E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2020; 8(6): 01-07

www.fisheriesjournal.com
Received: 01-09-2020
Accepted: 04-10-2020

Jogesh Laishram
Department of Forestry and Environmental Science, Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Bishnupur, Utlou, Manipur, India

Corresponding Author:
Jogesh Laishram
Department of Forestry and Environmental Science, Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Bishnupur, Utlou, Manipur, India

Seasonal variations and significant difference in selected Physico-chemical characteristics of Loktak lake, Manipur, North-East India

Jogesh Laishram

Abstract
Assessment of some selected physico-chemical characteristics of Loktak lake was conducted in five water sampling stations (sites) i.e. Nongmaikhong, Phoubakchao, Laphupat Tera, Karang and Ithing villages located in and around Loktak lake from March 2013 to February 2014. During the study parameters such as Air Temperature (mean ranged from 21.50-24.33°C), Water Temperature (24.08 - 25.88°C), pH (6.97-7.50), Dissolved Oxygen (4.59-7.10 mg/l), Biochemical Oxygen Demand (2.94-4.88 mg/l), Free CO_2 (5.87 - 17.60 mg/l), Total Dissolved Solids (60.83-80.83 ppm), Phenolphthalein Alkalinity (0-3.33 mg/l), Total Alkalinity (57.50-61.25 mg/l), Conductivity (115 -140.83 µS/cm) and Transparency (82.33-125 cm) across the five stations were analysed. Comparison of means of each physico-chemical parameter of the five sites and the variation of means over the sites is tested by one way ANOVA. Seasonal variations in physico-chemical parameters is studied. All the mean values of the parameters analyzed were observed below or between the standard limit lay down by WHO (World Health Organisation) except lower mean values of Dissolved oxygen recorded in Phoubakchao and Nongmaikhong stations. Hence, the water quality parameters of the studied season indicated moderate organic pollution of the lake. In order to maintain good water quality of the lake the concerned authorities and the communities living in and around the lake need to stop all those activities which causes pollution of the lake.

Keywords: Physico-chemical, loktak lake, anova, seasonal variations

1. Introduction
The freshwater sources are facing pollution problem all over the world; Lakes are part of freshwater ecosystem, and useful to man. The survival of all life in and around lakes depends on the quantity and quality of water available. Lakes play a significant role in the ecological sustainability of the region. However, continuous inputs of various forms of chemical pollutants from a variety of human activities have seriously deteriorated the quality of many lake ecosystems in India. Lakes are under increasing threat due to point and nonpoint sources of pollution. Major degrading factors include excessive eutrophication due to nutrient and organic matter loading, construction and logging activities etc. (Nirbhavane and Khobragade, 2017) [1]. The quality of surface water is mainly affected by natural processes (weathering and soil erosion) as well as anthropogenic inputs (municipal and industrial wastewater discharge). The anthropogenic discharges represent a constant polluting source, whereas surface runoff is a seasonal phenomenon, mainly affected by climatic conditions (Singh *et al*., 2004) [2]. The availability of good quality water is an indispensable feature for preventing disease and improving quality of life. The physico-chemical properties will also help in the identification of sources of pollution, for conducting further investigations on the ecobiological impacts and also for initiating necessary steps for remedial actions in case of polluted water bodies (Ekwenye and Oji, 2008; Singh and Singh, 2008) [3, 4].
The Loktak lake is the largest freshwater lake in Northeast India. Because of its ecological status and its biodiversity values the lake has been designated as a "Wetland of International Importance" under the Ramsar Convention on 23rd March, 1990. Keibul Lamjao, the only floating national park in the world and the home of the endangered Manipur Brow Antlered Deer "Sangai"– *Cervus eldi eldi* is situated at the south-west part of the lake (Trisal and Manihar, 2004) [5]. *Amblypharyngodon mola, Ctenopharyngdon idella, Apocheilus panchax*,

Acanthophthalmus pangia, Mystus bleekeri, Ompok bimaculatus, Eutropiichthys vacha, Bagarius bagarius, Clarias batrachus, Heteropneustes fossilis etc. are some of the fish species found in the Loktak lake (Trisal and Manihar, 2004) [5].

In recent years, the Loktak lake have been facing several threats because of increasing
human dependency on the lake and other human activities. Untreated sewage from Imphal city draining into the lake, plastic waste, degradation of the biomass in the water body, municipal waste, fertilisers and pesticides used in agriculture and human activities such as bathing, washing of clothes and utensils in the lake are the main threats to the lake. People living in and around the lake depend on the water of this lake for drinking and other domestic purposes. Therefore, an attempt has been made to study the water quality to know about the status of water of the lake and necessary steps that can be taken up to control the pollution of the lake and prevent the local people from being affected by diseases. The objective of the present study was to assess some of the selected physico-chemical characteristics of Loktak lake in five water sampling stations i.e. Nongmaikhong, Phoubakchao, Laphupat Tera, Karang and Ithing villages located in and around Loktak lake from March 2013 to February 2014.

