*International Research Journal of Environment Sciences*_____ ISSN 2319–1414
Vol. **2(5),** 1-8, May **(2013)** *Int. Res. J. Environment Sci.*

Assessment of Lake Water Quality by Using Palmer and Trophic State Index- a Case Study of Upper Lake, Bhopal, India

Upadhyay Rahul[1*], Pandey K. Arvind[2], Upadhyay S.K.[1]
[1]SSL Jain PG College, Vidisha, Dist: Vidisha, MP, INDIA
[2]JS Government PG College, Betul, MP, INDIA

Available online at: www.isca.in
Received 19th January 2013, revised 8th April 2013, accepted 10th April 2013

Abstract

In India, various natural and manmade lakes, wetlands and reservoirs are located within the urban limitsof major cities. These limnetic water resources objectively fulfill various demands of mankind but due to ever increasing anthropogenic influences and extensive urbanization, several water bodies are gradually being degraded badly. The cumulative effects of anthropogenic pressure and exerted pollution load from point and non-point sources are affecting water quantity and quality of these urban water bodies. Upper Lake is one of the important urban lakes of India,located in Bhopalwhich is a state capital of Madhya Pradesh.This lake is being used as a prime source of drinking water supply for Bhopal city. In view of its ecological importance, the Ministry of Environment and Forests, Government of India has recognized this lake along with another lake (Lower lake) located downstream of Upper Lake as wetland of national importance and designated them as "Bhoj Wetland" in 1998 and later declared as Ramsar site in year 2002. Present investigation was an attempt to assess the Upper Lake water quality by using palmer and trophic state index for better understanding of limnetic chemistry. Results revealed that concentration of important parameters which mainly govern the lake chemistry were found beyond the permissible limits andabove to the threshold level of eutrophication. By perusing the results of Palmer Index, out of 20 Genus, 12 Genus were found with total index value of 27 that indicate organic pollution in lake while results of trophic state index indicate that Upper Lake is in higher stage of eutrophy due to high nutrients loading.

Keywords: Upper Lake, palmer Index, tophic State index, anthropogenic pressure.

Introduction

Organic pollution and nutrient enrichment is one of the most significant and widespread water quality issues.Due to demographic pressure and rapid urbanization around the water bodies, eutrophication has become a common problem in fresh water ecosystems. The increasing severity of water eutrophication has been brought to the attention of both the governments and the public in recent years but the mechanisms of water eutrophication are not fully understood, but excessive nutrient loading into surface water system is considered to be one of the major factors[1,2]. Many freshwater lakes undergo eutrophication with the increasing input of nutrients[3]. Certain chemicals, such as nitrogen, phosphorus play the main role in distorting aquatic ecosystems by increasing the productivity.In most of the lakes, the severe eutrophication, degeneration of ecosystems and deterioration of water quality has resulted in uncontrolled nutrient inputs to water bodies and their proximity to agriculture and use in aquaculture[4]. In recent past, in different parts of the world including India, there were several studies conducted on physic-chemical and biological characterization of lotic and lentic ecosystems by different authors viz. Parikh and Mankodi[5], PatilShilpa G et al[6], Seyed Ahmad Reza Hashem et al[7], Hashemzadeh and Venkataramana[8], Safari et al[9], Joshi P.P[10], and Pathakand Mankodi[11]. Apart from surface water bodies, physico-chemical and microbiological characterization of subsurface water was reported by several authors[12,13]. In line with wise use of resources, Lake Gahar Basin was assessed as a potential site for focused ecotourism by Mehranoosh[14].

Surface water quality in a region is largely determined both by natural processes and by anthropogenic inputs. The anthropogenic discharges constitute a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climate within the basin [15,16]. Land erosion in the lake catchment not only affects the physical and chemical properties of soils but also enriched the lake water with nutrients[17]. For any urban water body, growth of the habitation around the lake vicinity without a proper sewerage system further exaggerates organic and nutrient loading in the lake. In line with that hydro chemical changes are also found in lakes due to immersion of idols and religious offerings which are common in India[18]. Thus, point and non-point sources both are responsible for degradation of water quality of limnetic environment.

In this paper, we have considered the Upper Lake of Bhopal as a test case. The Upper Lake is located in Bhopal which is a capital of Madhya Pradesh, India and is the only source of water for the city. Economic as well as recreational activities of the city are also heavily dependent on the availability of water in the lake, which is received organic and nutrients load through various

point and non-point sources. Therefore, present study is carried out to achieve following targets: i. Assessment of organic pollution and concentration of plant nutrients in Upper Lake, ii. Assessment of Palmer index to determine the level of organic pollution in Upper Lake, iii. To determine the trophic level of Upper Lake by using Trophic State Index (TSI).

