

Seasonal Variation in Physicochemical Parameters of Chilika Lake after Opening of New Mouth near Gabakunda, Orissa, India

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Abstract: Some physicochemical parameters like colour, odour, total dissolved solid, floating materials, suspended materials, temperature, pH, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, chloride content, salinity, nitrate-nitrogen, phosphate and silicate content of water samples collected from 3 different sectors of Chilika Lake were evaluated from March 2008 to Feb 2009 after the opening of new mouth near Gabakunda. From overall analysis, it was observed that there was a lot of fluctuations in the physico chemical parameters of water samples. The pH of water was alkaline through out the lake and both pH and salinity varied widely. The values of DO and BOD fluctuate according to the seasons and sectors. COD was very less due to absence of chemical pollution. Opening of natural new mouth helped subsequently to bring rise to salinity through out the lake, flush out the sediment load from lake, disintegrate the weeds, increase the biodiversity etc which would enhance the fish, prawn and crab catch. Other parameters like nitrate, phosphate and silicate were under permissible limit and fluctuated widely according to seasons and sectors.

Key word: Physico chemical parameters % Water quality % Nutrients % Chilika Lake

INTRODUCTION

Chilika lake is the largest brackish water lagoon in the Subcontinent along the east coast of India, situated between 19° 28'-19° 54'N; 85° 05'-85° 38' E (Fig. 1) [1]. It was declared as a Ramsar site under the convention on "Wetlands of International Importance". It is a shallow, brackish water lake formed due to the silting action of the Mahanadi River. It has wide variety of habitats such as marshes, mudflats, fresh water and open water with varying depths, salinity and coastal vegetation areas. It is one of the biodiversity hotspots in India. Scientific exploration over past 80-85 years suggested that physico chemical parameters of Chilika Lake have undergone many changes due to variation in climatic condition, desilting action of mouth of the lake Chilika Lake is presently under threat from both natural and anthropogenic pressures.

A new mouth was dredge opened near Sipakuda to facilitate free water exchange between the lagoon and the sea in September 2000. Again in March 2008 a very wide natural new mouth opened near Gabakunda which facilitate the mixing of sea water with lake water, causing a wide variation in the physico chemical parameters of the

lake. Earlier workers have studied the physico chemical characteristics of Chilika lake [2-5]. Hydrological condition of lake water affects the aquaculture activities, decrease in fish productivity, change in species composition of avifauna, eutrophication and overall loss of biodiversity that resulted in the degradation of Lake Ecosystem. So the present study was undertaken to assess the quality of water samples with special reference to physicochemical properties from 2008 to 2009 after the natural opening of new mouth near Gabakunda.

MATERIALS AND METHODS

The total study area (Fig. 1) is comprised of 16 sampling station covering three sectors of Chilika Lake i.e. Central, Southern and Outer Channel during the period from March 2008 to February 2009. Seasonal collection of water samples from various sites of three different sectors were analyzed for physicochemical parameters. The exact sampling locations were fixed by using Global Positioning System (GPS). Only ambient water samples were collected from the lagoon as the depth of water is less than 5m. Samplings were done in the morning hours between

