



Assessment of eco-hydrological dynamics and its impact on ecological status of upper lake, Bhopal

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Abstract

Present study has been carried out seasonally in Upper Lake, Bhopal during the tenure of 2015. To evaluate the present scenario of water quality a total of 14 parameters have been analyzed. On scrutinization, majority of water parameters are at the verge of optimum level or do not fall with the range of maximum allowable concentration given by BIS, likewise few of the parameters remain below normal values. Hence, it is inferred that the Lake represents deteriorated and stressful condition caused by anthropogenic and organic pollution. The heavy load of pollution is evident from different sites when compared with standard reference table. Among the most affected sites which approaches anorexia conditions includes "S6" (GMC) 5.2 mg/l during winter and "S6" (GMC) 5.3 mg/l in monsoon season. The range of pH varies from 7.5 -9.3 during winter and summer respectively. Although, most of aquatic organisms thrive well in pH ranging from 6.5-9, beyond these set of limits sensitive organisms begins to respond by either migrating from localized area or they will be replaced by more tolerant species. Hence, Upper Lake represents moderately disturbed state of ecological status for various flora and fauna.

Keywords: ecohydrology, ecological status, anthropogenic, wetland, physico-chemical and anorexia

Introduction

Wetlands are transitional areas between terrestrial and aquatic ecosystems. The interactions of physical, chemical and biological components of wetland such as soils, water, plants and animals, enable the wetland to perform many vital activities such as water storage, flood mitigation and storm protection, shoreline stabilization and soil erosion control, groundwater discharge, groundwater recharge, water purification through retention of nutrients, sediments, pollutants and stabilization of local climatic conditions, particularly rainfall and temperature. The capacity for wastewater purification by both natural and artificial wetlands is well documented (Gersberg et al., 1986) [6]. Water in abundant quality and quantity, at a right time and place has been the key factor for the establishment of all civilizations and is considered a divine gift by all faiths. The fact is reflected if we look back to the history of human civilization, settlements were made near a perennial source of water. The amount of potable water consumption has exceeded its renewal rate, creates increasing demand in terms of price and a non-sustainable situation. Dar et al., (2016) [7].

Beneficial use of water in terms of primary water quality criteria is related to water quality management. The designated 'best use' concept was evolved to interpret the water quality. Wetlands are considered to be one of the richest sources of biological diversity. Due to urbanization and anthropogenic pressure most of the wetlands are succumbed to greater degree of biologically active nutrient accumulation Pani and Misra (2000) [9]. Man has been much responsible for

the over exploitation and misuse of this natural resource. The present work, physico-chemical analysis of water is aimed to fill the gap of monitoring program and to provide a preliminary data to understand the important and major lentic ecosystem of Bhopal city.

Material and Method

The main purpose of sampling was to determine the quality of water in its natural state. The quality of water varies with time in a water body due to various natural and human induced factors. The sampling frequencies adopted for monitoring was done seasonally and were carried out in different seasons of a year. From all sampling stations, water samples were collected seasonally in two replicates from surface and near bottom, the mean value obtained from the replicated of sampling was recorded for statistical analysis.

Water Sample Collection and Analysis

Water samples were collected in one liter plastic canes with the help of Ruttner sampler from sampling stations. At sampling stations analysis of highly unstable parameters were immediately analyzed which include air and water temperature, depth, transparency, fixing of sample for dissolved oxygen, pH, conductivity and total dissolved solids. Water sample for other physico-chemical parameters were stored and carried to the laboratory and then immediately analyzed. The physico-chemical parameters of water were analyzed by following methods of Adoni (1985) [2], APHA (1992) [1] and NEERI (1985) [8].

Study Area

Bhopal, the picturesque capital of Madhya Pradesh known as "city of lakes" on an account of large numbers of Water bodies. The geographical location of the Bhopal City lies within North Latitude 23°16' and East Longitude 77°36'. The location of Bhopal falls in the north-western portion of Madhya Pradesh. The upper lake is the source of drinking water to the urban population; whereas water of the lower lake is used by a large population for miscellaneous purpose viz., aesthetics, recreational use and washing purpose (Dar et al., 2015) [7].

Sampling Design and Site Selection

Based on the geographical location, least and highest human interference as well as ecological aspects ten sampling sites were selected after careful habitat observation. Symbolically sampling sites were represented by a letter (S) followed by numerical suffix. The description of sampling stations is given as under:

The sites selected for sampling purpose were taken from rural and urban zone, so the selected sites comprise Central point (S1) from urban zone, two sites were selected from Van-Vihar designated as (S2, S3) and another site was selected from Boat club (S4). Government medical college was taken as another site symbolically represented by (S5), Koifiza was taken as (S6), another site was selected from the deeper area from border line between rural and urban zone (S7). Two more site were selected from Khanagaue and Batagaue designated as (S8, S9) respectively. Last sampling site was selected from the extreme deeper area from rural zone (S10). The sampling has been done seasonally i.e. in winter, summer, Pre-monsoon, monsoon and post-monsoon. The months chosen for different seasons were, January, March, June, August and October which correspond for winter, summer, pre monsoon, monsoon, post monsoon respectively. The main objective of the study was to assess the water quality of Upper Lake, Bhopal.

