated in the north-west part the country is relatively a drier state. The erstwhile kings of this princely state constructed rain water harvesting structures such as tanka (underground covered tank in the palace for harvesting roof water), pond, babri (large open underground tank having access to water through stairs) and reservoir for meeting potable water and irrigation demands. Except for reservoirs, society has forgotten most of the other water harvesting structures which either exist no more or being polluted due to influx of urban wastes. In this communication, we are presenting state of health of a water body Mansagar (popularly known as Jalmahal) presently in transition phase due to ongoing lake restoration program of the Government of India in collaboration of Jaipur Development Authority, Jaipur.

Study Area

The Mansagar lake is a large manmade lake on the northern fringe of Jaipur city. Maharaja Mansingh I (1590-1619) impounded Darbhavati river and Nagtalai nala on the north side of the Khilangarh fortress by constructing a dam in 1610 that created this lake (Fig.1a). The lake is approximately 130ha in its spread with a maximum depth (>7m) at the dam's outflow point. It has a catchment of 23.5km^2, about 40% of which falls inside the dense urban area is presently the major source of water (about 90%) in the lake in the form of storm water runoff during rainy season while sewage in the dry weather. The remaining 60% watershed in the form of denuded and forested hills virtually contributes very little on account of impediments such as human settlements and hotels in the foot hills on western side and construction of roads on three sides of the lake (Fig.1b)**.** The maximum level of the lake is at 99.0m contour at which volume of water is 3136569.75MCM.

The lake glory as a pristine water body lasted until the former rulers had their control over the city and its surroundings having thick forest cover and a very thin human settlement of cowmen. The unpleasant history of the lake began shortly after independence, when new administration of Jaipur diverted walled city sewage in 1962 through 2main wastewater drains namely Brahampuri and Nagtalai. The most notorious aquatic weed water-hyacinth (*Eichhornia crassipes*) entered in the lake in 1975. It suppressed algal growth markedly disturbing lake trophic structure and also accelerated siltation by adding dead organic matter that catalyzed water quality deterioration leading to mass fish mortality (Sharma et al. 1978, Goel 1980, Trivedy 1980). This lake suffered maximum when unprecedented down pour for 2 days in August 1981 deposited enormous amount of sand and silt through two drains.

After 40 years of neglect, under the banner of National Lake Conservation Programme of Ministry of Environment and Forest, New Delhi, the State Government of Rajasthan received funding for lake restoration which is being executed by the Jaipur Development Authority (JDA). The total cost of this project is Rs. 24.72crores; of which 70% is the Government of India contribution while the rest is borne by the State Government.

Figure 1a. Satellite photograph of Mansagar lake.

Figure 1b. Mansagar lake during summer (2007).

LAKE WATER QUALITY MONITORING

Physico-chemical Characteristics

Water quality of lake had been maintained at 10 sampling sites for more than two years (March 2005-May 2007). The sampling at each site was made both from the surface and at 1m depth (sub-surface), with the exception of site 1 receiving municipal and industrial sewage in to the lake. Two surface water samples were collected from this site, one from wastewater outfall (S1a) and the other was from 100m of outfall (S1b). The remaining 9sites (S_2-S_{10}) from which both surface and sub-surface samples were collected are far away from each other**.** Temperature, dissolved oxygen and free carbon di oxide content of the water samples were estimated at the lake while other parameters in the laboratory following standard methods (APHA1989).

Since water quality data of surface samples are almost similar to sub-surface samples and therefore,

these are pooled and seasonal variations in values of various parameters are presented in Table 1.

Table 1. Physico-chemical characteristics of Mansagar lake water in different seasons during March 2005- June 2007.