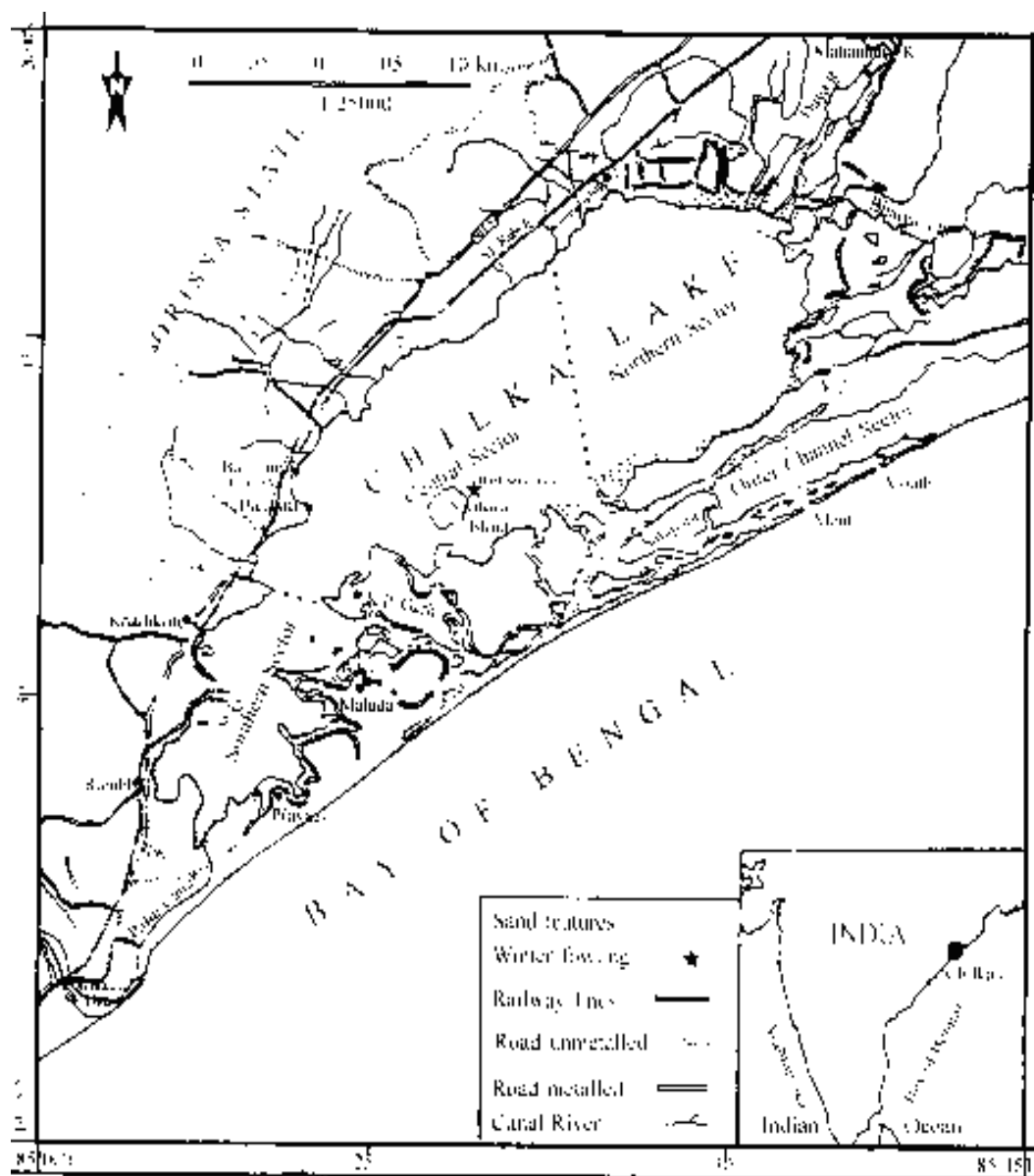


Fig. 1: Map of Chilika Lake showing sampling station

7am-10am. During sample collection in the lake, necessary precautions had been taken to collect undisturbed water samples. Samples were collected in 250 ml polypropylene bottle and were kept in the icebox and transferred to laboratory for analysis. The experiments were carried out within 15 days of collection. Chemicals used for preparation of reagents in the present investigation were of analytical reagent grade and double distilled water was used for preparation of solutions. Physical parameters like colour, odour, floating materials, suspended materials, temperature and pH of the samples was determined on the spot of collection of samples. Chemical parameters like

total dissolved solid, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, chloride content, salinity, nitrate-nitrogen, phosphate, silicate content were analyzed in the laboratory by following standard methods as prescribed by National Institute of Oceanography, Goa for seawater analysis and methods [6].

Statistical Analysis: All the data presented in the tables were mean of the triplicate with standard deviations. Inter relationship studies between different variables are very helpful tools in promoting research and opening new

frontiers of knowledge. The study of correlation reduces the range of uncertainty associated with decision-making. The correlation co-efficient 'r' was calculated using the equation

$$R = \frac{\sum xy}{\sqrt{\sum x^2 \times \sum y^2}}$$

where $x = X - \bar{X}$ and $y = Y - \bar{Y}$, X and Y represent two different parameters

\bar{X} = Mean value of X ; \bar{Y} = Mean value of Y

RESULTS AND DISCUSSIONS

The physico chemical parameters of lake water samples collected from different sampling stations during March 2008 to Feb 2009 are presented in tabular form (Table 1-6). In the present study all the water samples collected from different stations of Chilika Lake were found to be colourless and odourless in sample bottles, but it appeared to be greenish in central and Southern Sector and brownish in Outer Channel of the Lake body as a whole. Floating materials like debris of algae and plant materials were visible and suspended materials of sewage and dust particles were observed in most of the collected samples.

The temperature of the water was observed on the sampling station by mercury thermometer in degree Celsius. In pre monsoon season maximum $34.2 \pm 0.25^\circ\text{C}$ temperature was observed in sea mouth area of outer

channel and minimum of $30.6 \pm 0.31^\circ\text{C}$ temperature in Rambha of Southern sector (Table1). In monsoon season, even distribution of temperature was observed in all the sectors i.e 28.5 (Table-3). In post monsoon season temperature of the water was maximum of $30.2 \pm 0.12^\circ\text{C}$ in Manika patana of outer channel and minimum of $25.7 \pm 0.75^\circ\text{C}$ in Kruna Prasad of central sector (Table-5).

