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Seasonal Dynamism and Correlation study of Physico-chemical parameters of Lower Lake, Bhopal, Central India

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Abstract

During this survey some physico-chemical properties of Lower Lake, Bhopal was investigated to assess its water quality status. Water samples were collected from four different stations of Lower Lake on a seasonal basis. Physico-chemical parameters which were analysed throughout the study include Atmospheric Temperature, Water Temperature, pH, Total Dissolved Solids (TDS), Turbidity, Electrical Conductivity (EC), Total Alkalinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). Pearson's correlation coefficient (r) value is decided using the matrix to identify the highly correlated and interrelated water quality parameters. It had been found that the general water quality of Lower Lake is contaminated and not safe for irrigation and drinking purpose at all the sampling stations. The main sources of pollution in this lake are sewage, agricultural runoff and other anthropogenic activities.

A major life-giving factor on earth is water and it supports a wide range of activities. Water is pure in its natural form whether it is underground or surface water except in the sea. But because of human population increases, as people need a more robust standard of living, economic activities still expand in scale and miscellany, and as land use/land cover changes, the water demand and its quality arises and still grow. So water quality is an emerging problem within the contemporary world. Evaluation of inland water ecosystem's health relies on the information of its limnological regime in various time periods[13].

Before the completion of the Bhoj Wetland Project the Lower Lake, Bhopal is especially affected by the inflow of untreated sewage water and accumulation of silt and dead organic matter. The latter problem is more intensified because the catchment basin is vast. Silt, sewage and dead organic matter joins into the lake with the runoff of the rainwater during monsoon. The assessment of water quality changes during a decade is predicated on physico-chemical and biological analysis and the change in physico-chemical constituents of water are often reflected directly in the community of the lake.

The pollution of this lake may be a matter of great concern since it is reached an alarming level because of the inflow of huge volume of sewage and solid wastes. The quality of water in Lower Lake has far more deteriorated than that in the Upper Lake[16]. The Lower Lake receives an outsized amount of raw sewage from its densely populated habitation. The water body is an urban eutrophic lake where the amount of nutrients is very high and oxygen depletion is very prominent[21]. The untreated wastewater contains effluent rich in phosphate, sodium hydroxide, and detergent, etc. Organic enrichment of the lake through floral offerings, idol immersion, and decomposition of aquatic weeds also are the numerous causes of its eutrophication.

Study Area :

Lower Lake (Chhota Talaab) is situated within the heart of the capital city (Bhopal) of the state Madhya Pradesh, India. This Lake is located along with the geological coordinates of 23°14'20"3 N and 77°24'0"E. It has the surface area of 1.29 km^2 and the average depth of 6.16 m (20.21 ft), with the utmost depth of 10.7 m (35.10 ft). The Lake water isn’t suitable for drinking as it is being employed by large number of people living near or round the lake for daily needs of bathing, washing clothes, cattle and vehicles. The Lake is surrounded by rows of homes within a hilly terrain the water remains stagnant with none circulation and mixing of the aerated and anaerobic bottom water and increases the sinking rate of the silt particles into the bottom. The primary inflow of the lower lake comes from the seepages from the Upper Lake Bhopal and drainage from 28 sewage-filled nallahs.

Sampling stations :

During the present study, the samples were collected between 7:00 am to 5:00 pm from four sampling stations and analysed for the seasonal dynamism and correlation study of physico-chemical parameters of Lower Lake in the year 2016. The details of study area and stations are given (Table 1 and Fig. 1):

Table-1. Latitude and longitude of sampling locations

S. No.	Stations	Name of stations	Latitude	Longitude
1.	Station- I	Kalika mandir	23°15’15.25"N	77°24’32.72"E
2.	Station- II	Karishma park	23°14’46.84"N	77°24’27.62"E
3.	Station- III	Dhobi ghat	23°14’50.48"N	77°24’09.22"E
4.	Station- IV	Hamidia college	23°15’00.93"N	77°24’19.56"E

Physico-chemicals analysis :

The collected water samples from different sampling stations of Lower Lake were analysed for different physico-chemical parameters such as Atmospheric temperature, Water temperature, pH, Total Dissolved Solids (TDS), Turbidity, Electrical Conductivity (EC), Total Alkalinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) as per the standard methods described by Adoni[1] and as given in APHA[3].

Statistical analysis :

The physico-chemical parameters for all the study stations were analysed by calculating Pearson's correlation coefficient (r) value. In order to calculate correlation coefficients, correlation matrix was constructed by calculating the coefficients of different pairs of parameters and correlation for significance was further tested by applying p value. The variations are significant if $p<0.05$, $p<0.01$, and non-significant if $p>0.05$. The significance is considered at the level of 0.01 and 0.05 (2- tailed analysis).