Parameters/ Sites		Summer (April- June) 2005-06	2006 -07	Rainy (July – October) 2005-06	2006 -07	Winter (Nov. – March) 2005-06	2006 -07
Temp.	O	NA	21.0-24.0	NA	22.0-30.0	14.0-20.0	12.0-19.0
	L	NA	20.0-26.0	NA	23.0-29.0	14.0-22.0	8.0-21.0
EC	O	3.6-6.5	2.6-5.1	1.4-2.39	1.3-4.5	1.85 -2.7	2.6-3.3
	L	2.1-3.06	2.1-5.1	1.24 -3.7	0.9-3.23	1.71-2.71	1.9-2.84
pH	O	7.6-8.4	7.2-8.3	7.1-7.8	7.6-8.3	7.6-8.4	7.4-7.9
	L	7.2-8.1	7.9-8.9	5.2-8.2	7.8-8.5	6.9-8.8	8.1-8.9
TH	O	860-1620	694-1050	300-568	414-876	576-716	432-728
	L	576-748	568-720	400-992	456-604	464-664	480-736
Chloride	O	568-917	536-1040	136-358	310-838	318-412	216-556
	L	219-880	424-630	267-615	366-462	310-412	444-850
Sulphate	O	NA	154-374	95-1578	98-448	130-1432	68-224
	L	NA	166-212	82-1160	100-558	144-1556	98-228
Sulphide	O	NA	Nil -17.3	NA	Nil -6.4	NA	1.74-8.1
	L	NA	Nil – 0.3	NA	Nil -1.28	NA	Nil -9.3
TKN	O	55-145	53-150	51-66	31-73	60-121	35-82
	L	48-120	31-80	11-39	13-50	21-106	13-60
TP	O	5.9-6.9	3.96-9.04	0.45-3.75	3.08-5.04	4.8-6.21	3.93-5.97
	L	5.2-7.8	4.6-10.04	0.6-9.95	2.82-6.31	2.2 – 8.7	1.97-8.56
BOD	O	202-350	154-589	16-540	155-333	132-205	218 - 364
	L	135-330	120 - 287	10-185	74-189	26-361	31-240
COD	O	425-988	319-1830	30-1051	204-416	271-643	239-376
	L	268-498	224-355	13-365	151-298	54-610	102-480
DO	O	1.0-4.9	Nil	Nil -3.6	Nil -7.3	Nil -1.35	Nil -2.6
	L	1.3-17.5	Nil -11.7	1.5-12.1	1.61-16.2	0.5-21.4	3.0-16.7
FreeCO2	O	132-350	Nil	22-145	5-95	8-66	40-244
	L	Nil - 647	Nil - 97	Nil - 335	Nil - 44	Nil - 41	Nil - 73

O = Outfall (Site 1-2); L = Lake samples (Site 3-10); NA = Not available; Except for pH and EC (mS), **a**ll values are in ppm.

In general, values of all the parameters were significantly higher at the Outfall sites (S1a, b) in comparison to other sites (S_2-S_{10}). Secchi disc transparency was found very low (<10.0cm) throughout the study period due to increased turbidity caused by phytoplankton and suspended matter. However, large seasonal variations were observed in the values of other water quality parameters, their values being minimum in the rainy season due to dilution caused by rains and maximum in the summer due to higher evaporation. In comparison to 2005-06 data, maximum values of free carbon di oxide, COD, BOD, TKN, sulphate and chloride contents decreased in the lake (S_2-S_{10}) during 2006-07, on account of diversion of sewage drain in the year 2006, whereas those for other parameters such as water temperature, pH, EC, oxygen content (between 9.0a.m-10.0a.m), total hardness and total phosphorus differed little. The higher sulphate content in the lake is ascribed to influx of textile dye wastewaters. Except for pH and EC (mS), all values are in ppm.

The excessive rain (for almost 24hr) in October 2005 decreased values of most of the water quality parameters due to dilution, more particularly BOD and COD values (Table 2).

Table 2. Physico-chemical characteristics of Mansagar lake in October 2005.

Parameters	Outfall sites	Lake Samples (Site 3-10) Surface	Sub-surface
EC	1.4	1.3 ± 0.02	1.28 ± 0.03
pH	7.8	8.0 ± 0.1	8.0 ± 0.2
TH	320	483 ± 40	NA
Chloride	358	347 ± 15	NA
Sulphide	Absent	Absent	NA
TKN	50	35 ± 12	26 ± 7
TP	1.22	1.83 ± 0.31	1.24 ± 0.1
BOD	16	19 ± 11	28 ±17
COD	30	52 ± 24	77 ± 53
DO	0.9	4.6 ± 3.8	NA
Free CO_2	22	2 ±5	3 ± 5

Water samples were also calloused from the pits formed during lake desilting by Jalmahal Resort Pvt. Ltd. in 2006 summer and recorded very high sulphate content (1036ppm). The lake water also had high sulphate content following rains, in comparison to the year 2005 (Table 3). Sediment is rich in organic matter including of heavy metals (Table 4). It is likely that desilting exposed metallic sulphides

(insoluble in water) in the sediment to atmospheric air that oxidized them in to water soluble sulphate. The sediment spread over for raising platform of land adjoining southern bank of the lake during desilting in the year 2006 might have also contributed sulphates (possibly of heavy metals) through leaching in the rainy season (Table 3). The onset of rains possibly increased microbial activity in the loose sediment (due to desilting) consuming dissolved oxygen of water. A sudden change in water qualities was unfavorable to the aquatic fauna, especially fish that led to their mass mortality during the rainy season of 2007 (Fig. 2).