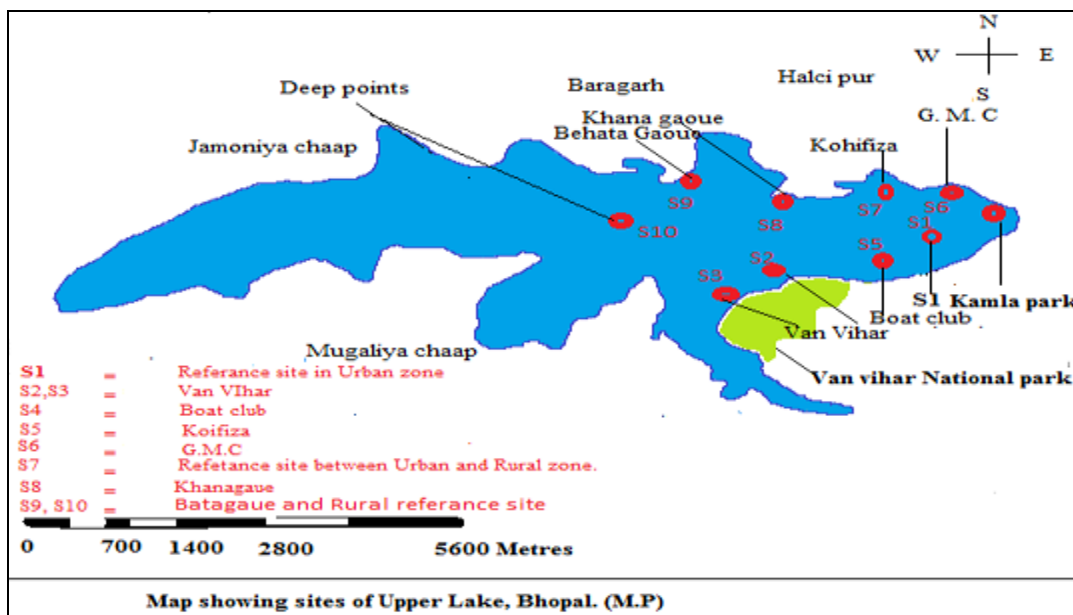


Fig 1

Results

Table 1: Seasonal variation of water temperature in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	Monsoon	Post monsoon
Minimum	17.5	21.5	22	20.7	23.5
Maximum	23	28	25.3	25.2	28
Mean	20.12	24.25	23.67	22.3	26.6
Variance	2.875111	3.402778	0.964556	2.677778	2.044444
Standard deviation	1.695615	1.844662	0.982118	1.636392	1.429841

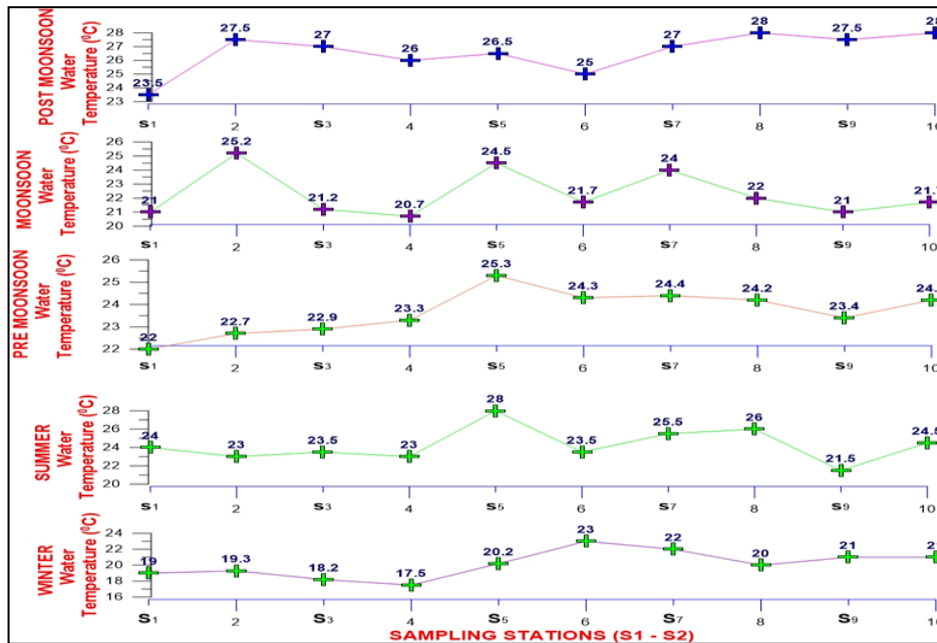


Fig 2: Showing seasonal variation of water temperature in Upper Lake, Bhopal

Water Temperature (°C)

At sampling site S4 (Boat Club), the minimum water temperature value of 17.5 ° was recorded in winter season. On an average basis a value of 20.12 °C was recorded for Water temperature with SD±1.69 and variance of 2.87. While as, during Post monsoon season at sampling site S8 and

(Khanagaoue), the maximum value of 28 °C was recorded and same temperature was observed at S10 (reference point of rural zone) was recorded in the in the same season. On an average basis a value of 23.37 °C was recorded for water temperature with SD±1.84 and variance of 3.40 was obtained.

Table 2: Seasonal variation of Air temperature in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	Monsoon	Post monsoon
Minimum	19.5	35.5	35.5	28.5	23
Maximum	23.4	42	37.3	32	33.5
Mean	21.39	39.56	36.3	30.53	30.51
Variance	1.685444	2.624889	0.415556	1.253444	15.96767
Standard deviation	1.298247	1.620151	0.644636	1.119573	3.995956

