Water Quality Status of Loktak Lake, Manipur, Northeast India and Need for Conservation Measures: A Study on Five Selected Villages

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Abstract- The present study was carried out to assess the physico-chemical properties of Loktak lake at five selected villages– three lakeshore villages i.e. Phoubakchao, Laphupat Tera, Nongmaikhong and two island villages-Ithing and Karang. A total of eleven parameters were monitored for a period of one year to assess the standard of water quality of Loktak lake with reference to its status of pollution. It was observed that air temperature ranged between 11-33°C, water temperature between16-32°C, pH ranged between 6.05-9.10, Dissolved oxygen between 4.05-14.18 mg/l, Biochemical oxygen demand between 1.51-10.65 mg/l, Free CO_2 between 0-35 mg/l, Total dissolved solids between 50-150 ppm, Phenolphthalein Alkalinity between 0-20 mg/l, Total Alkalinity between 35-90 mg/l, Conductivity between 90-220 µS/cm and Transparency between 29-162 cm. Seasonal variations of the parameters across the five sites have been observed. Mean values of the physico-chemical parameters like DO and BOD studied were found higher than the World Health Organization (WHO) guideline. The result revealed that discharge of municipal sewage, domestic wastes, fertilizers and pesticides from agricultural practices have degraded the water quality. The water of Lokak lake is moderately polluted and unsuitable for human consumption and for the survival of life forms unless treated properly. There is need for implementing conservation measures and generating awareness among the people towards the lake which provides livelihood to the people and forms an integral part of the social, economic and cultural life.

Index Terms- Loktak lake, Physico-chemical properties, Seasonal variations and Water quality

I. INTRODUCTION

Water is most essential for all living organisms. Water from surface sources provides sustenance to plants and animals and constitutes the habitat for aquatic organisms and meets importance of agriculture and industrial needs (Prasad and Gaur, 1992). The rapid industrialization, growing urbanization and increasing use of chemicals in agriculture constitutes some of the important factors responsible for various forms of pollution of water bodies (Tripathi and Pandey, 1990). The beginning of systematic limnological studies in India was made by Ganapati (1940) and his associates (Ganapati and Chacko, 1951 and Ganapati *et al.*, 1953). Many workers have worked on the assessment of water quality by conducting physico-chemical and biological analysis (Pandey *et al*., 1999; Bhanja and Kumar, 2000; Chen *et al*. 2000; Ojajire and Insokparia, 2001; Khwaja *et al*. 2001; Zafar and Sultana, 2003; Devi, 2005; Kalita *et al*., 2006; Kosygin and Dhamendra, 2009).

Loktak Lake is located between 93° 46' and 93° 55' E and from 24° 25' to 24° 42'N in the southern part of the Imphal valley of Manipur. Loktak lake is the largest freshwater wetland of Manipur and declared a Ramsar Site in 1990 (LDA, 1996). The lake is oval in shape with maximum length and width of 26 Km and 13 Km respectively. The depth of the lake varies between 0.5 to 4.58 m with average depth recorded at 2.7 m. Loktak lake can be considered as a sub-basin of the Manipur River basin. It has a direct catchment area of 980 sq.km and indirect catchment area of 7157 sq.km. There are 55 rural and urban settlements around the lake with a total population of 100,000 (LDA and WISA, 1999). The lake provides livelihood to the settlements in the form of fishing, agriculture, collection of vegetables etc.

Municipal wastes, agricultural fertilizers and pesticides, bathing, washing of clothes and utensils makes the lake polluted. A large number of people living in these villages use the water of the lake for drinking and other domestic purposes. Hence, it is necessary to study the quality of water to know the extent of pollution and aware the concerned authorities to take up steps in controlling the pollution of the water so as to prevent the local people from being affected by the possible health hazards. With these objectives the present study was carried out to assess the physico-chemical variables of Loktak lake at the five lakeshore villages of Phoubakchao, Laphupat Tera, Nongmaikhong, Ithing and Karang of Loktak lake. The villages were selected considering their dependency on the lake resources.