Material and Methods

The Study Site: In the present study, the Upper Lake which is geographically located at 23^0 12'N latitude and $77^0$18' Elongitude of Bhopal (M.P) is considered as a test case. The Upper Lake is one of the oldest and largest impoundments and a major drinking water source for the city of Bhopal. This historic lake was created by Raja Bhoj of Dhar in the 11th Century A.D. by constructing an earthen dam on the river Kolans by virtue of that it is known as Bhoj Wetland. In view of its ecological importance, the Ministry of Environment and Forests, Government of India has recognized Upper Lake along with another lake (Lower Lake) located downstream of Upper Lake as wetland of national importance in 1998 and later declared it as Ramsar site in the year 2002. Majority of conservation works for Upper Lake was started from year 1995 under Bhoj Wetland Conservation Project through financial assistance of JapanBank for International Corporation (JBIC) and completed in year 2004.

Morphological Features of Upper Lake: The Upper Lake is an east-westerly elongated manmade lake with the total submergence area of 36.54 Km^2. Total water storage capacity of the lake is approximately 117 Mm^3 with maximum depths of 11.7 m. In shallow portion of lake, luxuriant growth of aquatic vegetation can be observed. Some of the important salient features[19] of the lake are given in table-1.

Table-1
Salient Features[10] of the Study Site

S.No	Features	Upper Lake of Bhopal
1	Period of Formation	11th Century A.D.
2	Longitude	77^0 18'- 77 ^{0} 23' E
3	Latitudes	23^0 12'- 23 ^{0} 16' N
4	Catchment area	361 sq. km
5	Submergence area at FTL	36.54 sq. km
6	Storage capacity	117.05 M.cum
7	Maximum Depth	11.7 m
8	Maximum Water level (R.L)	508.65 m
9	Main water uses	Potable water supply
10	Source of water	Rain water

Catchment Area: Catchment of the Upper Lake displays a complete range of urban and rural activity with varying intensities that contribute nutrients and pollution load through point and non-point pollution sources. As shown in figure-1, majority of the catchment area is under agricultural activities (213.1 Km^2) followed by scrub or without scrub (87.7 Km^2) and built-up area (20.9 Km^2).

Sampling Plan and Analytical Procedure: Sampling Plan: As shown in figure-2, sampling network was designed to cover a wide range of determinates of key sites, which reasonably represent the shallow and deeper zone of lake. Water sampling was carried out for twenty seven months from October 2009 to December 2011. Twelve sampling points were identified in shallow zone while in deeper zone, eight sampling points identified for the collection of water samples. From the deeper zone, water samples were collected from the surface (epilimnion), middle (Metalimnion) and bottom (hypolimnion) while from shallow zone, samples were collected from surface (epilimnion) and bottom (hypolimnion) part only. Water samples were collected using open water grab sampler (1.5 L capacity) equipped with a simple pull-ring that allowed for sampling at various water depths. Collected samples were preserved and brought to the laboratory for analysis; the laboratory is approved by the Ministry of Environment and Forests (MoEF), Government of India.

Parameters and Analytical procedure: The physico-chemical and biological parameters, viz. Transparency, Biochemical Oxygen Demand, Total Nitrogen, Total Phosphorous, Chlorophyll-a and Phytoplankton were analyzed in collected water samples of Upper Lake. All the samples were collected, preserved (if required) and analyzed as per *Standard Methods for the Examination of Water and Wastewater*[20]. On-site measurement of transparency was performed with the help of a 25 cm diameter secchi disk. Phytoplankton species were identified in living conditions under high magnification microscope (X 400). The identification of the phytoplankton was done with the help of standard books written by Edmondson[21], Pennak[22], Fitter and Manuel[23]. Palmer index was calculated by studying the algae present in a sample of water. Palmer[24] reviewed a composite rating of algae, tolerating organic pollution and developed an index to establish the status of the aquatic body. Trophic state index was calculated on the basis of regression equations used by Reokhow and Chapra[25]. Water quality parameters associated with their abbreviation, units used in the study and reference method used for analysis are summarized in table-2.

Results and Discussion

Physico-chemical and Biological Parameters: Secchidepth transparency is the simplest, most extensive and appropriate parameter for determination of ecosystem health. In present investigation, secchi depths in Upper Lake were recorded in between 0.18 m to 0.84 m, with an average value of 0.63m. The Organization for Economic Cooperation and Development (OECD)[26] has developed the boundary values of transparency for various types of lakes. As per the their norms, the hyper-eutrophic lakes generally show the maximum transparency

values ≤ 1.5 m and minimum transparency ≤ 0.7 m. Therefore, present data of 0.63 m indicate that Upper Lake is a high productive ecosystem having low euphotic zones. Biochemical oxygen demand (BOD) is the amount of oxygen required by microorganisms to decompose biologically degradable organic matter in water under aerobic conditions. Input of large amount of sewage effluents, human excreta, etc. are known to cause increase in BOD levels. High BOD value in productive lakes is a general feature because of death and decay of phyto and zooplankton increases in eutrophic waters.