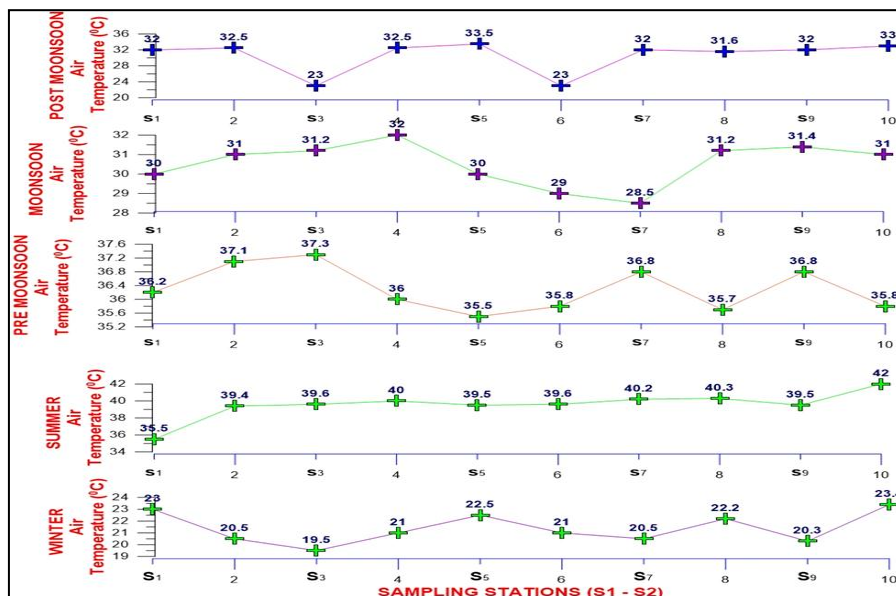


Fig 3: Showing seasonal variation of Air temperature in Upper Lake, Bhopal

Air Temperature (°C)

During winter season at sampling site S3 (Van Vihar), the minimum air temperature value of 19.5°C was recorded with a mean value of 21.39°C and variance of 1.68 was recorded for air temperature, with SD±1.29, while as maximum value of 42

°C was recorded at S10 (reference point of Rural zone) during summer. On an average basis a value of 39.56°C and a variance of 2.62 was observed for air temperature, with SD±1.62.

Table 3: Seasonal variation of pH in Upper Lake, Bhopal.

	Winter	Summer	Pre monsoon	Monsoon	Post monsoon
Minimum	7.7	8.1	8.2	7.7	7.5
Maximum	9.2	9.3	9.3	8.7	8.5
Mean	8.4	8.58	8.84	8.15	8.12
Variance	0.204444	0.177333	0.222667	0.082778	0.099556
Standard deviation	0.452155	0.42111	0.471876	0.287711	0.315524

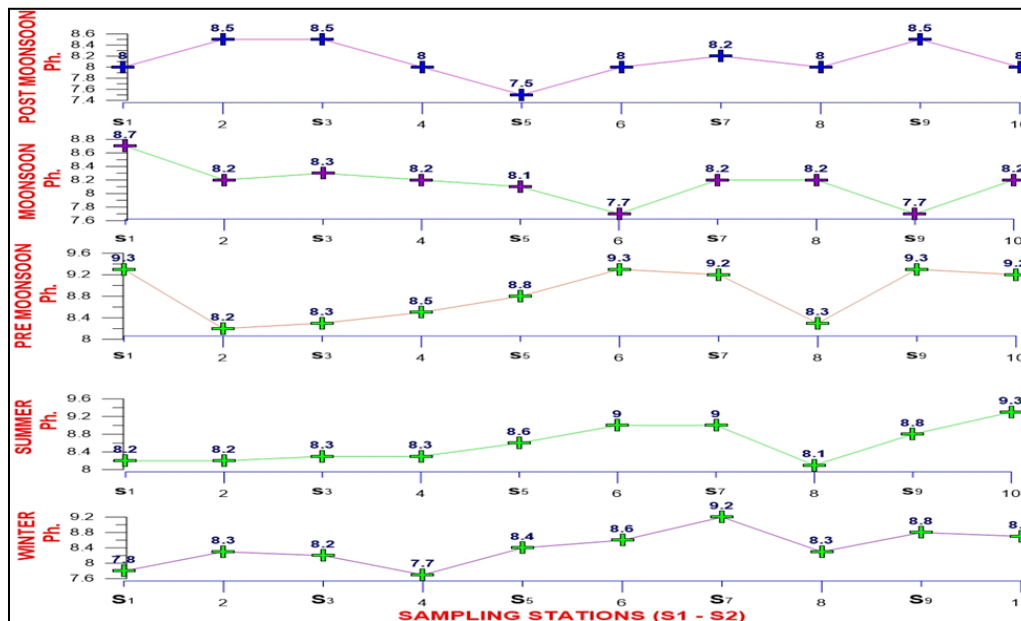


Fig 4: Showing seasonal variation of pH in Upper Lake, Bhopal.

Hydrogen Ion Concentration (pH)

During post monsoon at sampling station S5 (G.M.C), the minimum pH value of 7.5 units was recorded with an average value of 8.58 units and a variance of 0.17 was found with

SD±0.042, While as maximum value of 9.3 units at S1 (reference point of urban zone) was observed in Monsoon season. On an average basis a value of 8.84 units and a variance of 0.22 was recorded for pH with SD±0.47.