II. MATERIALS AND METHODS

Water samples were collected for physico-chemical analysis from five different sampling sites i.e. Phoubakchao, Laphupat Tera, Nongmaikhong, Ithing and Karang. Monthly water samples were collected once in every month from March, 2012 to February, 2013 for a period of one year. The samples were collected in two litre polythene bottle during morning hours between 7:00 A.M. to 11:00 A.M. Air temperature (AT) and water temperature (WT) were measured using mercury thermometer, pH was measured using digital pH meter (pHScan 3 Double junction of Merck company), Dissolved oxygen (DO) was estimated following Winkler's method and Biochemical oxygen demand (BOD) by titration methods after 5 days of incubation at 20°C and titration of initial and final DO. Free carbondioxide (FCO_2) was determined by titration methods,

Total dissolved solids (TDS) were obtained using digital TDS meter (TDScan 1 0-1990 ppm of Merck company), Phenolphthalein alkalinity (PA) and Total alkalinity (TA) were obtained by titration methods. Conductivity (CON) was measured by digital conductivity meter (EC Scan low 0-1990 µS of Merck company Microprocessor series) and Transparency (TRAN) by secchi disc of 20 cm diameter. AT, WT, pH, FCO_2, TDS, CON, TRAN were determined in the field. DO, BOD, FCO_2, PA, TA, TRAN were analyzed by following standard methods (APHA, 2005; Trivedy and Goel, 1986).

III. RESULTS AND DISCUSSION

The mean variations of the parameters along with the standard deviation and range is presented in Table 1. Seasonal variation of the physico-chemical parameters is presented in Table 2 and correlation coefficient among the parameters from five selected villages (March, 2012 to February, 2013) is presented in Table 3.

Table 1: Characteristics of physico-chemical parameters of Loktak lake from five selected villages (March, 2012 to February, 2013)

	Minimum	Maximum	Mean	SD	SE	WHO limits
AT (°C)	11	33	25.03	5.33	0.68	*N/A
WT (°C)	16	32	24.69	4.11	0.53	30-35°C
pH	6.05	9.10	7.31	0.71	0.0919	6.5-8.5
DO (mg/l)	4.05	14.18	8.58	2.54	0.32	5-7 mg/l
BOD (mg/l)	1.51	10.65	5.07	1.88	0.24	5 mg/l
FCO_2 (mg/l)	0	35	11	8.41	1.08	22 mg/l
TDS (ppm)	50	150	71.33	23.25	3.00	500 mg/l
PA (mg/l)	0	20	2.08	5.23	0.675	*N/A
TA (mg/l)	35	90	56.58	14.03	1.81	120 mg/l
CON (µS/cm)	90	220	161.67	23.15	2.98	750 µS/cm
TRAN (cm)	29	162	95.43	33.03	4.26	*N/A

*N/A = Not available

Table 2: Seasonal variation in physico-chemical parameters of Loktak lake from five villages (March, 2012 to February, 2013)

Seasons	AT (°C)	WT (°C)	pH	DO (mg/l)	BOD (mg/l)	CO_2 (mg/l)	TDS (ppm)	PA (mg/l)	TA (mg/l)	CON (µS/cm)	TRAN (cm)
Pre-monsoon											
March	23.6	22.8	7.99	8.79	7.29	7.04	72	4	83	146	58.8
April	26.66	26.22	8.18	8.28	4.3	6.6	132	7	77	144	110.4
May	27.3	26.62	7.38	8.3	4.62	11	82	3	65	198	79.8
Mean±SD	25.85±1.97	25.21±2.09	7.85±0.41	8.45±0.28	5.40±1.64	8.21±2.42	95.33±32.14	4.66±2.08	75±9.16	162.66±30.61	83±25.94
Monsoon											
June	28.3	27.4	6.66	7.59	5.61	13.2	74	5	44	186	107.6
July	28.9	28	6.91	7.09	4.63	19.36	64	2	39	156	99.6
August	29	28	7.62	6.92	3.7	16.72	58	2	43	152	90.6
Mean±SD	28.73±0.37	27.8±0.34	7.06±0.49	7.2±0.34	4.64±0.95	16.42±3.09	65.33±8.08	3±1.73	42±2.64	164.66±18.58	99.26±8.50
Post monsoon											
September	31.6	30.6	7.91	8.38	5.82	16.72	52	2	46	142	93.2
October	27	27.2	7.95	8.14	5.71	11.44	52	0	56	156	78.4
November	21.8	21.8	7.23	7.73	3.09	9.68	58	0	58	154	123.2
Mean±SD	26.8±4.90	26.53±4.43	7.69±0.40	8.08±0.32	4.87±1.54	12.61±3.66	54±3.46	0.66±1.15	53.33±6.42	150.66±7.57	98.26±22.82
Winter											