Table-2
Water Quality Parameters, Abbreviation, Units and Methods of Analysis

S. No	Parameters	Abbreviation	Unit	Reference method used
1	Secchi Depth Transparency	-	Meter	Secchi disc
2	Biochemical Oxygen Demand ^{5day}	BOD	mg/l	APHA,5210-B,2-9 to 2-11, 20th ED.1998
3	Total Nitrogen	TN	mg/l	APHA,4500-NorgB, 4-124 to 4-125, 20th ED.1998
4	Total Phosphorous	TP	mg/l	APHA,4500-PD, 20th ED.1998
5	Chlorophyll-a	CHA	µg/l	APHA10200 H, 10-18to 10-25, 20th ED.1998
6	Phytoplankton Species	-	-	APHA10200F, 10-13 to10-16, 20th ED.1998, Edmondson,1959; Pennak, 1958; Fitter and Manuel, 1986
7	Palmer Index	-	-	Palmer (1969)
8	Trophic State Index	TSI	-	Regression equation based on Carlson trophic index

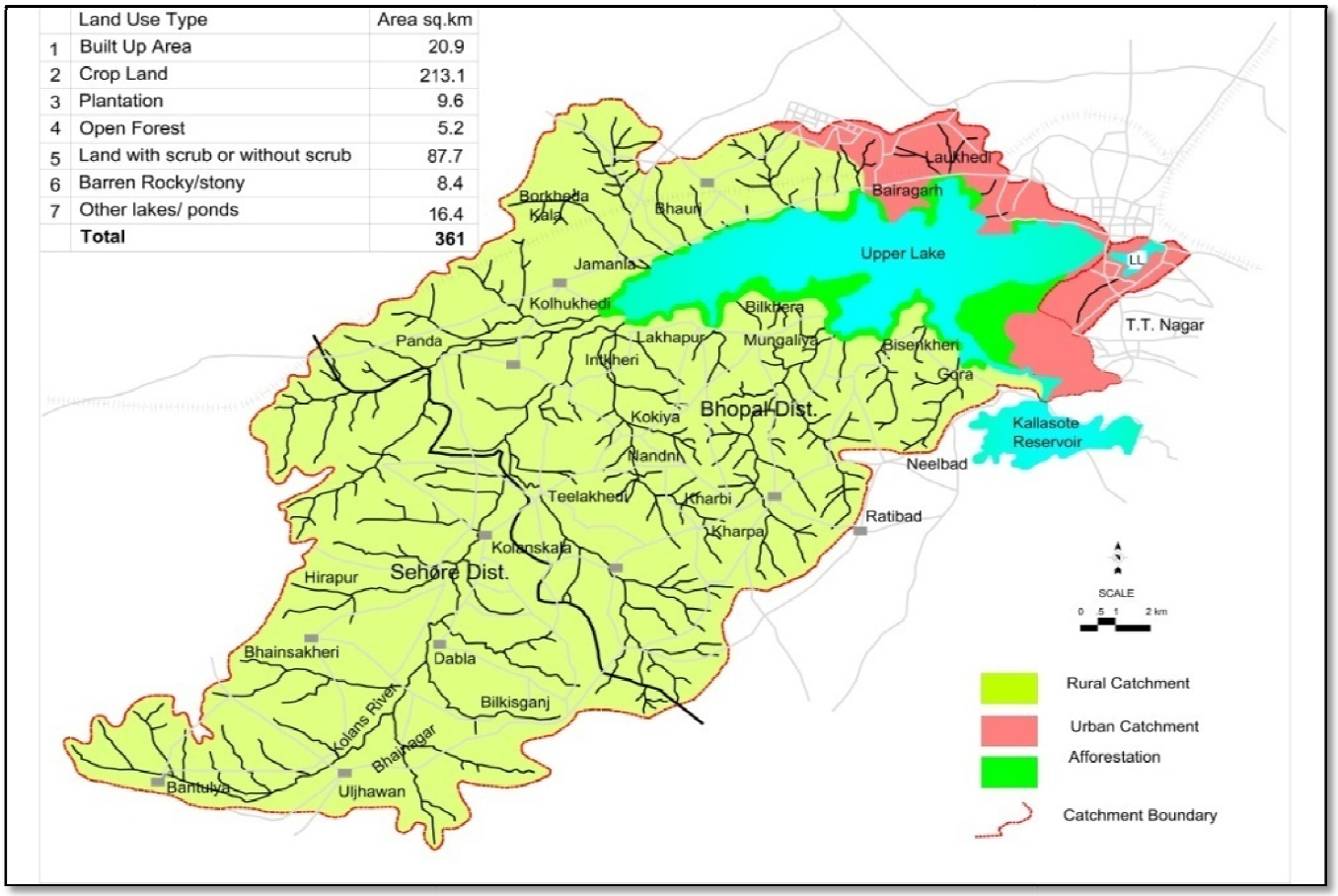

Figure-1
Catchment Area of Upper Lake, Bhopal

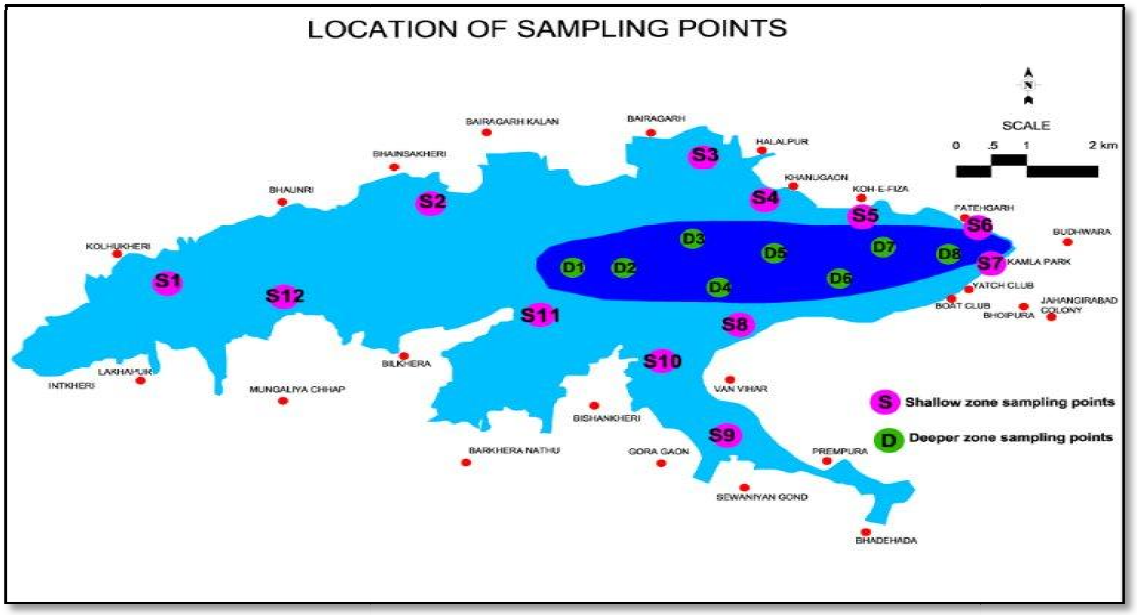

Figure-2
Location of Sampling Points in Upper Lake, Bhopal

In Upper Lake, BOD concentration of lake water ranged between 3.0 mg/l to 22.7 mg/l with an average value of 7.7 mg/l. BOD was recorded maximum at the bottom and minimum at the surface water samples. As indicated by present data range, values of BOD in Upper Lake water were found high and high BOD values at the deeper depths than surface water were due to settling autochthonous and allochthonous induced organic matters to the lower depths. As per CPCB water Quality criteria[27] for B class water, the threshold limit of BOD for inland surface water is 3 mg/l, when such waters are used as raw water for public water supplies and bathing purposes. According to Indian Council of Medical Research (ICMR)[28], BOD value of 6 mg/l or more in surface water should be taken as a boundary value for classifying the water body as polluted. In the present study, the BOD values most of the times crossed these limits indicating the high degree of organic pollution.

Nitrogen is one of the most important causative agents of eutrophication[29]. Total Nitrogen (TN) in Upper lake water samples was recorded in the range of 0.94 mg/l to 7.34 mg/l with an average concentration of 2.49 mg/l. At again, higher nitrogen concentration was recorded in bottom water samples especially in summer months because of high decomposition of nitrogenous organic matter.As far as Total phosphorous (TP)is concern, it was found very high in between 0.58 mg/l to 4.87 mg/l with an average concentration 1.8 mg/l. Concentration of TP fluctuated significantly during the study periods while the higher values were recorded during summer season in hypolimnion as well as in epilimnion also. TP concentration of less than 10µg/L in the lake is generally considered to be oligotrophic while 100µg/L often is used as the threshold for hyper-eutrophication[29,30]. Apart from this, the Organization for Economic Development and Co-Operation (OECD) trophic state classification[26] has been internationally accepted for nearly 30 years, including acceptance by U.S. EPA[31] who chose limit for TP for define eutrophic is 0.035 mg/l. Thus, the values in Upper Lake are >50 times greater than the prescribed limit for eutrophication. At this point, we can state that reduction in TP concentration will be an essential mechanism to control the process of eutrophication in Upper Lake.