The pH of the Chilika water is slightly alkaline. In pre monsoon season maximum value of pH was 8.41 ± 0.62 in Kaliyugeswara area of central sector and minimum value was 7.13 ± 0.25 in Badakuda in southern sector (Table-1). In monsoon season maximum value of pH was 8.4 ± 0.35 in Breakfast Island of Southern Sector and minimum value was 7.6 ± 0.53 in Dolphine site of Outer channel (Table3). In post monsoon season maximum value of pH was 8.67 ± 0.18 in Nalabana area of central sector and minimum value was 7.62 ± 0.22 in Kruna prasad area of central sector (Table 5).

Total dissolved solid was found to be very high in lake water. In pre monsoon season maximum value of TDS was 28.04 ± 0.64 g/L in sea mouth area of outer channel and minimum amount was found to be 6.45 ± 0.31 g/L in Kaliyugeswara area of central sector (Table 1). In monsoon season maximum value of TDS was 15.23 ± 0.32 g/L in Bird's Island of Southern Sector and minimum value was 4.13 ± 0.36 g/L in Nalabana in central sector (Table 3). In post monsoon season maximum value of TDS was 25.56 ± 0.76 g/L in sea mouth area of outer channel and minimum value was 6.12 ± 0.62 g/L in Nalabana area of central sector (Table 5).

Table 1: Physicochemical parameters of Chilika Lake during Pre Monsoon-2008

Parameters	Central Sector					Southern Sector					
	Chadheiguha	Kaliyugeswara	Nalabana	Kruna Prasad	Kalijai	Rambha	Breakfast island	Bird's island	Bada kuda	Sana kuda	Ghantasila hill
Colour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Odour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Floating material	P	P	P	P	P	P	P	P	P	P	P
Suspended solid	T	T	NV	NV	T	T	NV	NV	T	NV	NV
Temperature $^\circ\text{C}$	32.2 ± 0.62	30.3 ± 0.24	30.2 ± 0.62	31.2 ± 0.31	32.6 ± 0.15	30.6 ± 0.31	31.1 ± 0.25	30.2 ± 0.61	31.7 ± 0.26	31.3 ± 0.65	33.4 ± 0.23
pH	8.04 ± 0.32	8.41 ± 0.62	8.13 ± 0.16	8.14 ± 0.19	8.13 ± 0.24	8.34 ± 0.15	8.33 ± 0.52	7.63 ± 0.64	7.13 ± 0.25	7.93 ± 0.16	8.4 ± 0.42
TDS (g/l)	6.98 ± 0.32	6.45 ± 0.31	7.13 ± 0.62	6.67 ± 0.12	7.32 ± 0.19	12.54 ± 0.23	11.65 ± 0.31	14.21 ± 0.21	11.98 ± 0.32	11.88 ± 0.54	13.63 ± 0.62

Table 1: Continue

Parameters	Outer Channel				
	Manika patana	Sea mouth	Sea mouth side	Dolphine site	Arakhakuda
Colour	Nil	Nil	Nil	Nil	Nil
Odour	Nil	Nil	Nil	Nil	Nil
Floating material	P	P	P	P	P
Suspended solid	T	T	T	T	T
Temperature $^\circ\text{C}$	33.5 ± 0.26	34.2 ± 0.62	34.2 ± 0.25	32.4 ± 0.51	32.6 ± 0.32
pH	8.03 ± 0.35	8.09 ± 0.43	8.12 ± 0.65	8.14 ± 0.34	8.13 ± 0.26
TDS (g/l)	26.66 ± 0.32	27.27 ± 0.62	28.04 ± 0.64	17.03 ± 0.65	10.37 ± 0.62

*Keynote: "Nil"= No Odour, "P"= Present, "NV"= Not visible, "T"= Turbid

* Values are means of triplicates \pm Standard Deviations (SD)

Table 2: Physicochemical parameters of Chilika Lake during Pre monsoon-2008

Parameters	Central Sector					Southern Sector					
	Chadheiguha	Kaliyugeswara	Nalabana	Krusna Prasad	Kalijai	Rambha	Breakfast island	Bird's island	Bada kuda	Sana kuda	Ghantasila hill
DO (mg/l)	7.56±0.64	3.98±0.29	8.37±0.25	10.08±0.21	9.35±0.13	4.47±0.16	7.32±0.62	6.1±0.53	8.13±0.61	10.17±0.23	8.53±0.56
BOD (mg/l)	3.5±0.21	0.22±0.09	4.61±0.14	6.015±0.35	4.472±0.15	2.34±0.19	4.15±0.26	2.03±0.18	5.21±0.34	6.59±0.45	2.55±0.65
COD (mg/l)	0.04±0.06	0.034±0.04	0.065±0.02	0.026±0.06	0.054±0.21	0.056±0.06	0.043±0.04	0.09±0.06	0.056±0.02	0.04±0.02	0.09±0.04
Chloride content (g/l)	3.12±0.31	3.41±0.26	7.5±0.21	6.43±0.65	6.43±0.31	7.54±0.32	7.32±0.2	7.14±0.75	7.26±0.65	6.92±0.24	7.26±0.26
Salinity (‰)	5.44±0.1	5.734±0.13	12.78±0.12	10.619±0.15	10.62±0.26	13.32±0.35	12.83±0.65	12.51±0.84	12.77±0.95	12.23±0.76	12.74±0.45
Nitrate (µmol/L)	117.4±0.37	74.65±0.35	41.23±0.14	20.53±0.12	5.08±0.15	5.63±0.39	4.29±0.34	6.65±0.26	3.39±0.16	1.55±0.15	1.86±0.12
Phosphate (µmol/L)	0.81±0.12	1.035±0.06	0.45±0.03	0.39±0.03	0.76±0.53	0.312±0.64	0.245±0.76	0.225±0.86	0.18±0.64	0.585±0.15	0.906±0.19
Silicate (µmol/L)	59.04±0.94	76.08±0.65	45.12±0.64	62.43±0.51	56.64±0.46	44.62±0.56	39.54±0.24	38.78±0.35	46.22±0.64	42.46±0.53	46.87±0.95