The present work includes the detailed structure of physico-chemical parameters depicting water quality status of Lower Lake– A Ramsar site, Bhopal. Different physico-chemical aspects play a crucial role in ecology of aquatic ecosystems[5].

The water quality analysis of Lower Lake has been carried out for Atmospheric Temperature, Water Temperature, pH, Total Dissolved Solids (TDS), Turbidity, Electrical Conductivity (EC), Total Alkalinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

Atmospheric Temperature : In the present study, atmospheric temperature ranged between 22.2°C to 28.1°C. The higher air temperature was observed 28.1°C at station-III in pre monsoon season while lowest temperature 22.2°C was at station-I in post monsoon season. Air temperature was highest in pre monsoon due to photoperiod. Photoperiod is directly related to temperature[15].

Water Temperature : Water temperature was found to be lower than atmospheric temperature. Water temperature of lower lake ranged between 19.5°C to 26°C while minimum temperature 19.5°C was recorded at station-II in post monsoon and maximum water temperature 26°C was recorded at station-II and station-IV in pre monsoon. The variation in the water temperature may be due to different timing of collection and influence of season[9].

pH : The pH value control the chemical state of many nutrient including dissolved oxygen, phosphate, nitrate etc.[6] The value of pH ranges from 8 to 9 in Indian waters[22]. During the present study, the pH of the lake ranged from 7.3 to 8.1 and this may be due to the high buffering capacity of the lake. Maximum values reached 8.1 at station IV in monsoon season and station III in post monsoon season and lowest value of pH 7.3 at station-II in pre monsoon. The high pH values of different stations during monsoon and post monsoon could be attributed to decreased decomposition rate owing to reduced microbial activity and increased algal productivity[2].

Total Dissolved solids : In the present study, total dissolved solids (TDS) ranged between 176 to 274 ppm while minimum value recorded at Station-II in pre monsoon season and the maximum value was recorded at Station-I in monsoon season due to addition of solids from run-off water and different anthropogenic activities.

Turbidity : Water is taken into account to be of improved quality once it contains turbidity value of 1 NTU or below. In the present study turbidity was found in the range of 7.4 to 14.6 NTU. The observed values of lowest turbidity was at station-II in pre monsoon season and highest value was observed in monsoon season at station-I due to runoff water of rain brings clay, sand and organic matter from adjoining areas of the lake.

Electrical conductivity : Electrical conductivity values of water samples ranges between 230- 282 μ Scm^{-1}, with a maximum in pre-monsoon at station-III and a minimum at station-II in post monsoon. Dilution of water during the rains causes a decrease in electrical conductance. Such seasonal variation in EC indicates an increase in concentration of major ions in the non-monsoon season.

Total alkalinity : Total Alkalinity values in the present observations fluctuated from 118 to 248 mgl^{-1}. Total Alkalinity was higher during pre-monsoon season at station-III followed by steep fall in post monsoon season at station-II which may be due to decomposition of organic matter. Total Alkalinity fluctuated in accordance with the fluctuation in the pollution load. Total Alkalinity is caused by bicarbonates, carbonates, OH ions, borates, silicates and phosphates[10].

Dissolved Oxygen : The Council on Environmental Quality defines the threshold for water pollution alert as dissolved oxygen content of less than 5 mgl^{-1} of water[17]. Good water should have solubility of oxygen *i.e.,* 7.6 and 7 mgl^{-1} at 30 and 35°C respectively[4]. In the present study, the dissolved oxygen (DO) of water samples ranged from 3.3 to 6.1 mgl^{-1}. Maximum and minimum value was recorded at station-II in monsoon season and station-III in pre-monsoon season respectively. Low DO observed during pre-monsoon season, might be due to high metabolic rate of organisms. At higher temperature, the water has a lesser oxygen holding capacity and some oxygen is lost to the atmosphere[7, 12]. So the present study reveals that the inverse relationship between dissolved oxygen and water temperature was similar to that observed by many workers *viz.,* Ganapati[8], Reid[19] and Prakash[18].

Biochemical Oxygen Demand : During the study BOD was measured in the range of 8.1 to 25.5 mgl^{-1}. The minimum BOD 8.1 mgl^{-1} was observed at station-II in monsoon season which indicates that has not contributed to increase the pollution level of the lake while maximum values *i.e.* 25.5 mgl^{-1} was noted at station-III in pre-monsoon season which could be due to the influence of sewage.

Chemical Oxygen Demand : In the conjunction with the BOD test, the COD test is helpful in indicating toxic conditions and the presence to biologically resistant organic substances[20]. During the study COD measured in the range of 21.8 to 56.2 mgl^{-1}. The lowest COD 21.8 mgl^{-1} was observed at station-II in monsoon season which indicates that has not contributed to increase the pollution level of the lake. Maximum values *i.e.,* 56.2 mgl^{-1} was observed at station-III in pre-monsoon season which could be due to the influence of sewage.