Chlorophyll a in Upper Lake was found in the range of 6.0 µg/lto 22.0 µg/l with an average value of 11.2 µg/l. Concentration of chlorophyll-a was recorded high in spring (March) and autumn (October) months due to high phytoplanktonic activities. Deeper zone was found less abundant with chlorophyll-a as compare to shallow zone. As per OECD[26] classification of trophic state, 8 µg/l of chlorophyll-a concentration is the threshold for eutrophication and in the present study; all the samples were found to have chlorophyll-content beyond the above prescribed limit.

Phytoplankton species were also studied during the study. In this investigation, total 87 phytoplankton species were recorded during 2010 in which 45 species belonged to Chlorophyceae, 24 species belong to Bacillariophyceae, 15 belonged to Cyanophyceae while 3 species belonged to Euglenophyceae. Out of 5 classes, Chlorophyceae was found to be dominant. In year 2011, total 88 species of phytoplanktons were recorded in Upper Lake, in which 44 species belongs to Chlorophyceae, 24 species belong to Bacillariophyceae, 16 species to Cyanophyceae while 4 belong to Euglenophyceae.

Palmer Pollution Index: Palmer[24] reviewed a composite rating of algae, tolerating organic pollution and developed an index to establish the status of the aquatic body. In this method to determine the level of organic pollution by studying the algae

present in a sample of water. A pollution index factor of 1 through 5 has been assigned to each of the 20 types of algae that are most tolerant to organic pollution. Types of algae most tolerant of organic pollution were assigned a factor of 5. Less tolerant types were assigned a lower number. If the pollution index score is 20 or more, the score is evidence of high organic pollution. A score of 15-19 indicates probable organic pollution. Lower scores usually indicate less organic pollution, but they may also occur if something is interfering with algae growth.

In present study, Palmer index was calculated for Upper Lake and it is found that out of 20 Genus, 12 Genus were found with total index value of 27 that indicate organic pollution in Upper Lake. Detailed results of the Palmer Index are summarized in table-3.

Table-3
Palmer Pollution Index for Upper Lake, Bhopal

Genus	**Pollution Index**	**Upper Lake**
Microcystis	1	1
Ankistrodesmus	2	2
Chlamydomonas	4	-
Chlorella	3	3
Closterium	1	1
Cyclotella	1	1
Euglena	5	5
Gomphonema	1	1
Lepocinclis	1	-
Melosira	1	1
Micractinium	1	-
Navicula	3	3
Nitzschia	3	3
Oscillatoria	5	5
Pandorina	1	-
Phacus	2	-
Phormidium	1	1
Secnedesmus	4	-
Stigeoclonium	2	-
Synedra	2	-
Palmer Index Value Of Upper Lake		**27**

Trophic Static Index: Trophic level is the indicator of water quality for limnetic ecosystem. It shows the productivity of the system and biomass availability in that water body. The degree of nutrient enrichment is also classically indicated as trophic state of water bodies. It could vary between oligotrophic to hyper-eutrophic states.

Trophic status of Upper Lake was computed using regression equations of Reokhowand Chapra[25]. These equations (equation 1, 2, 3 and 4) were originally based on Carlson trophic static indices[32].

$$\mathrm{TSI\ (SD)} = 60.0 - 14.41 * \ln(\mathrm{SD}) \quad (1)$$

$$\mathrm{TSI\ (TP)} = 14.42 * \ln(\mathrm{TP}) + 4.15 \quad (2)$$

$$\mathrm{TSI\ (TN)} = 54.45 + 14.43 * \ln(\mathrm{TN}) \quad (3)$$

$$\mathrm{TSI\ (CHL)} = 30.6 + 9.81 * \ln(\mathrm{CHL}) \quad (4)$$

Where SD = Secchi Depth (m), TP = Total Phosphorous (µg/l), TN = Total Nitrogen, CHL = Chlorophyll (µg/l).

Average value of Secchi Depth, Total Nitrogen, Total Phosphorous and Chlorophyll-a were used to calculate the Trophic State Indices (TSI) which are shown in the table-4 that indicate variations of TSI values of Upper Lake during study period. Figure-3 and figure-4 shows eventual Trophic State Index and monthly variation of TSI values in Upper Lake. These obtained TSI values were compared with Carlson's trophic state classification criteria as given in table-5. Results of TSI clearly indicate that Upper Lake was found in hyper-eutrophic stage during entire study period.

Table-4
Calculated Trophic State Index values of Upper Lake during Study Period

TSI	**Year 2009 (Oct-Dec.)**	**Year 2010**	**Year 2011**
TSI (SD)	65	67	67
TSI (TN)	69	68	67
TSI (TP)	111	112	111
TSI (Chl-a)	54	54	54
Average	75	75	75
Eutrophic Threshold	50	50	50
Trophic Status	**Hyper Eutrophic**	**Hyper Eutrophic**	**Hyper Eutrophic**

TSI (TP) was found greater than TSI (CHA) which indicates the increasing phosphorous surplus in the water and TSI (SD) was found higher than TSI (CHA) is the sign of smaller particulate dominated turbidity along with phytoplankton turbidity. After assessment of computed results, it can be observed that phosphorous concentration along with smaller particulate dominated turbidity in Upper Lake are critical elements as far as eutrophication is concerned.