Table 2: Continue

Parameters	Outer Channel										
	Manika patana		Sea mouth			Sea mouth side			Dolphine site		Arakhakuda
DO (mg/l)	2.34±0.12		1.626±0.21			3.24±0.35			4.63±0.62		4.47±0.35
BOD (mg/l)	1.21±0.36		0.73±0.25			1.14±0.54			1.78±0.21		1.7±0.21
COD (mg/l)	0.024±0.04		0.034±0.04			0.065±0.032			0.067±0.062		0.056±0.05
Chloride content (g/l)	17.46±0.69		19.86±0.59			18.54±0.36			18.92±0.62		2.87±0.34
Salinity (‰)	32.91±0.57		36.82±0.26			34.42±0.62			34.86±0.35		5.27±0.21
Nitrate (µmol/L)	16.74±0.19		13.94±0.46			74.65±0.95			68.45±0.76		44.59±0.62
Phosphate (µmol/L)	0.17±0.13		0.135±0.16			0.2±0.15			0.192±0.56		0.315±0.26
Silicate (µmol/L)	18.32±0.42		3.552±0.26			16.464±0.62			15.184±0.95		156.2±1.12

* Values are means of triplicates ± Standard Deviations (SD)

Table 3: Physicochemical parameters of Chilika Lake during Monsoon-2008

Parameters	Central Sector					Southern Sector					
	Chadheiguha	Kaliyugeswara	Nalabana	Krusna Prasad	Kalijai	Rambha	Breakfast island	Bird's island	Bada kuda	Sana kuda	Ghantasila hill
Colour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Odour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Floating material	P	P	P	P	P	P	P	P	P	P	P
Suspended solid	T	T	NV	NV	T	T	NV	NV	T	NV	NV
Temperature°C	29.6±0.65	29.2±0.35	28.5±0.32	29.4±0.61	29.3±0.34	28.5±0.26	28.5±0.32	28.8±0.21	29.6±0.16	29.5±0.14	29.4±0.24
pH	8.06±0.25	8.31±0.56	8.03±0.29	8.14±0.32	8.15±0.36	8.38±0.24	8.4±0.35	8.12±0.42	8.06±0.65	8.04±0.43	7.92±0.95
TDS (g/l)	5.98±0.36	4.45±0.35	4.13±0.36	5.67±0.43	4.32±0.29	11.56±0.42	10.24±0.24	15.23±0.32	13.78±0.34	11.98±0.35	10.69±0.26

Table 3: Continue

Parameters	Outer Channel										
	Manika patana		Sea mouth			Sea mouth side			Dolphine site		Arakhakuda
Colour	Nil		Nil			Nil			Nil		Nil
Odour	Nil		Nil			Nil			Nil		Nil
Floating material	P		P			P			P		P
Suspended solid	T		T			T			T		T
Temperature°C	28.5±0.26		28.4±0.43			28.3±0.32			28.5±0.29		28.4±0.18
pH	7.94±0.62		8.09±0.54			7.94±0.43			7.6±0.53		8.09±0.15
TDS (g/l)	10.15±0.19		13.42±0.21			12.02±0.16			9.43±0.43		6.86±0.26

* Keynote: "Nil"= No Odour, "P"= Present, "NV"= Not visible, "T"= Turbid

* Values are means of triplicates ± Standard Deviations (SD)

Table 4: Physicochemical parameters of Chilika Lake during Monsoon-2008

Parameters	Central Sector					Southern Sector					
	Chadheiguha	Kaliyugeswara	Nalabana	Krusna Prasad	Kalijai	Rambha	Breakfast island	Bird's island	Bada kuda	Sana kuda	Ghantasila hill
DO (mg/l)	7.4±0.32	5.77±0.25	5.38±0.26	7.48±0.55	7.62±0.46	6.02±0.56	4.06±0.21	4.06±0.24	2.84±0.35	5.29±0.26	3.25±0.49
BOD (mg/l)	6.6±0.62	4.47±0.32	1.22±0.21	2.6±0.35	3.73±0.53	3.38±0.14	0.73±0.64	1.38±0.21	0.4±0.23	1.62±0.29	1.39±0.21
COD (mg/l)	0.024±0.03	0.04±0.08	0.05±0.09	0.05±0.51	0.06±0.34	0.056±0.06	0.087±0.05	0.082±0.05	0.067±0.09	0.078±0.04	0.039±0.05
Chloride content (g/l)	2.45±0.25	2.62±0.26	5.41±0.29	5.12±0.35	4.92±0.62	4.91±0.64	7.18±0.45	7.18±0.36	7.92±0.56	6.32±0.16	6.56±0.17