2. Materials and Methods

Water samples from five sampling stations (Nongmaikhong, Phoubakchao, Laphupat Tera, Karang and Ithing) located in and around the Loktak lake was collected at a depth of 50 cm every month starting from March 2013 to February 2014 for a period of one year. From all the five sites surface water samples were collected in clean glass stoppered sampling bottles. Sampling for water quality analysis was done in sterile plastic bottles carefully cleaned and rinsed thoroughly with distilled water (APHA, 1998) [6]. Some of the parameters were analysed in the field while some other samples were brought to the laboratory under ideal conditions and analysed. Parameters such as Air Temperature (AT), Water Temperature (WT) and pH were recorded by using mercury thermometer and digital pH meter (Systronics) respectively. Total Dissolved Solids (TDS) and Conductivity (CON) were measured by using digital TDS and conductivity meter of Merck company Microprocessor series. The Transparency (TRAN) of water to light was measured by using Secchi disc. Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Free CO_2 (FCO_2), Phenolphthalein Alkalinity (PA) and Total Alkalinity (TA) were determined by standard methods in the laboratory as per the standard method APHA (1998) [6].

The data obtained was compiled and interpreted using statistical tools and appropriate software. Statistical analysis was performed using MS Excel 2010 and Statistical Package for Social Sciences (SPSS) Version 25. Station-wise comparison of the mean physico-chemical parameters (March 2013 to February 2014) and the significance of differences is tested by one way ANOVA. For the test $P< 0.05$ and $P< 0.01$ were taken as the cut off values for significant and highly significant respectively. Seasonal variations in physico-chemical parameters from the five sampling stations was done by considering the intensity and duration of rainfall and grouping a given year into four seasons and presented in graphical form. The seasons were represented as Pre-monsoon (March, April and May), Monsoon (June, July and August), Post-monsoon (September, October and November) and Winter (December, January and February).

3. Results and Discussion

The station-wise comparison of the physico-chemical parameters of Loktak lake from March 2013 to February 2014 and the significance of differences as revealed by one way ANOVA is presented in Table 1. The table deals mainly with comparison of means of each physico-chemical parameter collected from the five stations and the variation of means over the sites which is tested by one way ANOVA, commonly known as F-test and its calculated value along with degree of freedom (df) and P-value. The table also compares the means of the studied parameters of the five water sampling stations with the WHO (1995) [7] limits. Seasonal variation in physico-chemical parameters of the five sampling stations during the study is presented from Figure 1 to Figure 4.

Table 1: Station-wise comparison of physico-chemical parameters (March 2013 to February 2014) and the significance of differences as revealed by one way ANOVA

		Mean	Std. Deviation	Df	F-value	P-value	WHO limits
AT (°C)	Phoubakchao	21.50	5.76	(4, 59)	0.656	0.625	Not available
	Laphupat Tera	22.25	5.46				
	Nongmaikhong	24.33	5.48				
	Ithing	23.92	4.71				
	Karang	23.79	4.50				
WT (°C)	Phoubakchao	24.08	4.64	(4, 59)	0.268	0.898	30-35°C
	Laphupat Tera	25.00	4.91				
	Nongmaikhong	25.25	5.22				
	Ithing	25.58	4.07				
	Karang	25.88	3.98				
pH	Phoubakchao	6.97	0.52	(4, 59)	1.493	0.217	6.5-8.5
	Laphupat Tera	7.04	0.52				
	Nongmaikhong	7.05	0.52				
	Ithing	7.50	1.00				
	Karang	7.49	0.98				
DO (mg/l)	Phoubakchao	4.59	2.06	(4, 59)	2.711	0.039*	5-7 mg/l
	Laphupat Tera	5.48	2.04				
	Nongmaikhong	4.94	1.54				
	Ithing	6.83	3.03				
	Karang	7.10	2.83				