Table 3. A comparison of physico-chemical characteristics of lake water in July 2005 & 2006.

Sites/Year	pH	EC	Dissolve Oxygen	Chemical Oxygen Demand	Biological Oxygen Demand	Sulphate
15th July, 05 S5*	5.2	2.8	2.8	228	210	82
S8*	7.7	2.5	4.9	224	115	137
13th July, 06 S5*	8.12	3.21	1.84	240	167	NA
S8*	8.32	3.24	1.91	256	159	194
29th July,06 S5**	9.55	2.98	14.6	205	149	328
S8**	9.74	2.81	13.6	184	124	296

Sampling time: * Morning at 7.30am; ** Noon at 12.30pm; Except for pH and EC (mS), **a**ll values are in ppm.

Table 4. Physico-chemical characteristics of sediment samples from Mansagar lake bed.

Parameters	Range	Source
pH	7.2-7.3	Present Study
EC (mS)	1.4-2.7	
Chloride	9-52	
Organic matter (%)	2.1-2.3	
TKN (mg/100g)	147-214	
Inorganic phosphorus (mg/100g)	15-20	
Total Phosphorus (mg/100g)	256-383	
Na (mg/100g)	115-255	
K (mg/100g)	335-415	
Ca (mg/100g)	1540-2780	
Cu (ppm)	5-30	Technical Report, PDCOR Ltd. Jaipur
Pb (ppm)	<20	
Zn (ppm)	25-70	
Cd (ppm)	ND	
Fe (%)	1.04-2.31	
Cr (ppm)	20-65	

Table 5. Physico-chemical characteristics of water in the check dam.

pH	EC	DO	Free CO2	Chloride	TH	BOD	COD	TKN	TP
7.9-8.7	1.71-3.55	3.4-17.6	Nil -31	179-659	440-724	29-170	53-309	17-26	1.2-3.1

Except for pH and EC (mS), all values are in ppm.

BIOLOGICAL CHARACTERISTICS

A. Primary Producers

The small pools formed in the lake bed following receding of water level during summer had prolific growth of *Spirodela* (Fig. 3). The rich algal bloom formed in the ensuing months (September-October) however, killed *Spirodela* possibly due to allelopathic effects (Fig 4).

Phytoplanktons were the other primary producers found through out the year in the lake. A composite lake water sample (about 5L) prepared by mixing about 500ml surface water samples from 9sampling points (S2-S10) in a clean plastic cane was transported to the laboratory and 500ml of this composite sample was centrifuged. The concentrated planktons were then fixed adding a drop of Lugol's solution and were identified using standard monographs (Prescott 1978, Pentecost 1984).

Algal blooms are common during warmer period of the year (April – October) forming thick scum on the water surface, especially along the bank in September spread further in October covering a larger part of the lake. The water samples collected from such areas are dark green in color (Fig. 5).

Fig. 2. Fish mortality following lake desilting in the rainy season.

Fig. 3. *Spirodela* in a ditch in the lake bed.

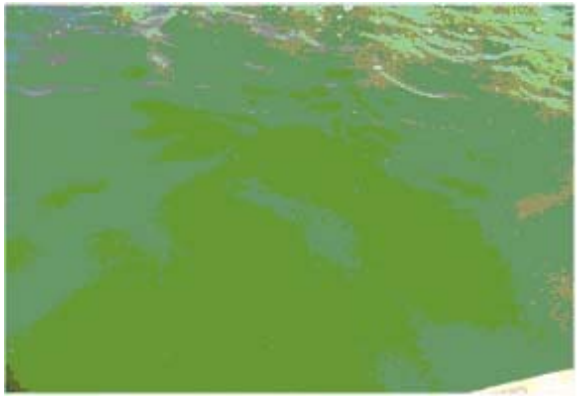

Fig. 4. Algal bloom formed during rainy season.