Table 4: Continue

Parameters	Outer Channel										
	Manika patana		Sea mouth			Sea mouth side			Dolphine site		Arakhakuda
DO (mg/l)	7.97±0.32		8.7±0.64			8.7±0.24			6.67±0.52		8.3±0.46
BOD (mg/l)	2.85±0.12		4.22±0.32			3.98±0.16			0.56±0.15		5.28±0.12
COD (mg/l)	0.076±0.02		0.046±0.06			0.092±0.05			0.67±0.24		0.034±0.06
Chloride content (g/l)	4.78±0.36		3.93±0.12			3.48±0.21			2.92±0.31		6.34±0.35
Salinity (‰)	7.56±0.43		6.23±0.84			5.37±0.62			5.45±0.16		10.62±0.32
Nitrate (µmol/L)	43.17±0.65		35.85±0.69			58.62±0.75			47.56±0.46		62.46±0.41
Phosphate (µmol/L)	5.4±0.24		4.275±0.21			5.04±0.31			3.105±0.09		2.925±0.46
Silicate (µmol/L)	72.19±0.64		56.9±0.52			46.08±0.34			42.6±0.35		30.75±0.24

* Values are means of triplicates ± Standard Deviations (SD)

Table 5: Physicochemical parameters of Chilika Lake during Post monsoon-2008-09

Central Sector						Southern Sector					
Parameters	Chadheiguha	Kaliyugeswara	Nalabana	Krusna Prasad	Kalijai	Rambha	Breakfast island	Bird's island	Bada kuda	Sana kuda	Ghantasila hill
Colour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Odour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Floating material	P	P	P	P	P	P	P	P	P	P	P
Suspended solid	T	NV	NV	NV	NV	T	NV	NV	T	NV	NV
Temperature°C	27.9±0.34	27.5±0.39	27.21±0.45	25.76±0.75	26.03±0.45	27.5±0.21	26.4±0.29	27.3±0.34	26.9±0.56	26.7±0.54	27.2±0.62
pH	8.25±0.09	8.15±0.04	8.67±0.18	7.62±0.22	8.18±0.08	8.44±0.32	8.18±0.54	8.52±0.33	8.38±0.36	8.32±0.53	8.24±0.41
TDS (g/l)	7.89±0.31	6.29±0.18	6.12±0.62	6.15±0.41	5.46±0.19	9.71±0.42	10.94±0.22	12.19±0.61	10.94±0.31	9.65±0.41	11.52±0.19

Table 5: Continue

Outer Channel											
Parameters	Manika patana	Sea mouth	Sea mouth side	Dolphine site	Arakhakuda						
Colour	Nil	Nil	Nil	Nil	Nil						
Odour	Nil	Nil	Nil	Nil	Nil						
Floating material	P	P	P	P	P						
Suspended solid	T	T	T	T	T						
Temperature°C	30.2±0.42	28.4±0.34	28.5±0.64	28.6±0.45	27.9±0.56						
pH	8.34±0.51	7.99±0.34	8.22±0.21	8.42±0.65	8.13±0.35						
TDS (g/l)	24.66±0.51	25.56±0.76	24.04±0.89	15.03±0.56	8.37±0.45						

*Keynote: "Nil"= No Odour, "P"= Present, "NV"= Not visible, "T"= Turbid

* Values are means of triplicates ± Standard Deviations (SD)