Conclusion

Main aim of this study was to understand the level of organic pollution and nutrient concentration in the lake and results revealed that concentration of all the important parameters which mainly govern the lake chemistry are beyond the permissible limits and threshold level of eutrophication. By perusing the results of Palmer Index and Trophic State Index, it can be concluded that Upper Lake is organic polluted and nutrient enriched lentic ecosystem. Concentration of Total Phosphorous and Total Nitrogen are mainly responsible for Upper Lake eutrophication and having significant impacts on lake water quality. These nutrients can also enhance the rate of

cultural eutrophication and increase the lake productivity which reflects through presence of floating algae such as Microcystisaeruginosa and several macrophytes in the Upper Lake. Decay and decomposition of these biological species may further increase the organic pollution load, reduction in the euphotic zone and hypolimnetic dissolved oxygen contents.

Over the period of about a decade, several good conservation and management actions had been taken to reduce the pollution and nutrients loading in the Upper Lake under Bhoj wetland conservation and management project funded by JBIC but present limnetic chemistry of the Upper Lake revealed that the time has come to further restart or continue the conservation practices to minimize the pollution load[33].

As far as conservation and management is concerned, primarily, emphasis should be laid on the overall prevention of external nutrient input into the lake thus lake drainage basin is the logical starting point for planning and management actions. Secondly, In-lake treatment could encourage the lake to restore its natural process. Control of internal ecological processes through modern eco-technologies or other in-lake treatment measures will be required for up-gradation of water quality. Augmentation of water, not only mass scale rainwater harvesting will be required in the immediate lake fringes but also channelization of storm water drains with proper screening and silt trapping will be needed to increase the water volume with reduced nutrient content. Setting of nutrient criteria and nutrients discharge standards specific to Upper Lake will play key role to regulate the nutrients load in to the lake.

Table-5
Carlson's Trophic State Classification Criteria

TSI	Classification	Description
<30	Oligotrophic	Clear water, dissolved oxygen throughout the year in the hypolimnion
30-40	Oligotrophic	Deep lakes still exhibit classical oligotrophy, but some Shallow lakes will become anoxic in the hypolimnion in the summer
40-50	Meso-trophic	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer
50-60	Eutrophic	Lower boundary of classical eutrophic, decreased transparency, anoxic hypolimnion during summer, macrophytes problems evident and warm water fisheries only
60-70	Eutrophic	Dominance of blue green algae, algal scum probable, excessive macrophytes problems
70-80	Hyper-eutrophic	Heavy algal blooms possible throughout the summer, dense macrophytes beds but extent limited by light penetration
>80	Hyper-eutrophic	Algal scum, summer fish kills, few macrophytes, dominance of rough fishes