BOD (mg/l)	Phoubakchao	3.05	1.71	(4, 59)	1.338	0.268	5 mg/l
	Laphupat Tera	3.68	2.56				
	Nongmaikhong	2.94	1.29				
	Ithing	4.80	3.84				
	Karang	4.88	3.57				
FCO_2 (mg/l)	Phoubakchao	17.60	8.99	(4, 59)	7.508	<0.001*	22 mg/l
	Laphupat Tera	10.08	3.56				
	Nongmaikhong	12.28	4.73				
	Ithing	5.87	4.12				
	Karang	8.43	4.94				
TDS (ppm)	Phoubakchao	68.33	11.93	(4, 59)	5.866	<0.001*	500 mg/l
	Laphupat Tera	80.83	15.64				
	Nongmaikhong	75.83	15.05				
	Ithing	60.83	7.93				
	Karang	62.50	8.66				
PA (mg/l)	Phoubakchao	0.00	0.00	22	2.283[a]	0.032*	Not available
	Laphupat Tera	0.00	0.00				
	Nongmaikhong	0.00	0.00				
	Ithing	2.92	6.89				
	Karang	3.33	7.78				
TA (mg/l)	Phoubakchao	57.50	15.30	(4, 59)	.116	0.976	120 mg/l
	Laphupat Tera	57.50	12.88				
	Nongmaikhong	58.75	16.80				
	Ithing	58.75	15.82				
	Karang	61.25	16.80				
CON (µS/cm)	Phoubakchao	123.33	19.22	(4, 59)	3.488	0.013*	750 µS/cm
	Laphupat Tera	140.83	27.12				
	Nongmaikhong	140.83	27.45				
	Ithing	115.00	22.76				
	Karang	115.83	21.93				
TRAN (cm)	Phoubakchao	114.67	32.66	(4, 59)	3.026	0.025*	Not available
	Laphupat Tera	85.17	40.40				
	Nongmaikhong	82.33	34.65				
	Ithing	115.75	45.61				
	Karang	125.00	39.11				

a = Independent Sample t-test is applied.
* = Significant difference

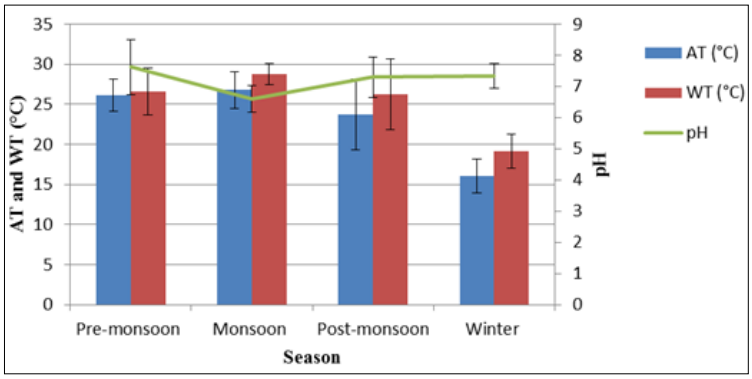

Fig 1: Seasonal variation in AT, WT and pH of Loktak lake (March 2013 to February 2014)

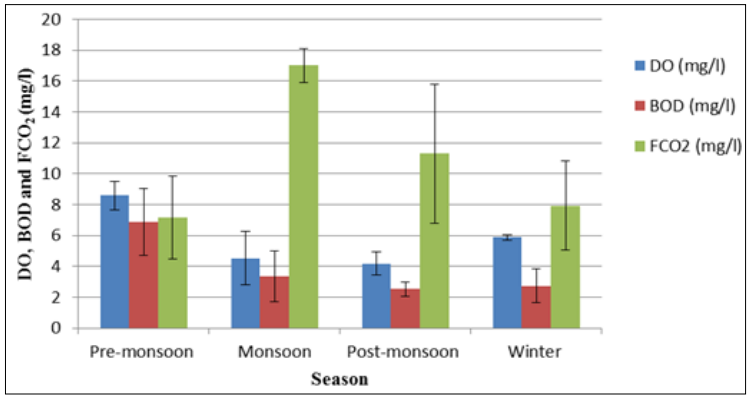

Fig. 2: Seasonal variation in DO, BOD and FCO_2 of Loktak lake (March 2013 to February 2014)

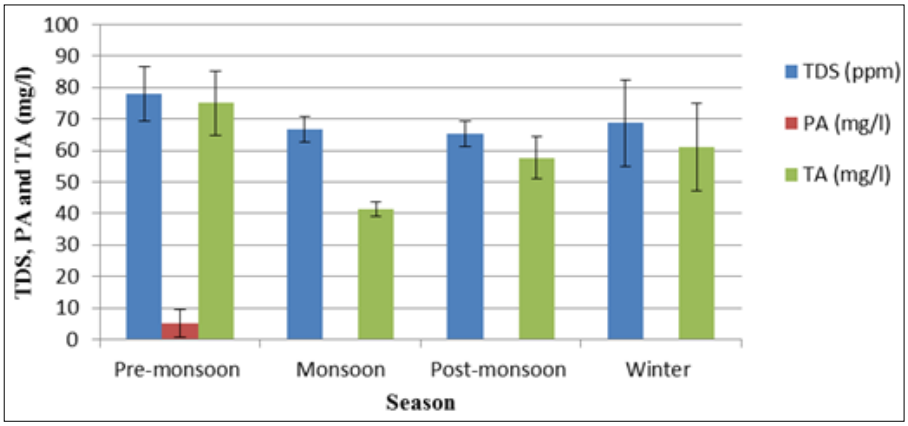

Fig 3: Seasonal variation in TDS, PA and TA of Loktak lake (March 2013 to February 2014)