Table 6: Physicochemical parameters of Chilika Lake during Post monsoon-2008-09

Central Sector						Southern Sector					
Parameters	Chadheiguha	Kaliyugeswara	Nalabana	Krusna Prasad	Kalijai	Rambha	Breakfast island	Bird's island	Bada kuda	Sana kuda	Ghantasila hill
DO (mg/l)	6.12±0.29	8.91±0.52	7.12±0.32	7.81±0.3	4.72±0.21	4.32±0.32	4.51±0.51	10.32±0.31	5.31±0.23	4.31±0.49	8.31±0.33
BOD (mg/l)	1.32±0.19	2.13±0.09	2.72±0.29	2.31±0.36	1.52±0.21	1.24±0.21	4.19±0.14	5.34±0.45	1.49±0.04	1.53±0.07	5.74±0.14
COD (mg/l)	0.035±0.36	0.031±0.06	0.06±0.03	0.045±0.02	0.041±0.02	0.029±0.19	0.073±0.03	0.019±0.22	0.029±0.06	0.062±0.16	0.034±0.03
Chloride content (g/l)	4.45±0.21	4.15±0.3	5.23±0.51	4.81±0.19	6.31±0.23	6.41±0.32	6.74±0.25	6.44±0.41	6.23±0.46	6.19±0.54	6.84±0.39
Salinity (‰)	8.19±0.39	7.49±0.41	9.42±0.35	8.68±0.43	11.35±0.25	11.57±0.21	12.17±0.3	11.62±0.39	11.25±0.31	11.18±0.49	12.35±0.62
Nitrate (µmol/L)	94.65±0.25	63.15±0.31	44.82±0.39	93.42±0.21	39.54±0.35	13.22±0.23	15.32±0.41	10.46±0.29	16.78±0.54	14.63±0.36	13.38±0.15
Phosphate (µmol/L)	3.54±0.15	0.99±0.09	1.26±0.04	1.08±0.12	0.72±0.09	0.39±0.16	0.24±0.18	0.34±0.13	0.32±0.22	0.43±0.14	0.19±0.23
Silicate (µmol/L)	64.23±0.31	43.51±1.1	33.4±0.29	24.15±0.26	51.3±0.69	22.54±0.31	30.33±0.21	25.32±0.39	50.73±0.41	57.58±0.38	33.94±0.71

Table 5: Continue

Outer Channel											
Parameters	Manika patana	Sea mouth	Sea mouth side	Dolphine site	Arakhakuda						
DO (mg/l)	3.24±0.21	2.91±0.15	2.7±0.46	3.15±0.29	4.52±0.18						
BOD (mg/l)	1.41±0.35	1.32±0.46	1.21±0.23	1.65±0.64	1.54±0.48						
COD (mg/l)	0.045±0.31	0.059±0.05	0.064±0.06	0.025±0.04	0.056±0.03						
Chloride content (g/l)	13.1±0.56	16.5±0.29	13.21±0.48	10.71±0.24	3.26±0.39						
Salinity (‰)	23.64±0.23	29.78±0.32	23.85±0.64	19.33±0.29	5.8±0.43						
Nitrate (µmol/L)	39.64±0.27	50.15±0.27	27.54±0.35	56.32±0.61	34.84±0.56						
Phosphate (µmol/L)	2.07±0.39	1.89±0.56	0.3±0.45	0.86±0.32	0.45±0.23						
Silicate (µmol/L)	35.19±0.51	16.46±0.23	3.55±0.63	28.32±0.75	154.24±0.98						

*Values are means of triplicates ± Standard Deviations (SD)

Dissolve oxygen varies widely through out the lake. In pre monsoon season maximum value of DO was 10.17±0.23 mg/L in Sanakuda area of Southern sector and minimum amount was found to be 1.626±0.21 mg/L in sea mouth area of outer channel (Table 2). In monsoon season maximum value of DO was 2.84±0.35 mg/L in Bada kuda area of Southern Sector and minimum value was 8.7±0.64 mg/L in Sea mouth in Outer channel (Table 4). In post monsoon season maximum value of DO was 10.32±0.31 mg/L in Bird's Island of Southern Sector and minimum value was 2.91±0.15 mg/L in sea mouth area of outer channel (Table 6).

In pre monsoon season maximum value of BOD was 6.015±0.35 mg/L in Krushna Prasad of Central sector and minimum amount was found to be 0.22±0.09mg/L in

Kaliyugeswara area of central sector (Table-2). In monsoon season maximum value of BOD was 4.47±0.32 mg/L in Kaliyugeswara area of central sector and minimum value was 0.4±0.23 mg/L in Badakuda area of Southern sector (Table-4). In post monsoon season maximum value of BOD was 5.74±0.14 mg/L in Ghantasila Hill of Southern Sector and minimum value was 1.21±0.23 mg/L in sea mouth area of outer channel (Table 6).

Chemical Oxygen Demand of water of Lake was found to be very low. In pre monsoon season maximum value of COD was 0.09±0.04 mg/L in Ghantasila hill of Southern sector and minimum amount was found to be 0.024±0.04mg/L in Manikapatana area of Outer channel (Table-2). In monsoon season maximum value of COD was

0.092±0.05 mg/L in Sea mouth area of Outer channel and minimum value was 0.024±0.03 mg/L in Chadheiguha area of Central sector (Table-4). In post monsoon season maximum value of COD was 0.073±0.03 mg/L in Breakfast Island of Southern Sector and minimum value was 0.019±0.22 mg/L in Bird's Island of Southern Sector (Table-6).

Chloride content of water varies widely throughout the lake. In pre monsoon season maximum value of Chloride was 19.86±0.59 g/L in Sea mouth area of Outer channel and minimum amount was found to be 2.87±0.34 g/L in Arakhakuda area of Outer channel (Table-2). In monsoon season maximum value of Chloride was 7.92±0.56 g/L in Bada kuda area of Southern sector and minimum value was 2.45±0.25 g/L in Chadheiguha area of Central sector (Table-4). In post monsoon season maximum value of Chloride was 16.5±0.29 g/L in Sea mouth area of Outer channel and minimum value was 4.15±0.3 mg/L in Kaliyugeswara area of central sector (Table-6).