Fig. 5. Dark green lake water during the rainy season.

16 algal species belonging to Cyanophyceae (4 species), Bacillariophyceae (4 species) and Chlorophyceae (8 species) were observed during study period (2006-2007). Minimum species richness (7-10 species) and their counts ($14500x10^3$-$61125x10^3$ L^{-1}) were found in winter, while their maximum values were in the warmer period (April-October) (12-15 species; Counts = 53875 x 10^3-$285180x10^3$ L^{-1}).

Chlorophyceae contributed maximum (45.1%-79.3%) to the algal count between February to July, but cyanophyceae dominated (41.7%-79.3%) afterwards (Aug.-Jan.). Bacillariophyceae representation (1.2%-8.9%) was however, very poor. The family wise dominant algal genera were *Microcystis* and *Spirulina* in Cyanophyceae; *Cyclotella*, *Navicula* and *Nitzschia* in Bacillariophyceae; and *Chlorella*, *Ankistrodesmus* in Chlorophyceae. Other algal genera having higher population size at one or two occasions during the study period were; *Merismopedia*, *Gomphosphaeria* (Cyanophyceae), *Nitzschia* (Bacillariophyceae), *Coelastrum*, *Ankistrodesmus* and *Chlorococcum* (Chlorophyceae).

B. CONSUMERS

B1. Zooplankton

The composite sample was filtered through bolting silk, and zooplanktons separated thus were fixed in 1% formalin and identified (Battish 1992).

Ten zooplankton species were found in the lake. *Moina*, *Euglena* and *Paramecium* were dominant during warmer period (April-October), more particularly in the rainy season (July-September) whereas *Daphnia* and *Mesocyclops* in the winter, both being more abundant in the check dam in 2005. However, diversion of sewage drains in 2006 has led to build up of their higher populations even in the

lake. *Brachionus*, *Philodina* and *Vorticella* species were found only in the check dam.

Arthropods

Insects on the water surface were trapped using net whereas those on/in the sediment were sampled from shallow regions (near bank) by Eckman dredge and were identified (Tonapi 1980, Batish 1992). Among the nine species recorded during study period, water boatman (*Corixa* species), Backswimmer (*Notonecta galuca*), creeping water bug (Naucoridae), Dragon fly and Damsel fly were dominant in the rainy and post-rainy season. Chironomus larvae occurring as a plankton in the rainy season were however, the most dominant benthos during winter. *Tubifex* species was found only in check dam sediment.

Fish

Gambusia affinis noted prior to hyacinth removal (2005) was however, absent during the study period (2005-2007). The fishermen catches from the lake had only *Clarius batrachus*, commonly known as African tiger/Mangur **(Fig.6a)**. Despite of a ban, this species was seeded by the contractor with a mute consent of the State Fishery Department. It is an omnivorous fish predating small fish, aquatic insects and even on organic waste of sewage origin. Besides Mangur, check dam also had *Channa gachua* surviving in a relatively less polluted habitat (**Fig. 6b)**. We introduced larvicidal fish *Gambusia affinis* in the check dam because of its food value to the waterfowls but it failed possibly on account of its predation.

Birds

Avian fauna of the lake and its vicinal forest environ was identified **(**Salim Ali and Daniel 1997, Kazmierczak and Perlo 2000, Kumar et al. 2005) and their tentative population size was recorded for two years using standard tools. During our two years study, we have observed 92species of birds; of them 41are aquatic while the remaining 51 are forest dwellers. The waterfowl population included 16 resident and 25 migratory species. Most of migratory species (18) stayed for about 1-4 months while others had a very brief stay (1-2 days). It is likely that such short staying birds use this habitat as a stop over during the course of their migration. Despite of the larger size of water body (130ha), only 4 species (1 migratory & 3 residents) had a good population size ranging from 50-300 (Total = about 1000) indicating unsuitability of habitat due to its pollution. The most notable among forest birds is Plum Headed Parakeet (*Psitacula cyamocephala*) – an endemic species visiting Sita Ram temple (Sacred grove) for feed offered by devotees (**Fig. 7**).

Fig. 6a. Mangur fish (African tiger) from the lake.

Fig. 6b. Asiatic snake head fish from the check dam.

Fig. 7. Plum headed and Ring rose parakeets.