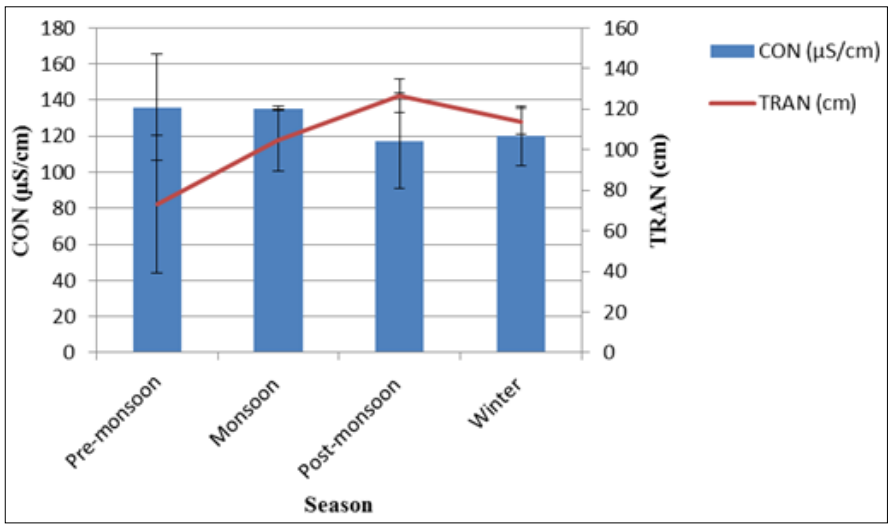

Fig 4: Seasonal variation in CON and TRAN of Loktak lake (March 2013 to February 2014)

3.1 Air Temperature (AT)

In the present study the mean AT in the five stations varied between 21.50 °C to 24.33 °C. The present range of air temperature is in line with the one recorded by Kaushik and Saksena (1999) [8] and Dar *et al.* (2013) [9]. Farooq *et al.* (2018) [10] in the study on the deterioration of water quality of Anchar Lake found air temperature in the range from 2.3 °C to 29.5°C. In case of AT the observed variation of means was tested and found to be insignificant statistically. AT was found to be higher in monsoon season and low in winter season.

3.2 Water Temperature (WT)

The temperature plays an important role for controlling the physico-chemical and biological parameters of water and considered as one among the most important factors in the aquatic environment particularly for freshwater (Singh and Mathur, 2005) [11]. The mean WT in the five stations varied between 24.08 °C to 25.88 °C. The observed value is in agreement with Sharma *et al.* (2013) [12] where the temperature of Keibul Lamjao National Park at Loktak lake, Manipur ranged from 10.4°C to 28°C. Similar temperature reading which ranged from 16.4°C to 28.2°C was recorded from Loktak lake, India (Kangabam *et al.*, 2017) [13]. There was no significant difference of WT among the five sites (P= 0.898). The mean WT of all the five sites under study is below the WHO standard of 30°C-35°C. 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. Low temperature of water was reported during winter season due to cold low ambient temperature and shorter photoperiod (Bohra and Bhargava, 1977) [14].

3.3 pH

The pH of water is an important water quality parameter because pH is a major factor in most chemical and biological reactions (Pant *et al.*, 2017) [15]. The mean pH value in the five villages varied between 6.97 to 7.50. Similar finding was observed by Babu and Mohan (2018) [16] where the pH of Thally lake of Tamil Nadu, India ranged from 6.7 to 8.9. Singh *et al.* (2010) [17] also examined the pH of Kharungpat lake, Thoubal district, Manipur from 6.1 to 7.9. No variation in pH was detected among the villages and P-value (0.217) was insignificant at 5% level of significance. The mean pH value of the water under study is within the WHO standard of 6.5-8.5. pH was found to be higher in pre-monsoon and low in monsoon. This is not in agreement with Shinde and Deshmukh (2008) [18] where low pH value in winter was found in Zirpurwadi lake, Yavatmal, Maharashtra. The high pH in pre-monsoon may be due to removal of large amount of CO_2 by photosynthetic process by aquatic plants during summer (Meetei and Singh, 2011) [19].