Table 4: Seasonal variation of Depth in Upper Lake Bhopal

Parameters	Winter	Summer	Pre monsoon	Monsoon	Post monsoon
Minimum	0.3	1.2	0.9	1.8	0.21
Maximum	3.8	4.6	4.2	5.3	3.8
Mean	1.04	2.05	1.58	2.47	0.846
Variance	1.089333	0.989444	1.028444	1.115667	1.208382
Standard deviation	1.043711	0.994708	1.014122	1.056251	1.099264

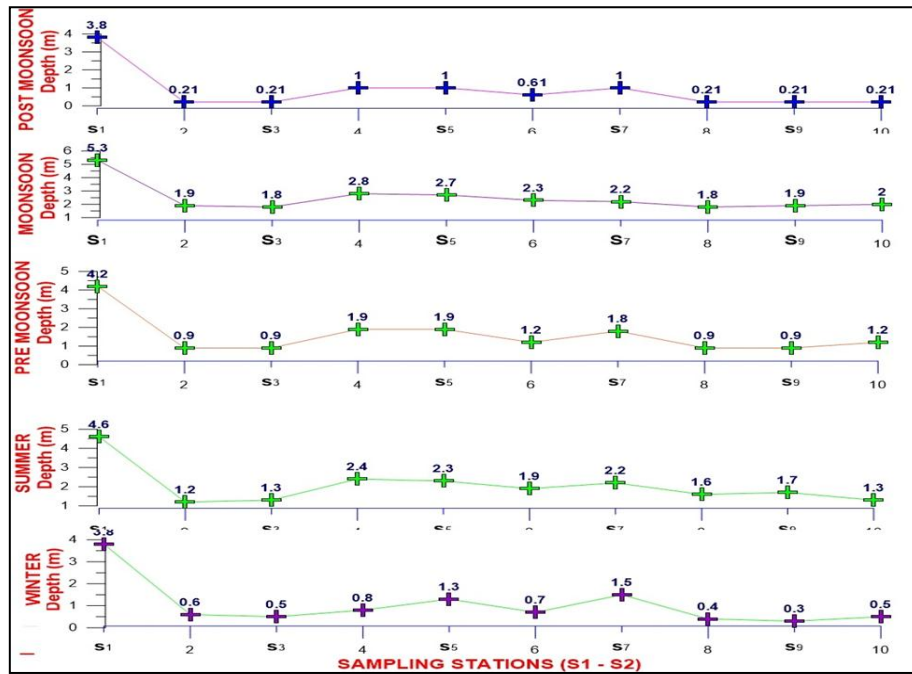


Fig 5: Showing seasonal variation of Depth in Upper Lake Bhopal

Depth (m)

At sampling station S9 (Batagoue), the minimum Depth of 0.3 meters was recorded in winter season with an average value of 1.04 units and a variance of 1.08 SD±0.104 meters, were

recorded for Depth, whereas maximum value of 4.6 meters at S1 (reference point of urban zone) was recorded in Monsoon season. On an average basis a value of 2.05 meters and a variance of 0.98 was recorded for depth with SD±0.99.

Table 5: Seasonal variation of Conductivity in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	210	195	155	130	140
Maximum	280	350	265	253	250
Mean	230.9	226.1	205.2	196	209
Variance	481.4333	2422.1	938.1778	2000.889	1293.333
Standard deviation	21.94159	49.21484	30.62969	44.7313	35.96294

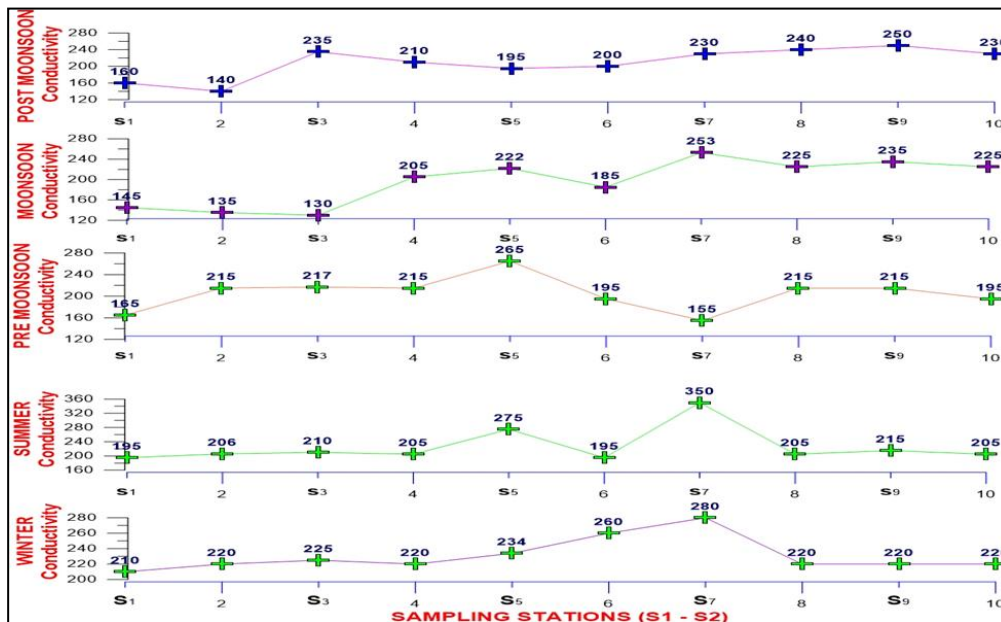


Fig 6: Showing seasonal variation of Conductivity in Upper Lake Bhopal

Conductivity ($\mu\text{S}/\text{cm}$)

At sampling site S3 the minimum Conductivity value of 130 $\mu\text{S}/\text{cm}$ was recorded in monsoon season. On an average basis a value of 196 $\mu\text{S}/\text{cm}$ and a variance of 2000 was recorded for

conductivity with $\text{SD}\pm 44.73$, while as maximum value of 280 $\mu\text{S}/\text{cm}$ in S7 (koifiza) was measured with an average value of 230 $\mu\text{S}/\text{cm}$ and a variance of 481, $\text{SD}\pm 0.21.94$ was observed.