The status of the seasonal physico-chemical parameters of the lower lake water sources is presented in table 2, 3 and 4.

Table-2. Physico-chemical parameters of Lower Lake at different stations during pre-monsoon season

Stations	AT	WT	pH	TDS	Turbidity	EC	TA	DO	BOD	COD
I	27.7	25.2	7.5	190	8.4	280	236	4.9	15.04	34.6
II	28	26	7.3	176	7.4	260	176	5.8	8.8	22.8
III	28.1	25.6	7.7	194	9.6	282	248	3.3	25.5	56.2
IV	27.9	26	7.6	184	7.8	276	188	4.6	14.24	33.6

Table-3. Physico-chemical parameters of Lower Lake at different stations during monsoon season

Stations	AT	WT	pH	TDS	Turbidity	EC	TA	DO	BOD	COD
I	25.6	23.2	8	274	14.6	270	168	5.4	10.4	25.2
II	25.1	22.9	7.6	184	7.8	260	152	6.1	8.1	21.8
III	25.9	23.7	7.7	246	10.4	276	172	4.8	15.04	34.6
IV	25.3	23.1	8.1	234	11.6	250	160	5.4	10.84	25.4

Table-4. Physico-chemical parameters of Lower Lake at different stations during post-monsoon season

Stations	AT	WT	pH	TDS	Turbidity	EC	TA	DO	BOD	COD
I	22.2	19.9	7.9	270	14	266	130	5.8	8.96	22.2
II	22.5	19.5	7.6	214	9.8	230	118	6	8.16	22.2
III	23.1	19.9	8.1	260	13.2	250	138	5.2	12	28.2
IV	22.9	20.1	7.9	228	10.2	250	124	5.8	13.44	29.4

AT: Atmospheric Temperature, WT: Water Temperature, TDS: Total Dissolve Solids, EC: Electrical Conductivity, TA: Total Alkalinity, DO: Dissolved Oxygen, BOD: Biochemical Oxygen Demand, COD: Chemical Oxygen Demand

Correlation is the mutual relationship between two variables. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of the other. The correlation is said to be positive when increase in one parameter causes the increase in other parameter and it is negative when increase in one parameter causes decrease in the other parameter. The correlation coefficient has a value between +1 and -1. The correlation between the parameters is characterized as strong, when it is in the range of ±0.8 to ±1.0, moderate in the range of ±0.5 to ±0.8, weak when in the range of 0.0 to ±0.5[11]. Correlation matrix was prepared within the studied parameters in pre monsoon, monsoon and post-monsoon and tabulated in Table 5, Table 6 and Table 7 for determining the relationship between the physico-chemical variables. All the attributes were positively co-related.

Fig. 1: Showing sampling stations of Lower Lake

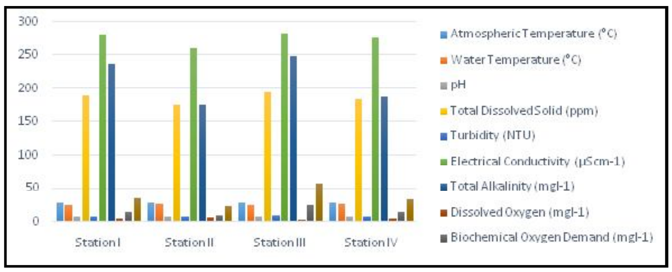

Fig. 2: Graphical representation of physico-chemical parameters of Lower Lake at different stations during pre-monsoon season

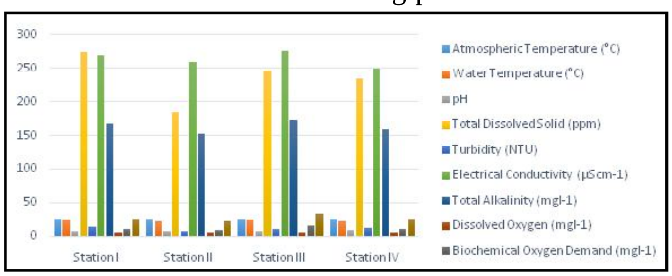

Fig. 3: Graphical representation of physico-chemical parameters of Lower Lake at different stations during monsoon season

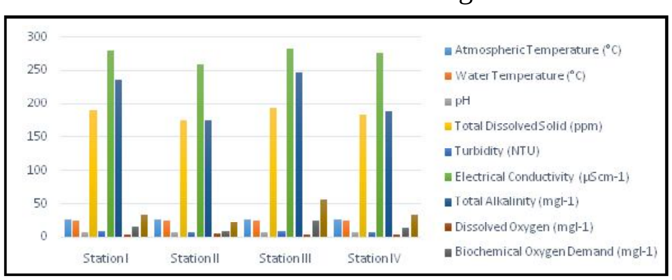

Fig. 4: Graphical representation of physico-chemical parameters of Lower Lake at different stations during post monsoon season