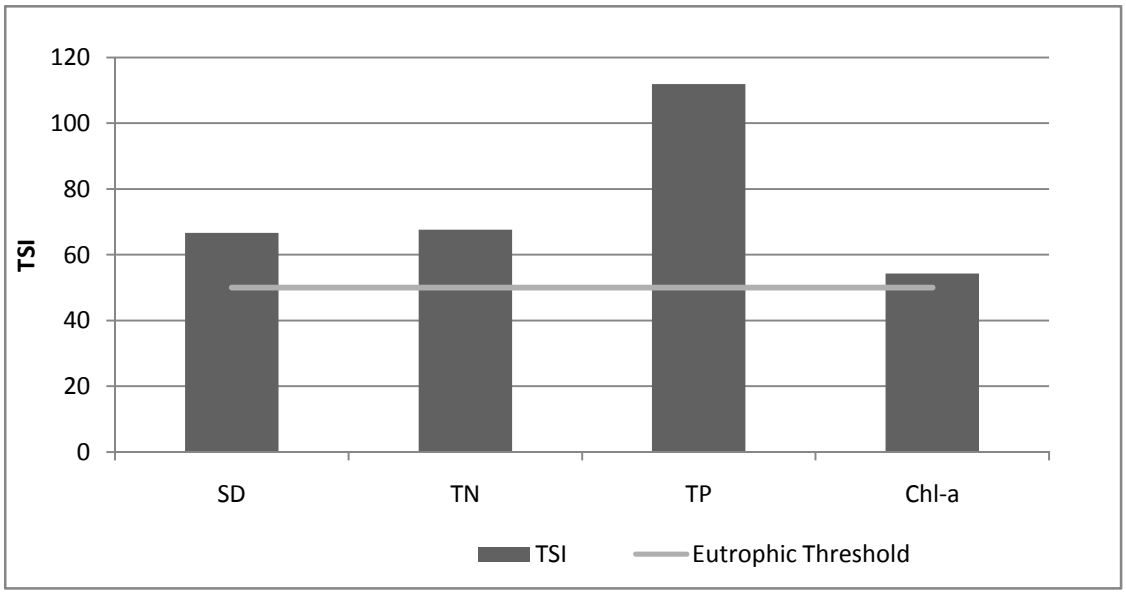

Figure-3
Trophic State Index of Upper Lake, Bhopal

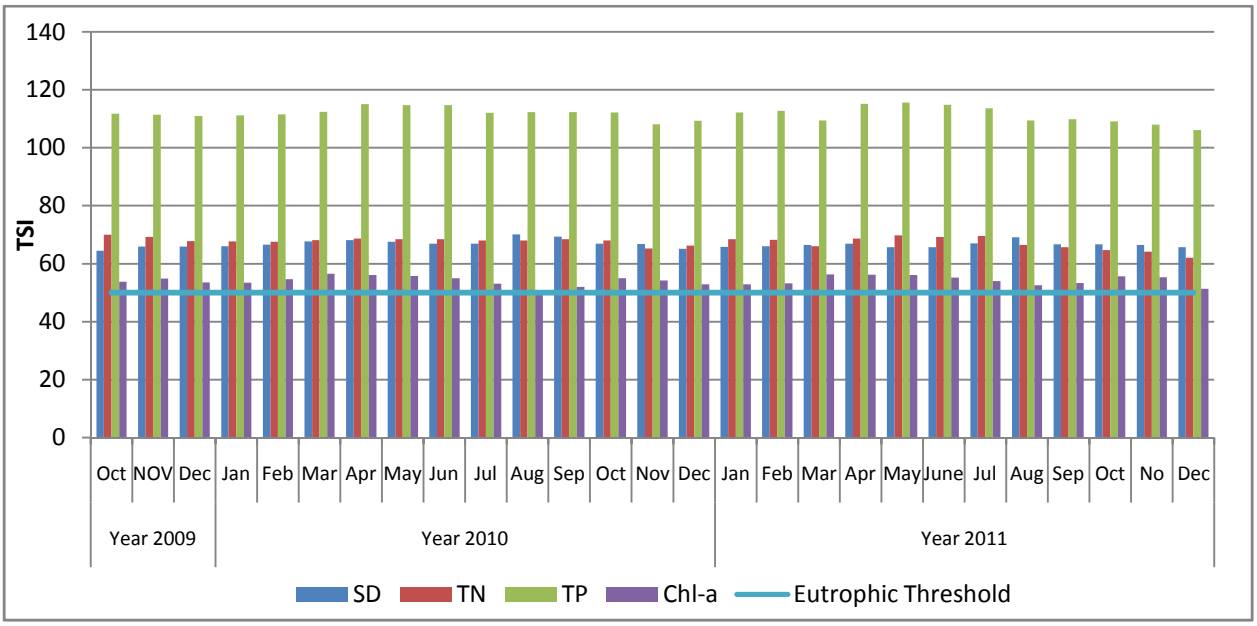

Figure-4
Monthly Variation of Trophic State Index of Upper Lake, Bhopal

Acknowledgement

Authors are grateful to Principal SSL Jain PG College Vidisha, M.P for granting permission to carry out the present research work.

References

1. Fang Y.Y., Yang X.E., Pu P.M., Chang H.Q. and Ding X.F., Water eutrophiocation in Li-Yang Reservoir and its ecological remediation countermeasures, *Journal of Soil and Water Conservation*, **18(6)**, 183–186 **(2004)**
2. Tong C.H., Yang X.E. and Pu P.M., Degradation of aquatic ecosystem in the catchment of Mu-Ge Lake and its Remediation countermeasures, *Journal of Soil and Water Conservation*, **17(1)**, 72–88 **(2003)**
3. Zhang M., Xu J. and Xie P., Nitrogen dynamics in large shallow eutrophic Lake Chaohu, China, *Environ Geol.,* **55(1),** 1-8 **(2008)**
4. Chen Y.Y., Hui E.Q. and Jin C.J., A Hydrological Method for Estimation of Non-Point Source Pollution Loads and Its Application, *Research of Environmental Sciences*, **16(1)** 10-13 **(2003)**
5. Parikh Ankita N. and Mankodi P.C., Limnology of Sama Pond, Vadodara City, Gujarat, *Res. J. Recent Sci.,* **1(1),** 16-21 **(2012)**
6. PatilShilpa G. et. al., Impact of Physico-Chemical Characteristics of Shivaji University lakes on Phytoplankton Communities, Kolhapur, India, *Res. J. Recent Sci.*, **1(2)**, 56-60 **(2012)**
7. Biomass of Fish Species in the Shadegan Wetland, IRAN, Seyed Ahmad Reza Hashem et al, *Res. J. Recent Sci.*, **1(1)**, 66-68 **(2012)**
8. HashemzadehFarshad and Venkataramana G.V., Impact of Physico-Chemical Parameters of Water on Zooplankton Diversity in Nanjangud Industrial Area, India, *International Research Journal of Environment Sciences* **1(4)**, 37-42 **(2012)**
9. Safari D., Mulongo G., Byarugaba D. and Tumwesigye W., Impact of Human Activities on the Quality of Water in Nyaruzinga Wetland of Bushenyi District – Uganda, *International Research Journal of Environment Sciences*, **1(4)**, 1-6 **(2012)**
10. Kumar Manoj and PadhyPratap Kumar, Climate Change, Water Resources and Food Production: Some Highlights from India's Standpoint, *International Research Journal of Environment Sciences*, **2(1)**, 9-87 **(2013)**
11. Pathak Neelam B. and Mankodi P.C., Hydrological status of Danteshwar pond, Vadodara, Gujarat, India, *International Research Journal of Environment Sciences*, **2(1)**, 43-48, **(2013)**
12. Parihar S.S. et. al., Physico-Chemical and Microbiological Analysis of Underground Water in and Around Gwalior City, MP, India, *Res. J. Recent Sci.,* **1(6)**, 62-65 **(2012)**
13. Nirmala B., Suresh Kumar B.V., Suchetan P.A. and ShetPrakash M., Seasonal Variations of Physico Chemical Characteristics of Ground Water Samples of Mysore City,