Table 6: Seasonal variation of Transparency in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	45	62	55	3	40
Maximum	98	123	113	75	85
Mean	73.3	91.5	82.2	42.1	59.3
Variance	364.4556	316.2778	316.4	349.2111	169.5667
Standard deviation	19.09072	17.7842	17.78764	18.68719	13.02178

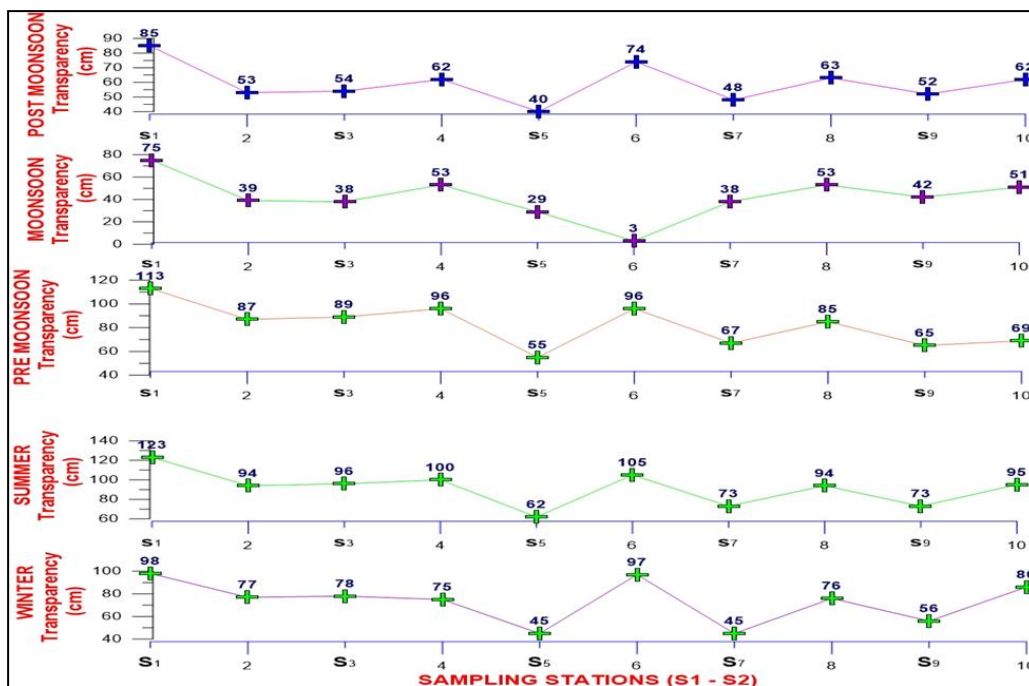


Fig 7: Showing seasonal variation of Transparency in Upper Lake Bhopal

Transparency (m)

During monsoon at sampling station S6, the minimum Transparency value of 3cm was recorded. On an average basis a value of 42.1 meters and a variance of 34.2 were recorded

for pH with $\text{SD}\pm 18.68$. On the other hand during summer at sampling station S1, maximum value of 123 meters was recorded with an average value of 91.5 meters and a variance of 316.2 were recorded for Transparency with $\text{SD}\pm 17.78$.

Table 8: Seasonal variation of Total Dissolved Solids (ppm) in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	110	130	115	115	115
Maximum	150	168	149	155	145
Mean	132	149.1	133.6	134	133.5
Standard deviation	14.07914	13.14407	12.99744	12.64911	10.01388

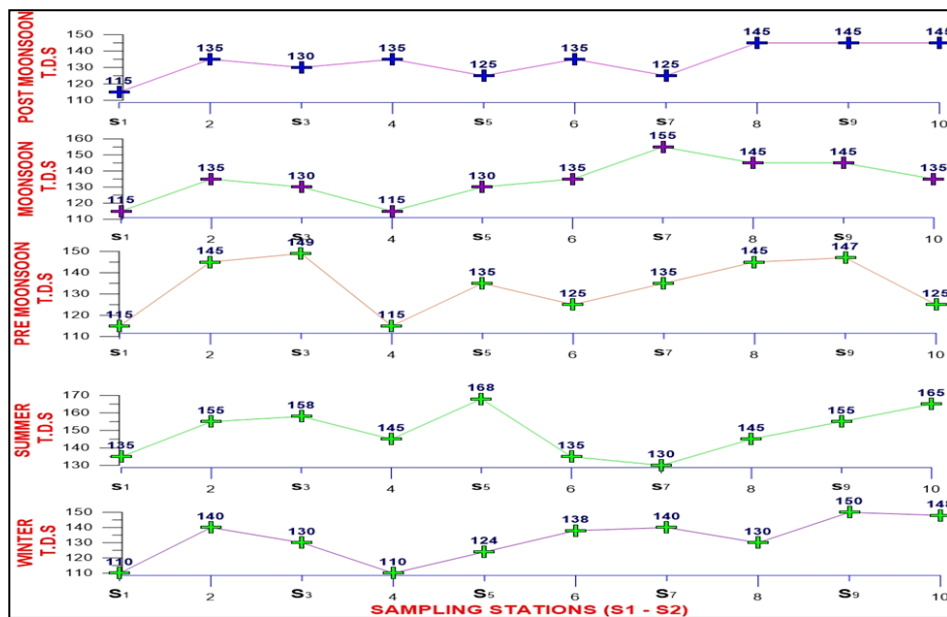


Fig 8: Showing seasonal variation of Total Dissolved Solids (ppm) in Upper Lake Bhopal

T.D.S (P.P.M)

During winter season at sampling station S1, S4, the minimum T.D.S value of 110ppm was recorded. On an average basis a value of 132ppm were recorded for T.D.S with $SD_{\pm 14.07}$.

While as, during summer season maximum value of 168ppm at S5 and S10 was recorded with an average value of 149.1ppm were recorded for T.D.S and $SD_{\pm 13.14}$.