3.4 Dissolved Oxygen (DO)

Dissolved Oxygen is a particularly useful parameter for water and is an excellent indicator of quality. Its presence in surface water plays a key role in the self-purification and maintenance

of aquatic life. However, its presence in urban water is seen as troublesome due to the possibility of corrosion of metal distributors (Bride and Rutherford, 1983) [20]. DO mean value in the villages varied between 4.59 to 7.10 mg/l. The obtained value of dissolved oxygen is similar to the value reported from two floodplain Lakes (Chaurs), North Bihar, India (Singh *et al.*, 2017) [21]. Kosygin (2002) [22] also noted that the DO of Loktak lake, Manipur, India in the open water area and areas covered by *phumdis* from DO (5.9-6.9 mg/l) and (4.8-5.7 mg/l). The mean DO level varied significantly over the sites (P=0.039). The mean DO of the two sites in the lake i.e. Phoubakchao (4.59 mg/l) and Nongmaikhong (4.94 mg/l) are below WHO standard of 5.0-7.00 mg/l while that of Karang (7.10 mg/l) is slightly higher that the WHO standard. 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) [23]. Observed lower values of DO in Phoubakchao and Nongmaikhong indicated moderate organic pollution of the lake at these sites where the survival of aquatic life is at threat. The mean DO of the other the two sites (Laphupat Tera and Ithing) are between the WHO standard of 5.0-7.00 mg/l. DO was found to be higher in pre-monsoon and low in post-monsoon. The high value of DO in pre-monsoon may be due to growth of large quantity of aquatic plants and the low value of oxygen in post monsoon may be due to the utilization of oxygen for metabolic activities by the increasing growth of bacteria (Pandey *et al.*, 1999) [24].

3.5 Biochemical Oxygen Demand (BOD)

Biological Oxygen Demand is most important parameter used to assess the quality of water. It was applicable in measuring organic loading on water bodies (Patil *et al*., 2011) [25]. The mean value of BOD in the villages varied between 2.94 to 4.88 mg/l. Kangabam *et al.* (2017) [13] also reported the BOD values of Loktak lake from. 99 to 4.19 mg/l. The BOD ranged between 6.9-11.3 mg/l in Nambol River, Manipur (Devi *et al*., 2015) [26]. The present value of BOD is higher as compared to one reported by Umerfaruq and Solanki (2015) [27] in Bibi Lake, Ahmedabad where the value is in the ranged of 1.18 mg/l - 2.41 mg/l. No significant difference of mean BOD levels was noticed among the sites (P= 0.268). The values of BOD are below the standards limit of 5 mg/l laid by WHO. The values of BOD was found to be higher in pre-monsoon and low in post-monsoon. Kangabam *et al.* (2017) [13] also reported the lowest value of BOD during post-monsoon and maximum during pre-monsoon in Loktak lake. The higher values of BOD in pre-monsoon may be due to high pollutant load drained from rivers of the urban areas of Imphal city.

3.6 Free CO_2 (FCO_2)

Carbon dioxide is present in water in the form of dissolved gas. Carbon dioxide, carbonate, bicarbonate and pH are interrelated in the water systems. Decomposition of organic content and respiration produce carbon dioxide in water. The carbon dioxide, thus release is used by phytoplankton and other aquatic plants to create new organic matter via photosynthesis (Das, 2000) [28]. The mean FCO_2 in the five stations varied between 5.87 to 17.60 mg/l. Manjare *et al.* (2010) [29] recorded Free Carbon dioxide value of Tamdalge Tank in Kolhapur district, Maharashtra ranges from 0.0 mg/l to 28.6 mg/l. FCO_2 values were found very high significant variation over the five sites as $P< 0.001$. The observed mean values of FCO_2 are below the WHO standards of 22 mg/l. FCO_2 was found to be higher in monsoon and low in pre-monsoon. Kosygin *et al*. (2007) [30] also observed highest value of free CO_2 in monsoon. The high level of free carbon-dioxide observed during monsoon season may be attributed to its influx through rainwater in the form of carbonic acid. This is in agreement with the observation of Chakrabati *et al*. (1959); Mansoori *et al*. (1995) [31, 32].

3.7 Total Dissolved Solids (TDS)

TDS is measure of all the dissolved substances, both organic and inorganic in water (Dubey *et al.*, 2013) [33]. TDS mean value in the villages varied between 60.83 to 80.83 ppm. This value is within the recorded range given by Singh *et al.* (2010) [17] at Kharungpat lake, Thoubal, Manipur which varies from 35 mg/l to 416 mg/l. TDS values were found very high significant variation over the five sites ($P< 0.001$). The observed mean values were found below the WHO permissible limit of 500 mg/l. 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.