JDA Role in Lake Management

JDA has implemented restoration plan of the lake and completed a series of tasks. The existing 27MLD Sewage Treatment Plant (STP) near Bhrampuri has been revamped from which 7MLD treated water will be diverted to lake for compensating evaporation losses during dry weather. However, the average flow of sewage (30-34MLD) exceeded the installed capacity becoming 50-56MLD at the peak. Thus, STP is overloaded with the sewage that is affecting

its efficiency in terms of pollution abatement. BOD values achieved so far ranged from 40-50ml/L against the guaranteed value of 20mg/L. Similarly values of suspended solids are higher (30-40mg/L) than the assured value of 20mg/L. Only COD values (200-250mg/L) matched with the guaranteed value (250mg/L) (Anonymous 2006). It means that secondary treated sewage must receive good tertiary treatment prior to release in to lake. Other tasks of JDA are diversion of sewage entering in the lake, desilting of lake, raising of three Islands for habitat to both resident and migratory birds in the lake, lake front promenade along Amber road and road construction along south–east lake bank to view Jalmahal palace, birds on Islands and in the lake, forest surrounding the lake from three sides and its dwellers, especially birds.

The road construction along the lake has formed a new water body (about 5ha in size) hereafter termed as check dam for storing hill run off during rainy season to wild life which includes Hanuman langur (*Semnopithecus entellus*), Black-naped Hare (*Lepus nigricollos*), Indian Porcupines (*Hystrix indica*), Blue bull (*Boselaphus tragocamelus*), Sambhar (*Cervus unicolor*), Common Mangoose (*Herpestes edwardsii*), Jackals (*Canis aureus*), Striped Hyaena (*Hyaena hyaena*) and panther (*Panthera leo*). Thus forest supports good wild life that can be improved by protecting/restoring food chains.

Although check dam is connected to the lake through pipes, but its water quality was found superior to lake during our detailed study, since wooden logs check free flow of water between them (Table 5, **Fig. 8**). The high evaporation losses dries check dam during summer.

Fig. 8. Check dam.

The JDA officials (Engineering wing) managed removal of thick water-hyacinth mats manually from the lake in the year 2004 at a very nominal cost (Rs. six hundred thousands). Since then, we have not encountered hyacinth plants in the lake. This manual control has set a good example to be followed in other hyacinth infested water bodies in the country, since it is ecofriendly.

Recently, JDA has awarded two projects related to tertiary treatment of 7MLD water from STP to compensate evaporative losses in the dry weather. It includes physico-chemical treatment for phosphorus removal (up to 2.0ppm) followed by polishing of water in constructed wetlands for nutrients, especially nitrate by microbial denitrification. The minimum detention period of wastewater for microbial nitrification and denitrification is three days, but the proposed system has provision only for 24h because of land constrain since most of it has been encroached by the people.

The sewage overloading in STP and low retention period of the treated sewage in the constructed wetland are the two major constrains for improving lake water quality. Thus lake will receive only partially treated sewage.

JDA has also awarded a project for *In Situ* Lake Bioremediation which comprises of extended aeration in the lake to achieve bottom oxygen content to 4.0ppm in conjunction with seeding of microbes. There is no provision to improve biological oxygenation of lake to offset cost of mechanical aeration, even partially, while natural systems rely on it. During a discussion at the time of award of this project, the consultant claimed to bring down phosphorus content in the lake water to as low as 0.2ppm from existing value of 4-5ppm. He however, fails to explain mechanism of phosphorus reduction when questioned by the senior author. This project has commenced in the second week of October 2007 and changes in physico-chemical and biological characteristics are being monitored by us.

Activities in the Forest

JDA funded (Rs.10 millions) to the State Forest Department for improving lake catchment falling in the Nahargarh hill area (Aravalli range); which is the only natural watershed surrounding lake almost from three sides. Various tasks completed so far are; dry stone wall fencing to minimize cattle menace from near by villages and loose rubble check dams, contour dykes and trenches for soil and water conservation **(Fig. 9, 10).** We found such structures very effective in conserving water during rainy season, since run off from the hills was very poor even after 4-5 good showers. As a result, hills turn green quickly. The forest department also made plantation that we did not find during our field surveys. All these measures help in conserving soil and moisture but cattle grazing continue uninterruptedly in the rainy season.

Fig. 9. Water harvesting structure (Trench) in the forest.

