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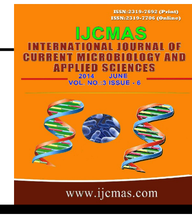

Original Research Article

Studies on the Assessment of Tropic Status of Lakes

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A B S T R A C T

Keywords

Eutrophication, Tropic State Index (TSI), Total Phosphorous (TP), Secchi Depth (SD), Chlorophyll 'a' (Chl 'a').

Lakes are vital parts of fresh water ecosystems of any country. A fresh water lake when maintained free from pollution can offer many beneficial uses in an urban area. Urban lakes more commonly act as thermal cooling, reaction centres and de-stressing points in the highly-stressed urban life. Nowadays due to the pressure from activities like urbanization, industrialization, as well as esthetical beauty of the water body. The commercial value of the surroundings is improved. Lakes provide life to various forms of aqua flora and fauna, livelihood for fishermen community, food for the local populace, pollution sink, and ground water recharge leading to rise in the water table and also as flood mitigators. The urban population can free themselves from the polluted urban air and find solace in the cool air by the lake side and relax in recreational activities such as swimming, boating, fishing and strolling along the lake shores. The present paper attempts to review the work done on the development of TSI for assessment of tropic status of lake and applicability of most important TSI methods for Indian lakes. The paper also deals with the methods of restoration of Byramangala lake.The results indicated that lake is highly eutrophic and needs immediate attention for its conservation.

Introduction

Reservoirs and lakes occupy a prominent place in the history of irrigation in South India. Lakes are considered to be useful life saving mechanism in the water scarcity areas which are categorized as Arid and Semi-arid zones. The lakes and reservoirs, all over the country without exception, are in varying degrees of environmental degradation.

The degradation is due to encroachments, eutrophication and siltation. There has been a quantum jump in population during the last century without corresponding expansion of civic facilities resulting in deterioration of lakes and reservoirs, especially in urban and semi urban areas becoming sinks for the contaminants. The degradation of reservoir and lake catchments due to deforestation, stone quarrying, sand mining, extensive agricultural use, consequent erosion and increased silt flows have vitiated the quality of water stored in the reservoirs.

Different problems of the lake include excessive influx of sediments from the lake catchment, discharge of untreated or partially treated sewage and industrial wastewater/solid waste,entry of diffused nutrients source from agricultural and forestry,improper management of storm water, over-exploatation of lake for ctivities like recreation, fishing, encroachments, land reclamation etc causing lake water shrinkage, shoreline erosion and impacting the lake hydrology, deterioration of water quality, impacting biodiversity, bringing climate changes, etc. There is, therefore, an immediate need to know the pollution status of a lake at a given time so that necessary conservation activities may be undertaken to regain/improve the health of water body. This can be done by measuring trophic state index (TSI) to know its trophic state.

The estimation of TSI requires six physical, chemical and biological parameters including total phosphorus (TP), total nitrogen (TN), chemical oxygen demand (COD), Secchi disk depth (SD), chlorophyll-'a' (Chl-a) concentration and phytoplankton biomass (CA) to know the eutrophication state of the lake environment. During 1960–70, a number of researchers have made attempts to quantitatively evaluate the trophic state of lakes using single-variable trophic indices or multi-parametric approaches (Vollenweider 1968 and 1976, Dobson et al 1974, Schindler 1977, Chapra 1980, Ritter 1981, Gregor and Rast 1982, Persson and Jansson 1988, Thornton and Rast 1988, Cobelas et al 1992, and Boers et al 1993). The single-variable trophic indices can be divided into abiotic and biotic aspects. Among the abiotic parameters, plant nutrients (phosphate, nitrate), oxygen demand (BOD, COD) and transparency were usually used to assess lake trophic levels. Rosenberg and Resh (1993) employed the biotic parameters to assess lake trophic conditions given the sensitivity of aquatic organisms, especially algae and macro-invertebrates,to eutrophication processes. Shannon and Brezonik (1972a and b), Carlson (1977) and Cruzado (1987) studied the multidimensional nature of the eutrophication and reported that no single variable can represent status of eutrophication of given water body. The contributions of Carlson (1977), Walker (1979) and Porcella et al (1980) offer a 0–100 scale providing continuous numerical classes of lake tropic states and a rigorous foundation for quantitative studies of the mechanisms behind the eutrophication. The TSI based on several biological, chemical and physical indicators is offered by Carlson TSI. Carlson (1977), Walker (1979) and Porcella et al (1980) along with Aizaki et al (1981), Jin et al (1990) and Swanson (1998) provided the most suitable and acceptable method for evaluating lake eutrophication status. As such, no TSI has been developed in India but Carlson's TSI is largely adopted and applied to the Indian lakes.