3.8 Phenolphthalein Alkalinity (PA)

In natural waters alkalinity is due to dissolution of CO_2 in water (Patil *et al*., 2018) [34]. The mean value of PA in the villages ranged from 0 to 3.33 mg/l. In Phoubakchao, Laphupat Tera and Nongmaikhong villages the mean value was found to be 0. The obtained value is in contrast with Singh *et al.* (2009) [23] where 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 while that of 2004 was found to be 4.5- 13.7 mg/l mg/l. In case of PA, two samples were available one from Ithing and another from Karang respectively and based on it mean PA for the two sites were found to be 2.92 mg/l and 3.33 mg/l respectively. Their difference of means was found to be significant statistically as evident by P=0.032. As there was a comparison between the means of two samples only independent sample t-test was applied instead of F-test. PA was found to be higher in pre-monsoon and mean values of PA in monsoon, post-monsoon and winter seasons was recorded as 0. The high values of PA in pre-monsoon may be due to the liberation of carbondioxide during the decomposition of organic matter. The mean values of PA or carbonate alkalinity in the villages of Phoubakchao, Laphupat Tera and Nongmaikhong was found absent. Hence the values were recorded as 0. The carbonate alkalinity in many waters is found absent (Ganapati, 1956; Singhal *et al.*, 1986) [35, 36]. This absence is caused by low photosynthetic rate of phytoplankton (Jana and Sarkar, 1971; Yousuf and Shah, 1988) [37, 38].

3.9 Total Alkalinity (TA)

Total alkalinity of water is the quality of water and kinds of components present in water such as bicarbonate, carbonate and hydroxide (Dubey *et al*., 2013) [33]**.** The mean value of TA in the villages varied between 57.50 to 61.25 mg/l. The observed values are within the range when compared to one reported by Singh *et al.* (2010) [17] in Kharungpat Lake, Manipur (38.0 to 284.0 mg/l). Idowu *et al.* (2013) [39] observed the alkalinity of Ado-Ekiti Reservoir, Nigeria ranged from 22 to 100.88 mg/l. Similar study was conducted by Patil *et al*. (2011) [25] where the alkalinity of lakes from Shivaji University Campus, Kolhapur ranged from 50 to195

mg/lit. The means of TA of Loktak lake were not significantly changed among the sites, considering the P-value was greater than 0.05, the cut off significant level adopted. The observed mean values were found below the WHO permissible limit of 120 mg/l. 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) [19]. Minimum values of TA was observed during monsoon months by Singh *et al.* (2009) [23].

3.10 Conductivity (CON)

Conductivity is a good and rapid method to measure the total dissolved ions and is directly related to total solids (Bhatt *et al.*, 1999) [40]. CON mean value in the villages varied between 115 to 140.83 µS/cm. Worker like Sharma *et al*. (2013) [12] reported similar values of conductivity from Keibul Lamjao National Park, Manipur, India ranging from 105.56 µS/cm to 201 µS/cm. Similar study was conducted by Khuhawar *et al.* (2009) [41] who observed that the conductivity of Baghsar Lake varied within the range 380-499 µS/cm. The means of the CON was found significant at 5% probability level as its P-value was less than 0.05. The observed mean value is found below the WHO permissible limit of 750 µS/cm. CON was found to be higher in pre-monsoon and low in post-monsoon. The high value of conductivity in pre-monsoon may be due to the addition of sewage from other rivers draining into the lake. The value of conductivity was found low during post-monsoon season (Sharma *et al*., 2013) [12].

3.11 Transparency (TRAN)

Clarity of water is measured by transparency value that indicates the amount of sunlight penetrate in the water column, the clearer the water greater the lights will penetrate. Phytoplankton and other vegetation growing in the water need sunlight to complete photosynthesis. Water transparency is influenced by solar intensity, plankton density and suspended soils, solids such as clay and silt particles (Singh *et al*., 2017) [21]. The mean value of TRAN in the villages varied between 82.33 to 125 cm. Kosygin and Dhamendra (2009) [42] also noted the transparency values of Loktak lake, Manipur ranges from 0.51 m - 2.98 m. Shah and Pandit (2012) [43] observed the transparency of Wular lake, Kashmir from 0.2 m to 2.2 m in a similar study. The TRAN of Loktak lake with respect to five villages it was observed that there was a disparity of its level (P= 0.025). TRAN was found to be higher in post-monsoon and low in pre-monsoon. The high value of transparency in post-monsoon 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.

4. Conclusion

From the present study it is observed that all the parameters analyzed were below or between the standard limit lay down by WHO except lower mean values of Dissolved oxygen observed in Phoubakchao and Nongmaikhong which indicated a threat to the survival of aquatic life and not fit for drinking purposes. Hence, the overall water quality parameters of the studied seasons (March 2013 to February 2014) indicated moderate organic pollution of the lake which is cause by discharging of sewage, other wastes and human activities like bathing, washing of clothes, utensils into the lake. Comparing stationwise, it can be concluded that the water quality of the Loktak lake at the three sampling stations of Laphupat Tera, Ithing and Karang can be regarded as stable and healthy environment which promotes primary productivity and fit for the survival of aquatic plants and animals.