Fig. 10. Fencing wall (stone) for minimizing cattle grazing (also note ground forest vegetation during rainy season.

One serious mistake of the State Forest Department was sowing of *Prosopis chilensis* seeds (*P. juliflora*) in the year 1990s – an exotic tree species in the foot hill. This is now becoming a threat in the forest ecosystem. Today, it has formed a thick cover on the foot hill competing with native species. It is invading hills, especially in the disturbed habitats, through seeds dispersed by goat and wild herbivores feeding its pods due to high sugar content. The undigested seeds are dispersed in droppings on the hill where they germinate during rainy season. This species has even spread on the lake bank, its bed and Islands. We remove its saplings constantly along the bank and Islands. JDA also initiated its uprooting in May 2007, but only in a limited section. Those remaining are growing well despite being partially submerged in the water entering lake in the rainy season (July - September 2007; **Fig. 11**). It is thus evident that *Prosopis chilensis* is a very hardy species. Following our advice, its shoots are cut just below the water surface which may finally die due to oxygen non-availability under submerged condition.

We are of the view point that the Forest Department should have planted indigenous species commonly found on the foot hill of Aravallis. *Butea monosperma* is one such native species flourishing in the foot hills of Aravallis near Ramgarh, about 30km from Jaipur. Few *Butea* trees also grow on the hills surround lake **(Fig 12).** This species is very hardy, as it grows well in water scarce and rich habitats including in mild saline one. In view of this field observation, we planted *Butea* saplings along eastern bank of lake in July 2006, which was unsuccessful. Instead of saplings, this year (2007) we have sown its seeds along the lake bank in May 2007 and seedlings emerged after rains (July 2007) are growing well. Hopefully they will grow in the forthcoming years and this success story may encourage us to venture its plantation in areas presently dominated by *Prosopis chilensis* from where latter may be removed gradually.

Fig. 11. *Prosopis juliflora* in the lake bed (Background).

Fig. 12. Butea monosperma growing on the hills.

The illegal practice of pasture collection (ground vegetation during rainy season and

Anogeissus leaf litter in winter) depletes food availability to wild herbivores presently supporting 2-3 panthers in the forest, besides other predators **(Fig. 13).** Besides, 30-40 ladies of nearby localities often visits forest for collection of *Anogeissus* for fuel wood. Forest guard (one) is incapable to arrest illegal pasture and fuel wood collection due to muscle power of local communities engaged in these malpractices **(Fig. 14a, b).**

Fig. 13. A head load of grasses in the rainy season.

Fig. 14a. Tree lopping for fuel wood collection.

Fig. 14b. Head loads of fuel wood.

Lake Bank Stabilization

Our team is executing a JDA sponsored project on bank stabilization since May 2005. Since Lake Bank has a steep slope (45^0), we therefore planted native marshy species (10species) along the water line while mesophytes on the upper reach of the slope. Mesophytes include 35species of tree and 28 of shrubs and under shrubs. Besides improving landscape, these plant species will provide shelter and food to the local fauna. The migratory birds may also be benefited. In addition to these aforesaid functions, marshy species will also improve water quality- a property bestowed in them. Similar plantation was also made on three Islands.

During the course of plantation, we faced serious challenges. One encountered immediately after rains was deposition of massive plastic garbage on the bank that killed marshy species planted immediately after rains. This problem continues even today. Cattle grazing from nearby villages were the other that did not stop even after police complaint on account of local politician intervention. We persuaded JDA for fencing which was completed in October 2007 in almost 2/3part of plantation.

Jalmahal Resort Pvt. Ltd. opened sluice gates of the lake in February 2006 to dry lake bed for desilting in the ensuing summer (April-June 2006). As a result, marshy plantation suffered seriously. With the exception of *Arundo donax*, most plants of the other marshy species died (**Fig. 15**). The lake bed drying led to good growth of *Alternanthera sessilis*; a favorite pasture of cattle **(Fig. 16).** This encouraged cattle grazing in the lake bed which also visited Islands and plantation sites often causing immense damage to plants that was checked only after fencing. However, when Jalmahal Resort Pvt. Ltd. took over control of the lake (without written permission of the State Government), they removed fencing around the Islands causing massive damage to plantation. The largest 3rd Island on the southern side is no more distinct now due to unplanned desilting activities, and presently it is a picnic spot to entertain guests of Jalmahal Resort Pvt. Ltd.**.** We strongly believe that this island will be developed by them for tourists camping visiting their resort. Thus wilder area left for bird nesting will be the personal property of the Resort.