The study area viz., Byramangala lake catchment has an areal extent of 340 sq.km,and command area of 28 sqkm It is encompassed by East longitude 77^0 23'45"- 77^0 34'16"and North latitude 12^0 45' 00"- $13^0$02' 40"at a distance of about 40 km from Bangalore. The water body selected for purposes of assessment of Tropic status of surface water of the Byramangala lake receives both treated and untreated waste water disposed of from Bangalore urban locality. The lake water is subjected to qualitative analysis for its physical, chemical and biological characteristics. Six samples were collected at a time: one kilometer distance prior to the lake, near the inlet of the lake, near the lake weir, near the northern side of the lake, and near the channel where water is used for irrigation.

Study Area

The Vrishabhavati a fourth order upstream river drains an aerial extent of 545 sq. km before it joins Suvarnamukhi river at Bhadragundamadoddi (North latitude 12^0 39' 40" and East longitude 77^0 25' 00") of Kanakapura taluk. The river Suvarnamukhi is one of the major tributaries of the river Arkavathi in Karnataka, part of the Cauvery Basin. But, the study area is sealed down to the Vrishabhavathi stream system terminating at Byramangala tank. This has an aerial extent of 340 sq.km. It is encompassed by East longitude 77^0 23'45"- 77^0 34'16" and North latitude 12^0 45' 00"- $13^0$02' 40". The topographic coverage of the area is in the survey of India topographic maps No. 57 H/5, H/9 and G/12 on scale 1:50000.

Byramanagala tank is located in Bidadi Hobli of Ramanagaram distsrict. The catchment of reservoir includes Bangalore urban areas which comes under Bhruhath Bangalore Mahanagara Palike and villages of Bangalore rural area, Rajajinagar Industrial area, Peenya Industrial area , Kumbalgod Industrial area and the Bidadi Industrial are located in the Reservoir catchment area. The Vrishabhavathi river which flows in the catchment carries urban domestic sewage, industrial sewage and storm water from urban, semi urban and rural areas. The agricultural wastes resulting from intensive farming in the rural areas of the catchment also enter the reservoir. The study reveals that the reservoir is highly polluted and the reservoir sediments are also contaminated. The annual rainfall data of 789mm and average monsoon rainfall of 551.69mm were collected from the records of the rain gauge installed at Byramangala. The minimum annual inflow to the reservoir is $23.92M^3$ and maximum annual inflow is $114.5x10^9$ M^3. The withdrawal from canal is recorded as 34.97M cum and the reservoir losses are noted up to 5.42M cum. The details of reservoir indicated FRL as $24.10Mm^3$, live storage at FRL as $22.01Mm^3$, dead storage at sill level of sluice as 2.09Mm3 and water spread area at FRL as 430.25ha. The spillway of the reservoir is of broad crested type located at right flank.

The length of spillway is 150.5m, its flood lift is recorded as 0.9m and discharge capacity is 230cumecs.The bund constructed for Byramangala reservoir is of earthern type and its height at the deepest point is recorded as 22.85m. The length of the bund is recorded as 2286m and top width of the bund as 3.66m. The MWL of the reservoir is noted as 32.9m its FRL as 32m and its sill level as 22.85m.The Reservoir is provided with 2 channels,viz., Left Bank canal and Right bank canal. The left bank canal is 26.4 km in length and Right bank canal is 8.4 km length having a command area of 1330 ha and right bank canal is 8.4 km having a command area of 444ha. Reconnaissance survey reveals that the soil in the command area is polluted with the application of sewage water.