In order to maintain good water quality of the lake communities living in and around the lake need to stop all those activities which causes pollution of the lake. For maintaining good water quality of the lake in every season the concerned authorities should continue playing the important role of cleaning the lake, regular monitoring of the water quality, taking legal actions against the one polluting the lake, organizing awareness programmes for conservation of the Loktak lake etc. in more effective way.

5. References

1. Nirbhavane G, Khobragade K. Study of Water Quality of Sion Lake, Mumbai, Maharashtra. Scholars Journal of Engineering and Technology. 2017; 5(8):413-415.
2. Singh KP, Malik A, Mohan D, Sinha S. Multivariate Statistical Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality of Gomti River (India) - a Case Study. Water Research. 2004; 38(18):3980-3992.
3. Ekwenye UK, Oji CA. Quality of water from boreholes in Umualia, Nigeria. Environment and Ecology. 2008; 26:543-545.
4. Singh DK, Singh I. Interrelationship of certain physico-chemical parameters with plankton community of Motipur Ox-bow lakes (Muzaffarpur, Bihar). Environment and Ecology. 2008; 26(2):800-803.
5. Trisal CL, Manihar TH. The Atlas of Loktak lake, Wetlands International-South Asia Programme, New Delhi, India and Loktak Development Authority, Imphal, Manipur, India, 2004,104p.
6. APHA (American Public Health Association), Standard methods for the examination of water and waste water 15th edition, American Public Health Association, Washington D.C., USA, 1998, 1134.
7. WHO. World Health Organization. Guideline for Drinking Water Quality, Geneva, 1995.
8. Kaushik S, Saksena DN. Physico-chemical limnology of certain water bodies of central India. *In*: Freshwater ecosystem of India (eds. K. Vijaykumar), Daya Publishing House, Delhi, 1999, 1-58.
9. Dar JA, Mir MF, Bhat NA, Bhat MA. Pollution Studies of a Monomictic Lake, Srinagar, Jammu and Kashmir, India. Forest Res. 2013; 2(1):1-4.
10. Farooq R, Chauhan R, Mir MF. Deterioration of water quality of Anchar Lake as indicated by analysis of various water quality parameters. International Journal of Advance Research in Science and Engineering. 2018; 7(4):2551-2558.
11. Singh RP, Mathur P. Investigation of variations in physicochemical characteristics of a fresh water reservoir of Ajmer city, Rajesthan. Indian Journal Environmental Sciences. 2005; 9:57-61.
12. Sharma ASC, Gupta S, Singh NR. Studies on the physico-chemical parameters in water of Keibul Lamjao National Park, Manipur, India. Journal of Environmental Biology. 2013; 34:1019-1025.
13. Kangabam RD, Bhoominathan SD, Kanagaraj S, Govindaraju M. Development of a water quality index (WQI) for the Loktak Lake in India. Applied Water Science. 2017; 7:2907-2918.