In the present investigation Salinity of water varies widely throughout the lake. In pre monsoon season maximum value of Salinity was 36.82±0.26 (‰) in Sea mouth area of Outer channel and minimum value was found to be 5.27±0.21 (‰) in Arakhakuda area of Outer channel (Table-2). In monsoon season maximum value of Salinity was 14.08±0.34 (‰) in Bada kuda area of Southern sector and minimum value was 4.10±0.19 (‰) in Chadheiguha area of Central sector (Table-4). In post monsoon season maximum value of Salinity was 29.78±0.32 (‰) in Sea mouth area of Outer channel and minimum value was 7.49±0.41 (‰) in Kaliyugeswara area of central sector (Table-6).

The nitrate nitrogen content water varied aberrantly throughout the lake. In pre monsoon season maximum value of nitrate nitrogen was 117.4±0.37 µmol/L in Chadheiguha area of Central sector and minimum amount was found to be 1.55±0.15 µmol/L in Sanakuda area of Southern sector (Table-2). In monsoon season maximum value of nitrate nitrogen was 96.21±0.54 µmol/L in Krushna prasad area of Southern sector and minimum value was 19.48±0.61 µmol/L in Bada kuda area of Southern sector (Table-4). In post monsoon season maximum value of nitrate nitrogen was 94.65±0.25 µmol/L in Chadheiguha area of Central sector and minimum value was 10.46±0.29 µmol/L in Bird's Island of Southern Sector (Table-6).

The phosphate content was found to be very low. In pre monsoon season maximum value of phosphate was 1.035±0.06 µmol/L in Kaliyugeswara area of Central sector and minimum amount was found to be 0.17±0.13

µmol/L in Manikapatana area of Outer channel (Table-2). In monsoon season maximum value of phosphate was 5.4±0.24 µmol/L in Manikapatana area of Outer channel and minimum value was 0.855±0.25 µmol/L in Rambha area of Southern sector (Table-4). In post monsoon season maximum value of phosphate was 3.54±0.15 µmol/L in Chadheiguha area of Central sector and minimum value was 0.19±0.23 µmol/L in Ghantasila Hill of Southern Sector (Table-6).

The silicate content of water varied according to the salinity of water. In pre monsoon season maximum value of silicate was 156.25±1.12 µmol/L in Arakhakuda area of Outer channel and minimum value was 3.552±0.26 in Sea mouth area of Outer channel (Table-2). In monsoon season maximum value of silicate was 72.19±0.27 µmol/L in Manikapatana area of Outer channel and minimum value was 9.7±0.27 µmol/L in Nalabana area of central sector (Table-4). In post monsoon season maximum value of silicate was 154.24±0.98 µmol/L in Arakhakuda area of Outer channel and minimum value was 3.55±0.63 µmol/L in Sea mouth area of Outer channel (Table-6).

All the hydrographical and physicochemical parameters studied showed noticeable seasonal as well as spatial variations, which may be attributed to the local climatic conditions and exchange mechanism between lagoon and the sea. Greenish and brownish colour of the Lake water may be due to presence of impurities and phytoplankton. Presences of floating and suspended materials make the water turbid and non-transparent.

High total dissolved solids found in pre monsoon season in mouth area due to high rate of evaporation that caused accumulation of salt and no inflow of fresh water to the lake during this period. Less amount of total dissolved solids found in monsoon season due to mixing of fresh water i.e. rain water and river water to the lake. The permissible limit of TDS is 500 mg/L by World Health Organization [7] and Indian Standard Index (ISI) limit for drinking water. So the lake water is unfit for consumption.

The pH of the water is found to be slightly alkaline through out the year with the range of 7.13 to 8.6. The coastal water used for various activities were within the prescribed limit i.e. 6.5 to 8.5 given by Bureau of Indian Standards 1983. Most marine organisms prefer conditions with pH values ranging from 6.5-8.5. So the water was conducive for growth of marine organisms. The pH in marine and brackish water system is always taken as the function of the salinity and was governed by amount of free CO₂ and HCO₃⁻ [8]. The pH of the water was found to be mostly alkaline due to presence of salt in water by mixing of river and seawater to the lake [9]. The result of the present study also showed the increase and decrease of pH followed the same trend as that of the salinity [10].