Table 9: Seasonal variation of Dissolved Oxygen in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	5.2	7.5	8.7	5.3	5.5
Maximum	9.7	13.2	13.8	8.2	8
Mean	6.81	9.53	10.3	6.79	6.91
Variance	1.838778	2.386778	2.011111	0.769889	0.732111
Standard deviation	1.356015	1.54492	1.418136	0.877433	0.855635

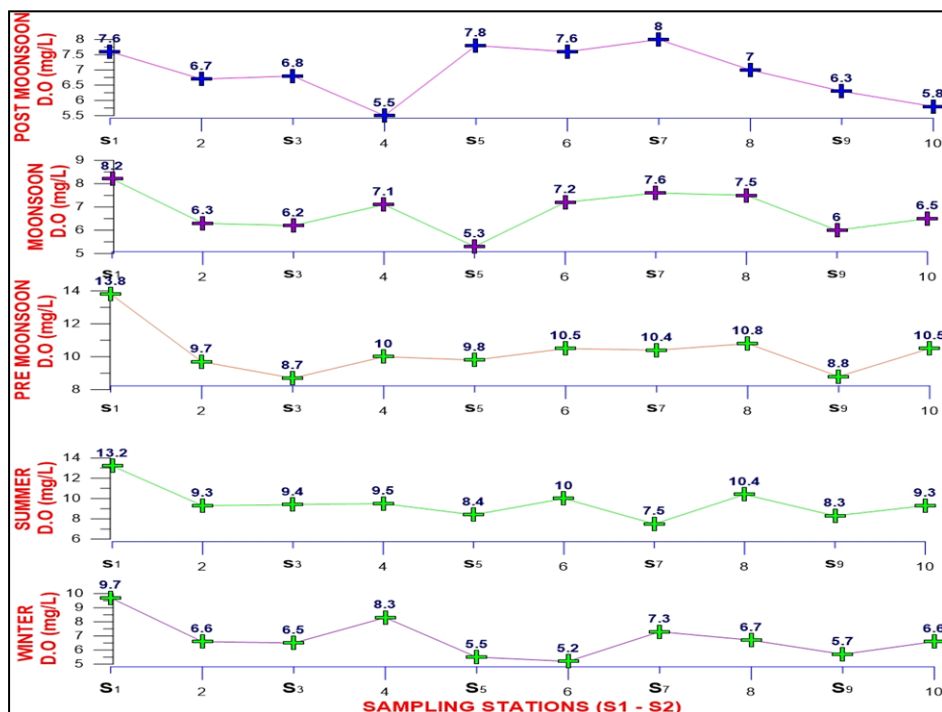


Fig 9: Showing seasonal variation of Dissolved Oxygen in Upper Lake Bhopal

Dissolved Oxygen (mg/l)

During winter season at sampling station S6 the minimum Dissolved Oxygen content of 5.2 mg/l was recorded with an average value of 6.61 mg/l for Dissolved Oxygen with

SD \pm 1.35 and a variance of 1.83. On the other hand maximum content of 13.8 mg/l at S1 during pre-monsoon. On an average basis a value of 10.3 mg/l were recorded for dissolved oxygen with SD \pm 1.41 and a variance of 2.01 was observed.

Table 10: Seasonal variation of Dissolved chloride mg/l in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	19.6	20.7	22.9	19	34
Maximum	43.3	41.3	44	40	69
Mean	33.89	32.62	32.71	29.76	52.9
Variance	57.41211	40.64622	40.62767	43.42044	89.65556
Standard deviation	7.577078	6.375439	6.373984	6.589419	9.468662

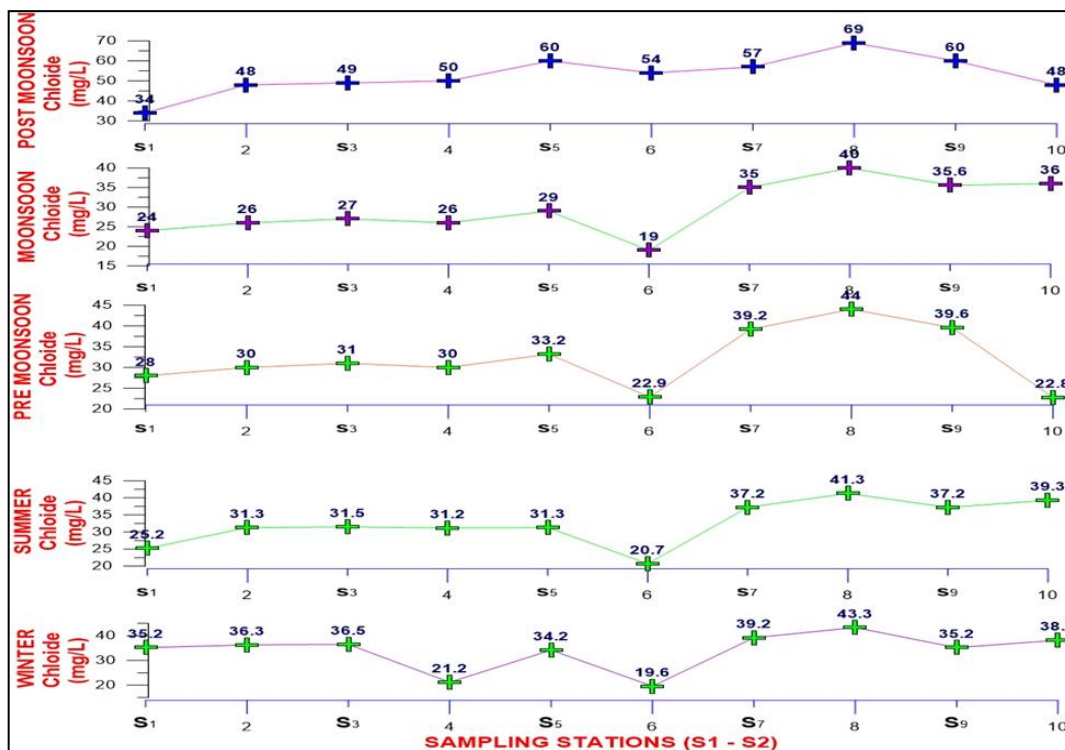


Fig 10: Showing seasonal variation of Dissolved chloride mg/l in Upper Lake Bhopal