The trophic status refers to the level of productivity in a lake as measured by phosphorous, algae abundance and depth of light penetration. TSI rates individual lakes, ponds and reservoirs based on the amount of biological productivity occurring in the water. Using the index, one can get a quick idea about the extent of productivity of a lake (Hillsborough 2008). TSI values can be used to rank lakes within a region and between the regions. This ranking enables the water managers to target lakes that may require restoration or conservation activities. An increasing trend in TSI over a period of several years may indicate degradation of the health of a lake.

Materials and Methods

Numerous methods have been developed to measure the trophic state (TS) of lakes. Twenty-nine different methods commonly used were compared with respect to their ability to measure TSI of lakes. Most of the methods have been found more effective in ranking the lakes using the total phosphorus standard compared to chlorophyll 'a' standard (Lambou et al 1983). A number of authors have used different methods in the literature to determine the TSI of lakes (Boland 1976; Dillon 1975; Dillon and Rigler 1974; Larsen and Mercier 1976; Naumann 1931; Nygaard 1949; Palmer 1969; Pielou 1966; Shannon and Brezonik 1972; EPA 1971, 1974a,b and 1975; and Vollenweider 1975).Out of these methods, the following two most important and popular TSI method selected for the present study are given below.

Carlson's Trophic Status Index and water quality index for lakes and rivers respectively are given in Table 1 and the Indiana TSI is given in Table 2.

The following equations can be used to compute the Carlson's TSI .

TSI - P = 14.42 * Ln [TP] + 4.15 (in ug/l)----------- (i)

TSI - C = 30.6 + 9.81 Ln [Chlor-a] (in ug/l)-------- (ii)

TSI - S = 60 - 14.41 * Ln [SD] (in meters)----------- (iii)

Average TSI = [TSI (P) + TSI (CHL 'a') + TSI (SD)]/3-- (iv)

where ,TP is total phosphorus, chlor 'a' is chlorophyll 'a', SD the seechi depth, Trophic status index and water quality of Indiana The Indiana trophic state index has a eutrophy points represented by total phosphorus, chlorophyll, nitrogen, DO and sechhi depth (Johns 1998). The TSI scores and trophic state of Indiana TSI is given in Table 3. To add the Eutrophy points of TP, TN,SD, DO and feacal, the status of lake can be computed on the basis of TSI Score and the details are provided in (Johns 1998).

Results and Discussion

The samples were collected for the analysis of physical, chemical and biological parameters at 6 locations in and around the lake. The sampling is done during September 2013 and april 2014.The analysis of SD, TN, TP, chlorophyll 'a' and other parameters were performed as per IS and APHA methods (Clesceri 1988). The TSI was calculated by standard equations given above. The TSI based on Carlson's and Indiana method is represented in Table 3, 4, 5 and 6.

The results of analysis of water samples reveal that lake is categorized under Hyper – eutrophic. The heavy metals like copper, Iron, Zinc, Manganese and Chromium are found to contain much above the permissible limits.

Fig.1 Satellite image of Byramangala reservoir

Fig.2 A View of Byramangala lake

Table.1 Carlson's Trophic State Indices

TSI	State	Status of Lake
< 30	Oligotrophy	Classical Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.
30-40	Mesotrophy	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes become anoxic in the hypolimnion during the summer
40-50	Mesotrophy	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer
50-60	Eutrophy	Lower boundary of classical eutrophy,Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
60-70	Eutrophy	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
70-80	Hyper-eutrophy	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but limited light penetration.(Often would be classified as hypereutrophic)
> 80	Hyper-eutrophy	Algal scums, summer fish kills, few macrophytes, dominance of rough fish etc.

Table.2 Indiana Trophic State Index (ITSI)

.Indiana TSI Scores	Trophic Class
0-15	Oligotrophic
16-31	Mesotrophic
32-46	Eutrophic
47-75	Hyper-eutrophic

Table.3 Results of analyses of water samples (1st Sampling, September 2014)

Sampling points	Total Nitrogen		Total Phosphorous		Chlorophyll A		Sechhi depth	
	TN mg/L	TSI	TP mg/L	TSI	CHL A ug/L	TSI	SD mt	TSI
Inlet	35.00	105.75	0.06	63.15	6.75	49.33	0.17	85.53
Left bank canal	28.00	102.53	0.09	69.03	200.00	82.57	0.20	83.19
Right bank canal	37.00	106.55	0.07	65.41	198.2	80.3	0.19	83.93
Reservoir	34.00	105.33	0.04	57.34	312.5	87.3	0.20	83.19
Command area – Canal	30.00	103.52	0.09	69.03	305.00	86.71	0.21	82.48
Weir outlet	42.00	108.38	0.08	67.33	309.1	86.9	0.23	81.17
Average		105.34		65.22		78.85		83.24