Table 7: Variation in Physicochemical parameters of Chilika Lake before and after opening of new mouth

Parameters	Before opening of new mouth	After opening of new mouth
pH	6.4-9.5	7.13-8.67
DO (mg/L)	3.9-12.4	1.63-10.32
BOD (mg/L)	0.25-9.56	0.22-6.01
Salinity (‰)	3.8-32	4.1-36.8
Nitrate	0.02-13.1 (µg/L)	1.55-117.4 (µmol/L)
Phosphate	0.12-0.40 (µg/L)	0.17-5.4 (µmol/L)
Silicate	0.21-0.45 (µg/L)	3.55-156.25 (µmol/L)

Table 8: Correlation matrix analysis of different physico chemical parameters of Lake water

	Temp	pH	TDS	DO	BOD	COD	Chloride	Salinity	Nitrate	Phosphate	Silicate
Temp	1.00										
pH	-0.16	1.00									
TDS	0.43	-0.03	1.00								
DO	-0.09	-0.15	-0.56	1.00							
BOD	0.01	-0.10	-0.34	0.78	1.00						
COD	-0.05	-0.33	-0.03	0.02	-0.22	1.00					
Chloride	0.47	0.02	0.87	-0.54	-0.31	-0.14	1.00				
Salinity	0.46	0.02	0.87	-0.56	-0.33	-0.13	1.00	1.00			
Nitrate	-0.11	-0.08	-0.25	0.00	-0.20	0.02	-0.14	-0.13	1.00		
Phosphate	-0.25	-0.13	-0.27	0.24	0.11	0.19	-0.39	-0.40	0.41	1.00	
Silicate	0.03	0.00	-0.37	0.20	0.13	-0.01	-0.49	-0.49	0.04	0.04	1.00

Low dissolved Oxygen in sea mouth area is due to less solubility of oxygen in salt saturated water that depends on water temperature, water movement and salinity [11]. Less amount of DO found in the Lake after opening of new mouth at Gabakunda is due to ingress of sea water into the lake [12]. Permissible limit of DO is 5mg/L (BIS). Higher DO values often more than the saturation values were found mostly in the stations where more weeds are present and may be due to their photosynthetic activities [13]. Normally high dissolved oxygen was encountered in unpolluted areas while at polluted areas level of DO is very less. Further depletion of DO to the level of anaerobia is the most critical manifestation of pollution. DO was an indicator for organic pollution [8].

BOD is an indicator of organic load of water. Low B.O.D. in central sector in monsoon season is due to growth of phytoplankton and zooplankton. In pre monsoon season due to less depth of water BOD is less. Low BOD shows the heavy infestation of microorganisms [14]. This implies growth of microorganism is more in monsoon season [15]. The high BOD value was found at the place where the decomposition of the weeds occurs which is the indication of assimilation of organic load and occurrence of more microorganisms [12,13]. After opening of new mouth BOD is less than previous value. This may be due to less growth of microorganisms as the salinity of

water increases. If C.O.D. /B.O.D. are greater than 2, then there is chemical pollution and biological treatment of material is needed [16]. In the present study C.O.D. /B.O.D. are less than 2, hence there is no chemical pollution in the lake water.

In the present investigation the overall chloride content was found to be very high as well as the salinity of the water. This is due to high rate of evaporation and free ingress of seawater through newly created mouth near Gabakunda area. The water is completely unfit for human consumption and domestic purpose. The lowest value of chloride content and salinity were observed during monsoon period in central sector of Chilika Lake. It is possible due to mixing of fresh water to the lake by river and rain [12,13].

Increase in temperature and rapid mixing of sub-surface and surface water during pre monsoon season might have favored the nitrate replenishment mechanism [17]. Mixing of seawater with lake water helps in increasing the nitrate content in the water than previous. The concentration of different forms of nitrogen give useful indication of level of micronutrients in the water and hence their ability to support plant growth. High nitrate content in water helps in growth of weeds in certain areas of the lake. The observed nitrate concentration is much below the WHO upper limit 50 mg/L.

Phosphate content in lake water is more than the previous value. This may be due to release of phosphate from bottom sediment and organic load of the water. This could be because of addition of phosphate along with land drainage and detergent rich sewage effluents. This helps in growth of the weeds in the lake.

Silicate content was found to be high in low salinity area and low in high salinity area. Relatively lower values of silicate were observed during the post monsoon period, which could be due to uptake of phytoplankton [18]. Silicate content is high in the area where water circulation is less and water become stagnant there near the village area where human activity is more and salinity of the water is less.

Large-scale changes were observed in Chilika Lake after opening of the new mouth with reference to the water quality. After opening of new mouth the most noteworthy feature is increase in salinity (Table-7). However increase in nutrient contents of the lake water may be due to influx of fresh water as well as their replenishment from sediment. Seawater intrusion into the lake will result in decrease in seaweed population and flushing out of silt load helps in increase in fish catch and reduction in pollution that restores the lake ecosystem.

The correlation co-efficient (r) among various water quality parameters are given in Table 8.

Correlation matrix analysis showed there were both positive and negative correlations between the different parameters. Out of the total 45 correlations found between two parameters, 12 showed positive correlation between the parameters. The negative (inverse) correlations were found in 33 cases (Table-8). There was no correlation between nitrate and Dissolved Oxygen. Salinity and chloride content showed highly correlate to each other. Insert attached tables here

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