December	17.2	17.8	6.61	11.18	5.47	5.28	62	0	55	156	113.6
January	16.6	18	6.19	11.38	4.67	7.04	70	0	52	178	112.4
February	22.4	21.8	7.15	9.2	6.02	7.92	80	0	61	172	77.6
Mean±SD	18.73±3.18	19.2±2.25	6.65±0.48	10.58±1.20	5.38±0.67	6.74±1.34	70.66±9.01	0±0	56±4.58	168.66±11.37	101.2±20.44

Table 3: Correlation coefficients among physico-chemical parameters of Loktak lake from five selected villages (March, 2012 to February, 2013)

	AT	WT	pH	DO	BOD	FCO_2	TDS	PA	TA	CON	TRAN
AT	1	.926(**)	.460(**)	-.237	.089	.312(*)	-.047	.184	-.192	-.136	-.115
WT		1	.504(**)	-.333(**)	.031	.355(**)	-.051	.211	-.249	-.116	-.119
pH			1	-.045	.157	-.195	.094	.461(**)	.442(**)	-.242	-.231
DO				1	.564(**)	-.626(**)	-.105	.220	.208	-.052	.326(*)
BOD					1	-.310(*)	-.193	.170	.206	-.093	-.038
FCO_2						1	-.141	-.529(**)	-.480(**)	-.080	-.143
TDS							1	.144	.448(**)	.122	.026
PA								1	.335(**)	.118	-.021
TA									1	-.100	-.092
CON										1	-.137
TRAN											1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Temperature is one of the most important factors in an aquatic environment. Changes in the air temperature naturally affect the water temperature (Kumar, 1997). The AT in this study ranges from 11°C to 33°C (Table I). AT was found to be higher in monsoon season and low in winter. Kaushik and Saksena (1999) also found that ambient temperature at Motijheel varied from 12°C to 43.8°C, at Surajkund from 15.5°C and 43.0°C and at Ranital from 21.5°C to 42.5°C. In the present study AT has high significant positive correlation with the value of WT (r=.926) and pH (r=.460) and a significant positive correlation with FCO_2 (r=.312).

Surface water temperature is one of the most significant parameters which control inborn physical qualities of water. WT fluctuates from 16°C to 32°C (Table 1). WT was found to be higher in monsoon season and low in winter. More penetration of sunlight and longer duration of receiving sunlight in a day is the reason for higher temperature during monsoon season. The water temperature of Kalyani lake in West Bengal was found to vary from 25° C to 37° C. The summer temperature (May-Jul) was always above the winter temperature (Jan-Feb) due to lack of sunlight (Sinha and Biswas, 2011). The WT across the five sites under study is below the WHO (1995) standard of 30°C-35°C and showed high significant positive correlation with pH (r=0.504) and FCO_2 (r=0.355) and a high significant negative correlation with DO (r=-0.333).

pH is an important factor in determining the productivity of an ecosystem (Singh, *et al.* 2009). pH in the present study ranged from 6.05 to 9.10 (Table 1). It was found to be higher in pre-monsoon season and low in monsoon. This may be due to removal of large amount of CO_2 by photosynthetic process by aquatic plants during summer while during rainy season there was active decomposition of organic matter (Meetei and Singh, 2011). Zafar and Sultana (2003) also noted highest pH in summers and lowest in rainy seasons in river Ganga. The pH of Narmada river water samples was found to be in the range 7.6-9.9 (Shraddha, *et.al*, 2011). The pH of the water under study is within the WHO standard of 6.50-8.50. pH limits laid by BIS (Bureau of Indian Standards) limits for drinking water are 6.5-8.5. pH has high significant positive correlation with PA (r =0.461) and TA (r =0.442).