14. Bohra OP, Bhargava SC. Abiotic factor, chlorophyll pigment and primary production in two lakes of Jodhpur. Geobios. 1977; 4:215-216.
15. Pant B, Lohani V, Trakroo MD, Tewari H. Study of water quality by physicochemical analysis of a Himalayan lake of Uttarakhand, India. Eco. Env. & Cons. 2017; 23(2):1128-1134.
16. Babu YS, Mohan MR. A study on physico-chemical parameters of Thally lake of Tamil Nadu, India. Global Journal For Research Analysis. 2018; 7(2):497-498.
17. Singh KK, Sharma BM, Usha KH. Ecology of Kharungpat lake, Thoubal, Manipur, India: Part-I Water quality status. The Ecoscan. 2010; 4(2&3):241-245.
18. Shinde AH, Deshmukh BD. Seasonal Changes in Physico-Chemical Characteristics of Zirpurwadi Lake. *In*: Proceedings of Taal 2007: The 12th World Lake Conference (eds. M. Sengupta and R.Dalwani), Conference Proceedings, 2008, 1794-1795.
19. Meetei WS, Singh NI. Effects of solid waste disposal on water in Imphal city, Manipur, Pollution Research. 2011; 30(1):21-25.
20. MC Bride, Rutherford JC. Handbook on estimating dissolved oxygen depletion in polluted rivers. Water and Soil Misc Publ, Wellington. 1983; 51:1-69.
21. Singh AK, Kumari R, Singh DK. Assessment of water quality using physico- chemical parameters in two floodplain Lakes (Chaurs), North Bihar, India. International Research Journal of Environmental Sciences. 2017; 6(9):26-37.
22. Kosygin L. Limnological studies of Loktak lake with special references to role of Phumdis in the lake. *In*: Proceedings of a workshop on Management of Phumdis in Loktak Lake, January 22-24, 2002, Wetlands International-South Asia, New Delhi and Loktak Development Authority, Manipur, India (eds. C.L. Trisal, and T.H. Manihar), Conference Proceedings, 2002, 18-21.
23. Singh AK, Tiwari RK, Kanaujia DR, Mishra P. Physico-chemical characteristics of Ganga river water at Varanasi. J. Ecobiol. 2009; 25(1):45-56.
24. Pandey BN, Das PKL, Dubey SV, Hussain S. Biomonitoring of water quality of river Ramjan (at Kishanganj) in relation to its impact on biological components. *In*: Freshwater ecosystem of India (eds. K. Vijaykumar), Daya Publishing House, Delhi, 1999, 310-336.
25. Patil SG, Chonde SG, Jadhav AS, Raut PD. Study of physicochemical and biological characteristics of lakes from Shivaji University Campus, Kolhapur, Maharashtra. Advances in Applied Science Research. 2011; 2(6):505-519.
26. Devi WS, Singh KR, Meitei NS. Assessment of Water Quality Index of Nambol River, Manipur, India. Universal Journal of Environmental Research and Technology. 2015; 5(3):165-172.
27. Umerfaruq QM, Solanki HA. Physico-chemical Parameters of Water in Bibi Lake, Ahmedabad, Gujarat, India. Journal of Pollution. Effects & Control. 2015; 3(2):1-5.
28. Das AK. Limno-chemistry of Some Andhra Pradesh reservoirs. J. Inland Fish. Soc. India. 2000; 32(2):37-44.
29. Manjare SA, Vhanalakar SA, Muley DV. Analysis of water quality using physico-chemical parameters Tamdalge tank in Kolhapur district, Maharashtra, International Journal of Advanced Biotechnology and Research. 2010; 1(2):115-119.
30. Kosygin L, Dhamendra H, Gyaneshwari R. Pollution status and conservation strategies of Moirang river, Manipur with a note on its aquatic bio-resources. Journal of Environmental Biology. 2007; 28(3):669-673.
31. Chakrabati RD, Roy RDP, Singh SB. A quantitative study of the plankton and the physico-chemical conditions of the river Yamuna at Allahabad in 1954-1955. Ind. J. Fish. 1959; 6(1):186-203.
32. Mansoori HA, Lavania RK, Tiwari RK. Hydrological study of Lakshmital lake Jhansi with special reference to plankton productivity, Flora and Fauna. 1995; 1(1):39-42.
33. Dubey M, Tiwari AK, Ujjania NC. The Study of Physico-Chemical Properties of Sahapura Lake, Bhopal (India). International Journal of Advanced Research. 2013; 1(8):158-164
34. Patil A, Patil S, Sathe S. Water quality index of Belawale Khurd Reservoir of Kolhapur district (MH) (India). J Ind Bot Soc. 2018; 97(1&2):131-135.
35. Ganapati SV. Hydrobiological investigations of the Hope reservoirs and of the Thambaraparani River at Papanasom Tirunalveli District Madras State. Ind. Geogr. Jour. 1956; 31:1-20.
36. Singhal RN, Jeet S, Davies RW. The physico-chemical environment and the plankton of managed ponds in Haryana, India. Proc. Indian Acad. Sci. India, 1986; 95(3):353-363.
37. Jana BB, Sarkar HL. The limnology of Swetganga-A thermal spring of Bakreswar, West Bengal, India. Hydrobiologia. 1971; 37:33-47.
38. Yousuf AR, Shah GM. Comparative limnology of some freshwater habitats of Kashmir. Geobios. 1988; 7:58-61.
39. Idowu EO, Ugwumba AAA, Edward JB, Oso JA. Study of the Seasonal Variation in the Physico-Chemical Parameters of a Tropical Reservoir. Greener Journal of Physical Sciences. 2013; 3(4):142-148.
40. Bhatt LR, Lacoul P, Lekhak HD, Jha PK. Physico-chemical characteristics and phytoplanktons of Taudaha lake, Kathmandu. Pollution Research. 1999; 18(4):353-358.
41. Khuhawar MY, Mirza MA, Leghari SM, Arain R. Limnological study of Baghsar Lake District Bhimber Azad Kashmir. Pak. J. Bot. 2009; 41(4):1903-1915.
42. Kosygin L, Dhamendra H. Ecology and conservation of Loktak lake, Manipur: An overview. *In*: Wetlands of North East India: Ecology, Aquatic Bioresources and Conservation (eds. L. Kosygin), Akansha Publishing House, New Delhi, 2009, 1-20.
43. Shah JA, Pandit AK. Physico-chemical characteristics of water in Wular Lake-A Ramsar site in Kashmir Himalaya. International Journal of Geology, Earth and Environmental Sciences. 2012; 2(2):257-265