TSI = 81.66: Hyper-eutrophic (70-90)

Table.4 Analysis of water samples of BML and TSI (2nd Sampling, April 2014)

Sampling points	Total Nitrogen		Total Phosphorous mg/l		Chlorophyll A		Secchi Disk depth in 'm'	
	TN mg/l	TSI	TP mg/l	TSI	CHL A ug/l	TSI	SD	TSI
Inlet	38.00	106.94	0.08	67.33	15.2	57.29	0.23	81.17
Left bank canal	26.00	101.46	0.11	71.93	137.5	78.90	0.21	82.48
Right bank canal	30.00	103.52	0.66	97.76	168.4	79.56	0.20	83.19
Reservoir	23.00	99.65	0.05	60.56	179.5	80.2	0.19	83.93
Command Area - canal	29.00	103.04	0.12	73.18	111.6	76.85	0.21	82.48
Weir outlet	33.00	104.90	0.09	69.03	170.2	79.3	0.20	83.19
Average		103.25		73.29		75.35		82.74

TSI = 82.57: Hyper-eutrophic (70-90)

Table.5 Catagorisation Byramangala lake based on TSI

Sampling	TSI of total Nitrogen	TSI of total Phosphorous	TSI of Chlorofill-a	TSI of Scchi Depth	Carlson's TSI	Indiana TSI
1st Sampling	28 - 42	57.2.9-69.1	49.33-86.71	81.17-85.53	Hyper – eutrophic (71-90)	Hyper - eutrophic (47-75)
2nd Sampling	23 - 38	60.76-92.1	57.20-78.90	81.17-83.93	Hyper - eutrophic (71-90)	Hyper - eutrophic (47-75)