Dissolved Chloride (mg/l⁻¹)

During monsoon season at sampling station S6 the minimum Dissolved chloride content of 19mg/l⁻¹ was recorded with an average value of 29.76mg/l⁻¹ were recorded for Dissolved chloride with SD \pm 6.58 and a variance of 43.42, During post

monsoon season at sampling station S8 the maximum dissolved content of 69mg/l⁻¹ at S8 was recorded. On an average basis a value of 52.9mg/l⁻¹ were recorded for Dissolved chloride with SD \pm 9.46 and a variance of 89.69.

Table 11: Seasonal variation of Total alkalinity mg/l in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	29	21	27	21	26
Maximum	67	80	59	65	70
Mean	47.4	41.2	40.2	38.2	42.7
Variance	169.6	355.2889	81.51111	219.0667	169.3444
Standard deviation	13.02306	18.84911	9.02835	14.8009	13.01324

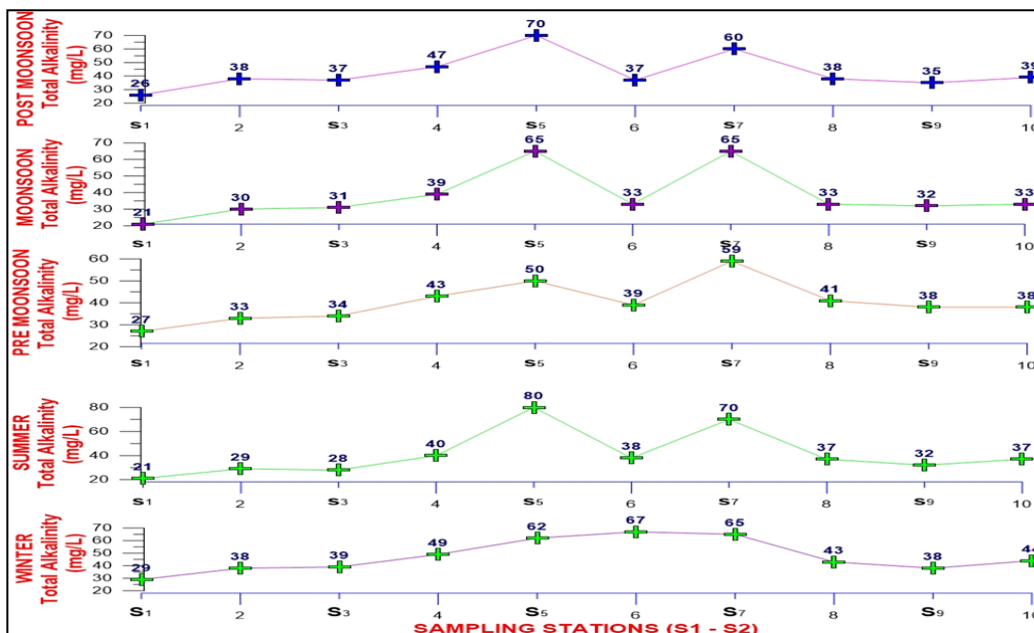


Fig 11: Showing seasonal variation of Total alkalinity 355 mg/l in Upper Lake Bhopal

Total alkalinity (mg/l)

During summer season at sampling station S1 the minimum Total alkalinity of 21mg⁻¹ was recorded with an average value of 41.2mg⁻¹ with SD±18.84 and a variance of 355, while as

during summer season maximum content of 80mg⁻¹ at S5 was recorded in. On an average basis a value of 41.2mg⁻¹ were recorded for Total alkalinity with SD±18.84 and a variance of 355.

Table 12: Seasonal variation of Total Magnesium Hardness mg/l in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	2	1.89	2.2	1.1	2.6
Maximum	7	7.2	5.6	2.8	4.8
Mean	3.4	3.527	3.44	1.87	3.69
Variance	3.791111	3.975734	1.424889	0.222333	0.427667
Standard deviation	1.947078	1.993924	1.193687	0.471522	0.653962