The arrival of water in the lake during current rainy season (2007) inspired us to undertake massive plantation of *Arundo donax*, *Phragmites karka* and *Saccharum spontaneum* which is very successful. Other wetland species such as *Cyperus alopecuroides*, *Scirpus species*, *Typha angustata* etc. will be planted only after stabilization of water level in the lake since they prefer to grow only under partially submerged condition (20-30 cm water depth).

We had also introduced submerged species such as *Vallisnaria spiralis* and *Ceratophyllum demersum*

in the lake during rainy season of the year 2005 and *Potamogeton crispus* during winter (February 2006), but they did not survive possibly due to allelopathic effects of algae (Sharma 1985).

Fig. 15. *Arundo donax* stand along the bank.

Fig.16. *Alternanthera sessilis* forming a thick carpet on the lake bed in the summer.

Check dam

We introduced *Lemna aequinoctialis* (free floating), *Ceratophyllum demersum Vallisneria spiralis* and *Potamogeton pectinatus* (submerged), all propagated by us in the University Botany garden tanks, and *Nymphea*, *Ipomea aquatica* (from Bharatpur) and *Potamogeton crispus* (from Silisate, Alwar) for improving water qualities of check dam between July 2005 – February 2006. Only *Lemna* and *Ceratophyllum* survived, and also multiplied covering almost 40-50% of check dam, while the rest died. *Lemna* and *Ceratophyllum* started dieing in the beginning of winter (November 2005), possibly on account of allelopathic effects of algae. The check dam remained dry in 2006 due to low rainfall but good rains in 2007 bring sufficient water which has led to reemergence of both *Ceratophyllum* and *Lemna* through their propagules in the sediment. Only biological control of algal growth may help in establishment of macrophytes which not only will augment water quality but also strengthen food chains, thereby conserving local biodiversity.

Almost two years of dry period (March 2006-June 2007) has led to establishment of *Prosopis juliflora* in the check dam from the neighboring areas which may hinder waterfowl's flights therein. Jaipur Development Authority must initiate its control at war footing otherwise this water body will be lost.

Role of Jalmahal Resort Pvt. Ltd., Jaipur (1) within lake

The State Government of Rajasthan appointed Rajasthan Tourism Development Corporation Ltd. (RTDC) as a nodal agency for developing facilities for tourists. After bidding, RTDC identified Jalmahal Resorts Pvt. Ltd. (JRPL) as a successful bidder for raising infrastructural facilities along the bank. However, instead of confining its activities outside the lake, JRPL has taken over the charge of entire lake. Today, it has command over the entire lake. It initiated lifting of lake sediment for raising platform of 100ha land leased for 99years which they term desilting of lake bed. To fulfill this objective, lake was kept dried for almost two years (Jan. 2006- June 2007) which has paved way for introduction and strong footing of *Prosopis juliflora* in the lake bed**.** Marshy vegetation raised by us for Lake Bank stabilization and biodiversity augmentation also suffered seriously.

During a lake visit by an expert group comprising Dr. R. Dalwani, Director, MOEF, Prof. Brij Gopal, member, Lake restoration Committee of MOEF, Senior author (K.P.Sharma) and JDA Officials, JRPL officials presented a proposal of Storm Water Management System with in the lake bed, which was denounced unanimously by all members on the ground that such structure should be outside the lake that will facilitate its desilting and solid waste removal to be made regularly prior to next monsoon. Dr. R. Dalwani specifically mentioned that JRPL has to seek prior approval of MOEF before initiating any activity in the lake bed. However, they ignored experts advice and managed permission of the State authority and constructed a Storm Water Management System within the lake bed in May 2007. This construction activity has following serious objections.

1. The construction of storm water management Plan was executed without EIA.
2. The storm water management structures are always made in the catchment area of a water body to facilitate its desilting and continuous solid waste removal, if any, accompanying with the storm water. However, in case of Mansagar lake, this structure begins at the discharge point to downstream, covering almost 1/5lake toward upstream. It has 4 interconnected large tanks;

most of them are damaged during the current monsoon. Since the first deepest tank has been made very near to reservoir foundation, it is likely that this tank may be silted in the event of torrential rains as in 1981, blocking the sluice gates with the sediment and plastic waste that may flood upstream areas. The release of water through sluice gates in July 2007 carried lot of sludge and plastics in the downstream which was objected by a priest residing in the temple constructed much before the Mansagar reservoir.