Fig.3 Spatial and temporal variation of TSI of Total Nitrogen

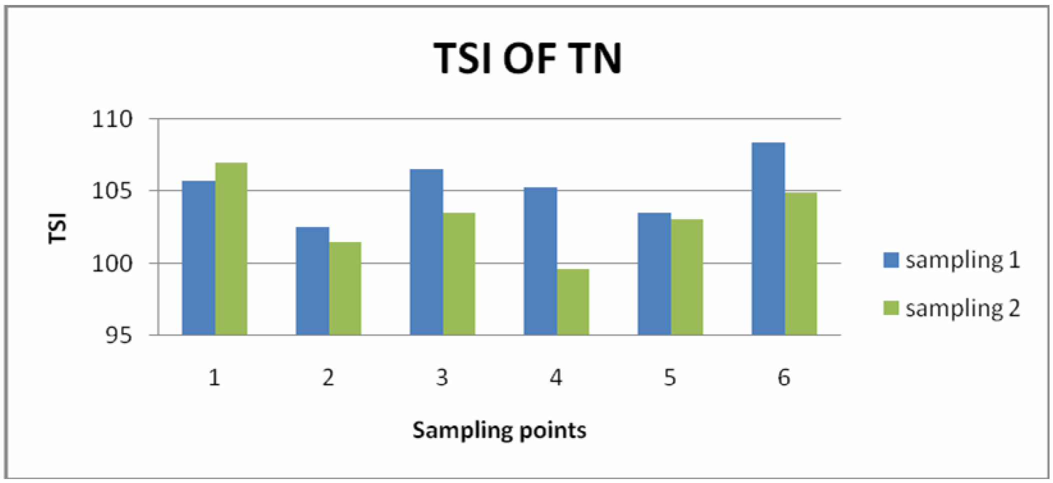


Fig.4 Spatial and temporal variation of TSI of Total Phosphorous

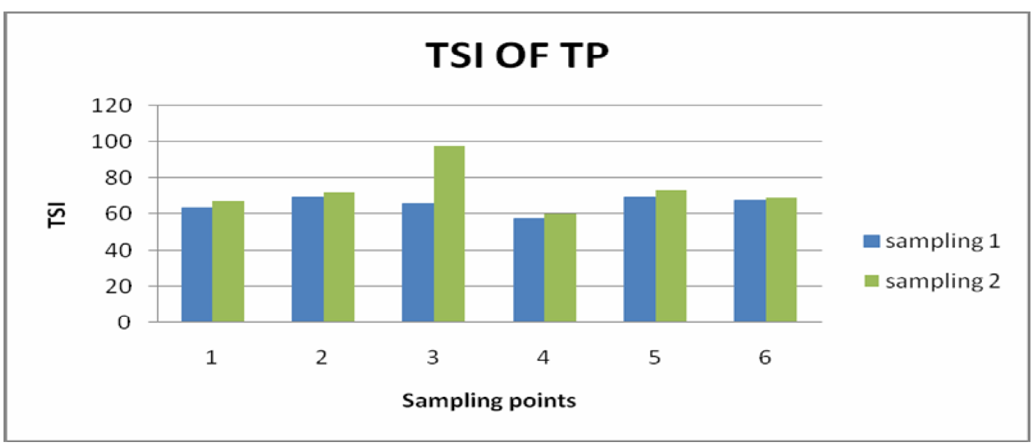


Fig 5. Spatial and temporal variation of TSI of Secchi Depth

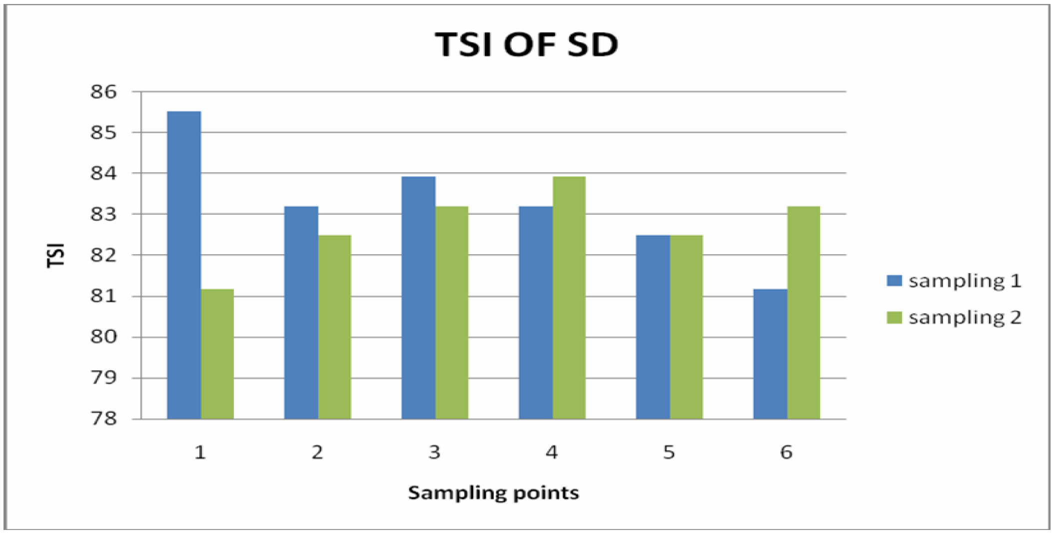
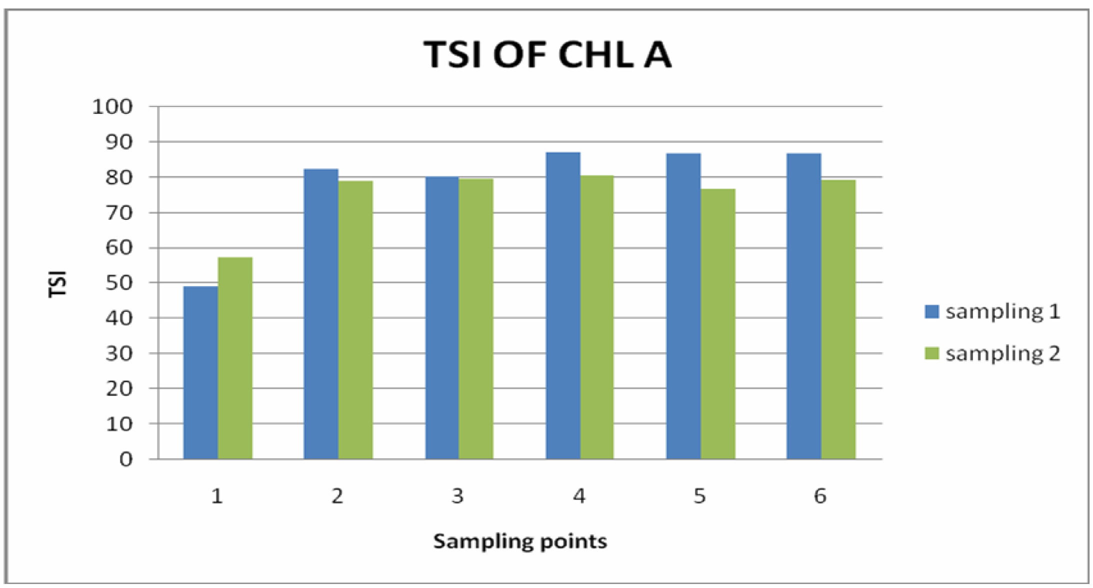