Dissolved oxygen is one of the important parameters of water which directly effects the survival and distribution of flora and fauna in an ecosystem. It is one of the most reliable parameters in assessing the trophic status and the magnitude of eutrophication in an aquatic ecosystem (Edmondson, 1966). The values of DO ranges from 4.05 mg/l to 14.18 mg/l (Table 1). The highest value of DO i.e. 14.18 mg/l was found from the village of Ithing in the month of January. DO was found to be higher in winter season and low in monsoon. The high value of DO during winter may be due to growth of large quantity of aquatic plants and the low value of oxygen in monsoon may be due to the utilization of oxygen for metabolic activities by the increasing growth of bacteria (Pandey *et al.* 1999). Kosygin *et al*. (2007) also observed highest value of DO in winter season and lowest in monsoon. Manjare *et al.* (2010) found that DO of Tamdalge tank in Kolhapur, Maharashtra fluctuates from 6.40 mg/l to 15.5 mg/l. The mean DO of the five sites in the lake is above the WHO standard of 5.0-7.00 mg/l. The royal commission has reported a scale for deciding the quality of water based on DO. The content of DO of 7 mg/l in water is considered as very clear, 6 mg/l as moderate, 5 mg/l as doubtful and 4 mg/l or below as bad (Singh, *et al.* 2009). DO in the present study shows high significant positive correlation with BOD (r =0.564) and high significant negative correlation with FCO_2 (r =-0.626) and a significant positive correlation with TRAN (r=0.326).

BOD is an indicator of organic pollution. The BOD of water samples fluctuates from 1.51 mg/l to 10.65 mg/l (Table I). The highest value of BOD i.e. 10.65 mg/l was found from the village of Karang in the month of February. It was found to be higher in pre-monsoon and low in monsoon. The higher values of BOD in pre-monsoon may be due to high pollutant load drained from rivers of the urban areas of Imphal. Pathak, *et al.* (2012) recorded higher values of BOD in monsoon compared to post monsoon. Gupta, *et al*., (2011) reported values of biological oxygen demand of river Chambal was varied from 1.20 to 12.20 mg/L. Observed values clearly indicate that the river water is moderately polluted by organic wastes. The values of BOD are above the standards limit of 5 mg/l laid by WHO. BOD have a significant negative correlation with FCO_2 (r=-0.310). The present study indicates moderate pollution of the lake.

Free CO_2 in water is derived from many sources such as atmosphere, respiration by the organisms, bacterial decomposition of organic matter etc. Rain also absorbs small amount of gas and delivers it to the water on which it falls (Kaushik and Saksena, 1999). The values of FCO_2 were found to be in the range of 0- 35 mg/l (Table 1). The highest value of Free CO_2 i.e. 35 mg/l was found from the village of Phoubakchao in the month of July. It was found to be higher in monsoon and low in winter. The high value of FCO_2 in monsoon may be due to high rate of composition of organic matters by bacteria resulting in rapid production of CO_2 (Pandey, *et al.*, 1999). Kosygin *et al.* (2007) also observed highest value of free CO_2 in monsoon and lowest in winter. According to Sarwar (1999), the FCO_2 of Anchar lake, Kashmir varied from 0.05-26.7 mg/l. The observed values are below the WHO standards of 22 mg/l. FCO_2 have highly significant negative correlation with PA (r = -0.529) and TA (r = -0.480).

The total dissolved solids in water comprise mainly of inorganic salts and small amount of organic matter such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium. The total dissolved solids in water originate from natural sources and depend upon location, geological nature of the pond basin, drainage, rainfall, bottom deposit and inflowing water (Kaushik and Saksena, 1999). The values of TDS were found to be in the range of 50-150 ppm (Table 1). TDS was found to be higher in pre-monsoon and low in post-monsoon. The high values of TDS in pre-monsoon may be due to deposition of inorganic salts and organic matter from other rivers draining into the lake. The observed value is in contrast with the one reported by Zafar and Sultana (2003) where the TDS values of river Ganga at Kanpur ranges from 200-640 mg/l having maximum values in winter and minimum values in monsoon. The observed values was found below the WHO permissible limit of 500 mg/l. TDS showed highly significant positive correlation with TA (r= 0.448).