Table-5. Pearson Correlation Matrix for pre-monsoon

	pH	TDS	EC	TA	Turbidity	BOD	COD	DO	AT	WT
pH	1									
TDS	0.85	1								
EC	0.89	0.96	1							
TA	0.66	0.95	0.84	1						
Turbidity	0.79	0.92	0.79	0.92	1					
BOD	0.89	0.9	0.8	0.84	0.98	1				
COD	0.89	0.89	0.79	0.83	0.97	1	1			
DO	-0.95	-0.87	-0.82	-0.76	-0.92	-0.98	-0.98	1		
AT	0.2	-0.05	-0.21	-0.07	0.31	0.39	0.41	-0.39	1	
WT	-0.25	-0.71	-0.65	-0.83	-0.54	-0.39	-0.37	0.29	0.56	1

TDS: Total Dissolve Solids, EC: Electrical Conductivity, TA: Total Alkalinity, BOD: Biochemical Oxygen Demand, COD: Chemical Oxygen Demand, DO: Dissolved Oxygen, AT: Atmospheric Temperature, WT: Water Temperature

In pre-monsoon season the strong positive correlation between pH and TDS, EC, BOD, COD, Total Alkalinity and turbidity were found. The moderate correlation between EC and turbidity, were found. DO, atmospheric temperature and water temperature were showing weak correlation with the other parameters.

Table-6. Pearson Correlation Matrix for monsoon

	DO	pH	TDS	Turbidity	EC	AT	TA	BOD	WT	COD
DO	1									
pH	-0.22	1								
TDS	-0.7	0.62	1							
Turbidity	-0.42	0.78	0.93	1						
EC	-0.55	-0.42	0.45	0.19	1					
AT	-0.93	0.22	0.73	0.44	0.82	1				
TA	-0.93	0.22	0.86	0.61	0.74	0.98	1			
BOD	-0.97	-0.01	0.52	0.19	0.59	0.91	0.85	1		
WT	-0.94	-0.1	0.55	0.2	0.74	0.96	0.89	0.98	1	
COD	-0.93	-0.13	0.45	0.1	0.66	0.91	0.83	0.99	0.99	1

DO: Dissolved Oxygen, TDS: Total Dissolve Solids, EC: Electrical Conductivity, AT: Atmospheric Temperature, TA: Total Alkalinity, BOD: Biochemical Oxygen Demand, WT: Water Temperature, COD: Chemical Oxygen Demand

In the monsoon season strong positive correlation between TDS and Turbidity, Total Alkalinity, Atmospheric temperature, BOD and COD were found. The moderate correlation between pH and Water Temperature and EC were found. DO and TDS were showing weak correlation with the other parameters.

Table 7. Pearson Correlation Matrix for post-monsoon

	DO	pH	TA	EC	TDS	Turbidity	WT	AT	BOD	COD
DO	1									
pH	-0.89	1								
TA	-0.92	0.94	1							
EC	-0.29	0.65	0.61	1						
TDS	-0.58	0.74	0.85	0.87	1					
Turbidity	-0.57	0.67	0.83	0.81	0.99	1				
WT	-0.38	0.74	0.48	0.7	0.43	0.3	1			
AT	-0.69	0.55	0.4	-0.23	-0.12	-0.18	0.38	1		
BOD	-0.51	0.66	0.37	0.21	0.04	-0.08	0.82	0.81	1	
COD	-0.57	0.64	0.38	0.08	-0.02	-0.13	0.72	0.9	0.99	1

DO: Dissolved Oxygen, TA: Total Alkalinity, EC: Electrical Conductivity, TDS: Total Dissolve Solids, WT: Water Temperature, AT: Atmospheric Temperature, BOD: Biochemical Oxygen Demand, COD: Chemical Oxygen Demand

In the post-monsoon season strong positive correlation between pH and Total Alkalinity and BOD were found. The moderate correlation between TDS and Water Temperature were found. DO and Atmospheric temperature, COD, EC and Turbidity were showing weak correlation with the other parameters.

Information about present status of wetland may be a key in development of perfect strategy of preservation and restoration[14]. The present study reveals that the water of various stations of the lower lake is contaminated and not safe for irrigation and drinking purpose. Most of the parameters showed the analogous trend in seasonal variation. It requires proper monitoring and environment management plans to regulate the discharge of effluents. Better water quality was found within the post-monsoon season than pre-monsoon season. The extent of pollution that has occurred because of urbanization, anthropogenic activities; increased human interventions within the water bodies are ascertained. The correlation analysis on water quality parameters revealed that each parameter is more or less correlated with one another Pearson’s matrix. It’s observed that some of the parameters don’t have a major correlation between them indicating the various sources of pollution.

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