Fig.6 Spatial and temporal variation of TSI for Chlorofil-a



Thus water is found to be unfit for drinking and irrigation purpose. Since the TSI value is above 71, at all locations of Byramangala lake, it is said to be Hyper-eutrophic. The lake is said to have heavy algal blooms possible throughout the summer, dense macrophyte beds, but limited light penetration.

Industrial waste is a major contributor to the pollution of tanks. Once the waste is disposed of into the water bodies without proper treatment it renders the Reservoir water unfit for use. The factors that affect the pollution of water depend on the type of industries, the nature of waste disposal etc. Many industries are situated in the catchment area and adjacent to the river disposing of their effluents without any primary treatment. Once these pollutants enter the water bodies it had polluted the entire reservoir and makes the water unsuitable. The most important aspect is that the illegal disposal of industrial effluent must be curbed and penalties must be levied on industries violating the rules. Every industry should strictly adhere to the effluent disposal system by providing necessary treatment unit at the source of disposal of waste water before it is finally released into the reservoir. Considering the above reason, it is also important to note that intensive farming in the village should be reduced. In many cases it is seen that the inflow of pollution into Byramangala reservoir is from ground water, as one of the sources, hence pollution of the ground water by the source has to be eliminated. Chemical fertilizers are a major contributor to the pollution of ground water. Hence, it is recommended that biofertilizers or organic fertilizers be used for crops rather than chemical fertilizers.

Rapid urbanization has resulted in discharging sewage into road side drains which resulted in ground water contamination. The sewerage system should also be well designed, the soak pits and septic tanks should be closed and the entire study area should be laid with sewers and domestic sewage should be treated in the urbanizing areas. The solid waste generated from industries should not be dumped near the water source and should be carried away and disposed of into the solid waste disposal sites specifically designed.

Even with all the measures in place, it is essential that the people should be educated about the hazards of pollution. Public awareness camps should be conducted in the study area with Industry-public interaction to educate the people to reduce problem of further contamination. In all these areas, door to door collection of garbage system should be strictly implemented.

The results of physico-Chemical and bacteriological analysis of water samples in the catchment, and command area reveal that water is highly polluted at certain areas where industrial effluents were directly discharged. Heavy metals were also detected in ground and surface water samples which were above the tolerance limits. Soil samples collected have low organic carbon, micro and macronutrients. Heavy metals were detected above the permissible limits in the soil and vegetation samples which were fed with reservoir water in the command area.

The cost effective and less energy intensive treatment methodology may be adopted to control the pollution emanating from point and non-point sources. The techno-ecological treatment systems such as soil Scape filter, Hydrash succession pond, and Green bridge technology may be adopted to prevent further pollution. The Bioremediation techniques will helps in reducing the reservoir pollution.

Lake management in India needs a revolutionary change in the approach as they influence the local/ regional ecology, climate, agriculture and economy.

The Urban lakes have additional role to play as centre of recreational activities in addition to water supply. The lake catchment management plan is essential which includes control of deforestation, control of erosion, treatment of industrial and domestic sewage at the source

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