3. The earthen dams separate sedimentation tanks with the main lake disturbing lake hydrology. Earlier storm water entering on the western side of lake near Jalmahal palace used to travel almost throughout the lake basin before being discharged through sluice gates at southern end for irrigation in the downstream areas in the winter (Fig. **17**). During its course, pollutant loads of the wastewater decreased markedly, as evident by physico-chemical characteristics of water collected from southern end. In the event of excess rainfall, as noted in October 2005, the surplus water was even released during the rainy season, which diluted pollutants maximum and water qualities of the lake was parallel to any unpolluted one in the region. This arrangement helped in washing out of salts and nutrients from the lake (Table 2**).** This scenario has now changed. Now water passing through sedimentation tanks will enter in to the lake. After attaining the desired level, only surplus water will be discharged directly through the sluice gates without passing lake basin; thereby there shall be no more dilution of pollutants in the lake. Under the present lake management plan, a constant water level will be maintained in the lake round the year by compensating evaporative losses using tertiary treated sewage. The evaporative losses will concentrate salts during summer and in the absence of flow of storm water through the lake basin, they will only be diluted to some extent but not washed out in the ensuing rainy season. As a result, salt contents will gradually built up with time turning freshwater body in to a brackish one that will alter its flora and fauna including of surrounding areas. All heritage monuments such as Jalmahal, Kanak Vrindaban and other nearby temples etc. will also suffer from increased salinity of lake. Further, groundwater qualities of the vicinal areas will also deteriorate leading to serious water crisis. Our assumption derives support from the water quality data collected for two years (Table 1).

Further, construction of sedimentation tanks has failed to check influx of solid wastes in the lake while maximum reduction of silt load as claimed by the experts of Jalmahal Resort Pvt. Ltd. is meager (20%) that too will stay in the sedimentation tanks for ever. Surprisingly, after failure to deliver expected services of sedimentation structure, the Jalmahal Resort Pvt. Ltd. allowed entry of storm water runoff from the earlier water course thereby raising doubts in mind about purpose of such structures. Further, these structures are also unsafe for wild life due to sudden increase in water depth at the bank. One Sambhar calf rescued by the Forest Department from the sedimentation tank (August 2007) died after hospitalization. Should be call storm water management plan- an effort for better future of the lake or its grave?

Fig. 17. Sedimentation tanks in the lake bed.

The senior author reported this matter to Rastrapati Bhavan, Ministry of Environment & Forest, New Delhi, Prime Minister Office, Supreme Court of India, Rajasthan High Court, Rajmata Gayatri Devi and Colonel Bhawani Singh (former rulers of Jaipur State) and NGO's when construction of first sedimentation tank was in progress. During a recent visit, the Joint Secretary of MOEF, New Delhi and Prof. Brij Gopal categorically raised issue related to construction in the lake bed. The Supreme Court of India has also made similar enquiry, but final action/recommendation is unknown. Rajmata Gayatri Devi also forwarded our complaint to the Chief Minister of Rajasthan but no attention was paid to it.

Also tried to draw people attention through local and national press as well as electronic media, but no one came forward to cover this news. After a prolonged persuasion, Ms. Sunita Narayan, Editor, Down to Earth has agreed to send a team of experts for investigation and subsequent follow up action.

We are of the opinion that basic objectives of lake restoration were forgotten in the array of magnificent surroundings for commercial exploitation. This example of Public-Private partnership will be a mute testimony of man's greed which could have been averted in case P. D. Core Ltd. who prepared detailed project report for Mansagar should have made a provision of land for

sedimentation tanks. In our opinion, the size of land for public-private partnership should be limited to 60hactares. The remaining 40hactares should have been diverted to storm water management and additional land for tertiary treatment system for treated sewage. Our hypothesis derives strength from Limnological data collected by us from March 2005-April 2007. If State Government is serious about the future of this lake, she can rectify her mistakes by ordering dismantling of construction in the lake bed, reducing size of leased land for sedimentation tanks and tertiary treatment system, since Jalmahal Resort Pvt. Ltd. has yet not begun construction on the leased land.

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