Alkalinity may also be caused due to evolution of CO_2 during decomposition of organic matters. The PA of the stations was found to vary from 0 to 20 mg/l (Table 1). PA was found to be higher in pre-monsoon and low in winter. The high values of PA in pre-monsoon may be due to the liberation of carbondioxide during the decomposition of organic matter. Lower values of PA was observed in winter by other workers (Singh, *et al.*, 2009). The values of PA of river Ganga during the year 2003 was found to be in the range of 4.5- 17.5 mg/l with a mean value of 9.5 mg/l while that of 2004 was found to be 4.5- 13.7 mg/l with a mean value of 9.17 mg/l (Singh, *et al.*, 2009). PA have highly significant positive correlation with TA (r=0.335).

Alkalinity of water is its capacity to neutralize acid and is characterized by the presence of hydroxyl (OH^-) ions capable of combining with hydrogen (H^+) ions in solution (Kaushik and Saksena, 1999). The values of TA ranges from 35 to 90 mg/l (Table 1). TA was found to be higher in pre-monsoon and low in monsoon. The high value of TA in pre-monsoon may be due to the dissolution of calcium carbonate from the sediments and use of detergent and soap (Meetei and Singh, 2011). Minimum values of TA was observed during monsoon months by Singh, *et al.* (2009). The observed values is found to be lower when compared to one reported by Singh, *et al.* (2010) in Kharungpat Lake, Manipur (38.0 to 284.0 mg/l). Similar study was conducted by Pathak, *et al.* (2012) who observed that the bicarbonate and total alkalinity in both the water bodies vary from 98.0 mg/l to 185.4 mg/l and 117.0 mg/I to 167.6 mg/l. The observed values were found below the WHO permissible limit of 120 mg/l. TA does not have any significant correlation with other parameters.

Water becomes a good conductor of electric current when substances are dissolved in it and the conductivity is proportional to the amount of dissolved substance. These substances are ions which act as conductor. The values of conductivity across the five sites ranged from 90 µS/cm to 220 µS/cm (Table 1). COND was found to be higher in winter and low in post monsoon. The high value of COND in winter may be due to the addition of sewage from other rivers draining into the lake. Sharma, *et al.* (2013) also reported the values of COND ranged from 105.56 µS/cm to 201 µS/cm in Keibul Lamjao National Park, Manipur, India from six selected stations and found high value of COND during winter and low during post-monsoon season. The observed values was found below the WHO permissible limit of 750 µS/cm. COND does not have any significant correlation with other parameters.

Transparent waters allow more light penetration which has far reaching effects on all aquatic organisms, including their development, distribution and behaviour, etc. (Kaushik and Saksena, 1999). TRAN in the present study ranges from 29 cm to 162 cm (Table 1). TRAN was found to be higher in winter and low in pre-monsoon. The high value of TRAN in winter is due to the better penetration of light while it is low in pre-monsoon season because of the abundance of floating plankton on the surface of the water. Khan and Choudhary (1994) reported higher values of TRAN during winter. Kosygin and Dhamendra (2009) noted the transparency values of Loktak lake, Manipur ranges from 0.51 m - 2.98 m.

IV. CONCLUSION

Among the eleven parameters analyzed across five sites it was found that the physico-chemical properties of DO and BOD are above the WHO standard limit due to discharge of municipal sewage, domestic wastes, fertilizers and pesticides from agricultural practices disturbing the ecology of the Loktak lake and potable nature of the water. Hence, we can conclude that the water of the Loktak lake is getting polluted. It needs to be controlled to prevent further pollution, spreading of water borne diseases and utilization of water for domestic purposes. Loktak

lake is the lifeline of the people of Manipur and bears significant importance in the social, cultural and economic life. The people of the three offshore and two island villages are dependent on the natural resources of the lake for livelihood and also for drinking water. Pollution due to various anthropogenic activities need to be checked and awareness regarding the conservation of the lake has to be generated. Although Loktak Development Authority (LDA) is actively involved in managing the ecological status of the lake, community participation is needed to prevent further degradation of the lake which would have a direct impact on the availability and abundance of various bioresources.

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