Karanataka, India, *International Research J. Env. Sci.,* **1(4)**, 43-49 **(2012)**

14. GholipoorMehranoosh., Lake Gahar Basin: Environmentally Potential for Focused Ecotourism, *Res. J. Recent Sci.,* **1(9)**, 6-12 **(2012)**

15. Singh K.P., Malik A., Mohan D. and Sinha S., Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India): a case study, *Wat. Res*., **38**, 3980–3992 **(2004)**

16. Vega M., Pardo R., Barrado E. and Deban L., Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis, *Water Res*., **32**, 3581–3592 **(1998)**

17. Upadhyay Rahul, Pandey Arvind, Upadhyay S.K. and Bajpai Avinash, Annual Sedimentation Yield and Sediment Characteristics of Upper Lake, Bhopal, *Research Journal of Chemical Sciences*, **2(2)**, 65-74 **(2012)**

18. Dhote Sangeeta and Dixit Savita, Hydro chemical changes in two eutrophic lakes of Central India after immersion of Durga and Ganesh idol, *Res. J. Chem. Sci.,* **1(1)**, 38-45 **(2011)**

19. Information sheet on Ramsar Wetlands http://www.wetlands.org/reports/ris/2IN011en.pdf Accessed on **(03.10.2011) (2011)**

20. A.P.H.A., Standard Methods for Examination of Water and Waste Water, American Public Health Association, New York **(1998)**

21. Edmondson, W.T., Freshwater Biology, John Wiley, New York, **(1959)**

22. Fitter R. and Manuel, Freshwater life of Britain and North West Europe, William Collins Sons & Co. Ltd. London, **(1986)**

23. Pennak R.W., Freshwater Invertebrates of the United States, 2nd edn., John wiley and Sons, New York, **(1958)**

24. Palmer C.M., A composite rating of algae tolerating organic pollution, *J. Phycology,* 78-82 **(1969)**

25. Reokhow K.H. and Chapra S.C., Lake Quality indices, Engg. Approaches for Lake Management, Butterworth Publisher, London., **1, (1983)**

26. OECD, Eutrofication of Waters, Monitoring, Assessment, and Control, Organization for Economic Co-operation and Development, Paris, 154 **(1982)**

27. CPCB, Water Quality Criteria-Designated Best Use, MINARS/31/2009–2010, **(2009)**

28. ICMR, Manual of standards of quality for drinking water supplies, ICMR New Delhi, **(1975)**

29. Vollenweider R.A., Scientific fundamentals of the eutrophication of lakes and flowing waters with particular reference to nitrogen and phosphorus as factors in eutrophication, Organisation for Economic Cooperation and Development , Directorate of Scientific Affairs, Paris, Report., 220 **(1968)**

30. Wetzel R.G., Limnology, W.B. Saunders Co. Philadelphia, USA, 743 **(1975)**

31. USEPA, Nutrient Criteria Technical Guidance Manual, Lakes and Reservoirs, US EPA, Washington D.C., EPA 822-B00-001 **(2000)**

32. Carlson E. Robert, A tropical state index for lakes. Limnology and oceanography, **22(2), (1977)**

33. Upadhyay Rahul, Pandey Arvind., Upadhyay S.K., Bassin J.K. and Misra S.M., Limnochemistry and Nutrient Dynmaics in Upper Lake Bhopal, India, *Environ Monit Assess*, **(2011)**