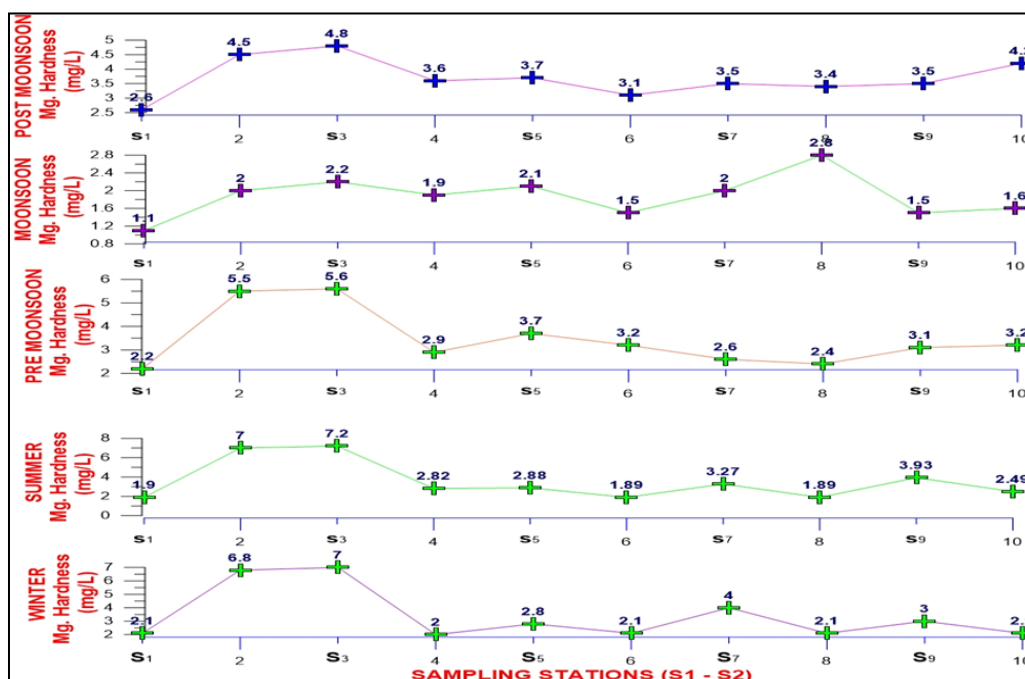


Fig 12: Showing seasonal variation of Magnesium Hardness mg/l in Upper Lake Bhopal

Magnesium Hardness (mg^l⁻¹)

During monsoon season at sampling station S1 the minimum Total magnesium hardness of 1.1mg^l⁻¹ was recorded with an average basis a value of 1.87mg^l⁻¹ SD±0.47 and a variance of

0.22, on the other hand maximum content of 7.2mg^l⁻¹ at S3 was observed during summer. On an average basis a value of 3.52mg^l⁻¹ were recorded for Total magnesium hardness with SD±1.99 and a variance of 3.97.

Table 13: Seasonal variation of Calcium Hardness mg/l in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	49.2	57.8	54.9	47.9	50
Maximum	108	124.6	124.8	107.5	108
Mean	83.47	94.75	92.62	85.9	82
Variance	359.8268	438.9717	516.7551	337.6956	458.8889
Standard deviation	18.9691	20.95165	22.73225	18.37649	21.42169

Fairfax Water Hardness Scale

Table 14

Milligram Per Liter (mg/l) or Parts Per Million.	Classification
Less than 17.1	Soft
17.1 - 60	Slightly Hard
60 - 120	Moderately Hard
120 - 180	Hard
Over 180	Very Hard

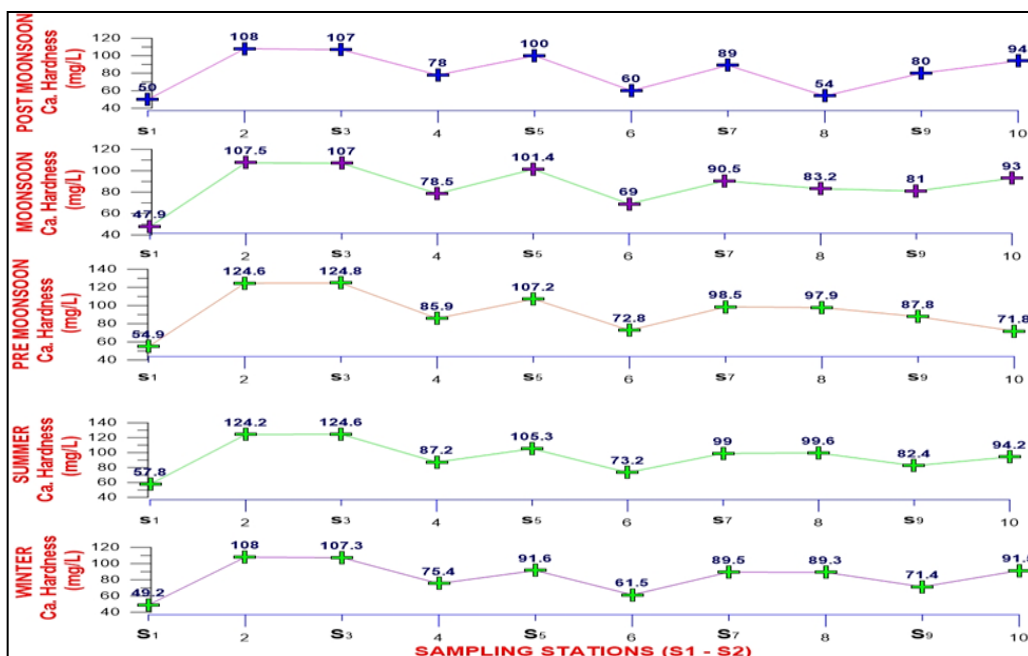


Fig 13: Showing seasonal variation of Calcium Hardness mg/l in Upper Lake Bhopal

Calcium Hardness (mg^l⁻¹)

During winter season at sampling station S1 the minimum Calcium hardness of 49.2mg^l⁻¹ was recorded with an average value of 83.47mg^l⁻¹ , SD±18.96 and a variance of 359,

Whereas during summer season maximum content of 124.6mg^l⁻¹ at S3 was observed. On an average basis a value of 94.75mg^l⁻¹ were recorded for Calcium hardness with SD±20.95 and a variance of 438.

Table 15: Seasonal variation of Free Co₂ mg/l in Upper Lake, Bhopal

Parameters	Winter	Summer	Pre monsoon	monsoon	Post monsoon
Minimum	0	0	0	0	0
Maximum	1.4	2	2.6	1.7	1.6
Mean	0.14	0.71	0.7	0.43	0.35
Variance	0.196	0.849889	1.291111	0.493444	0.376111
Standard deviation	0.442719	0.921894	1.136271	0.702456	0.613279

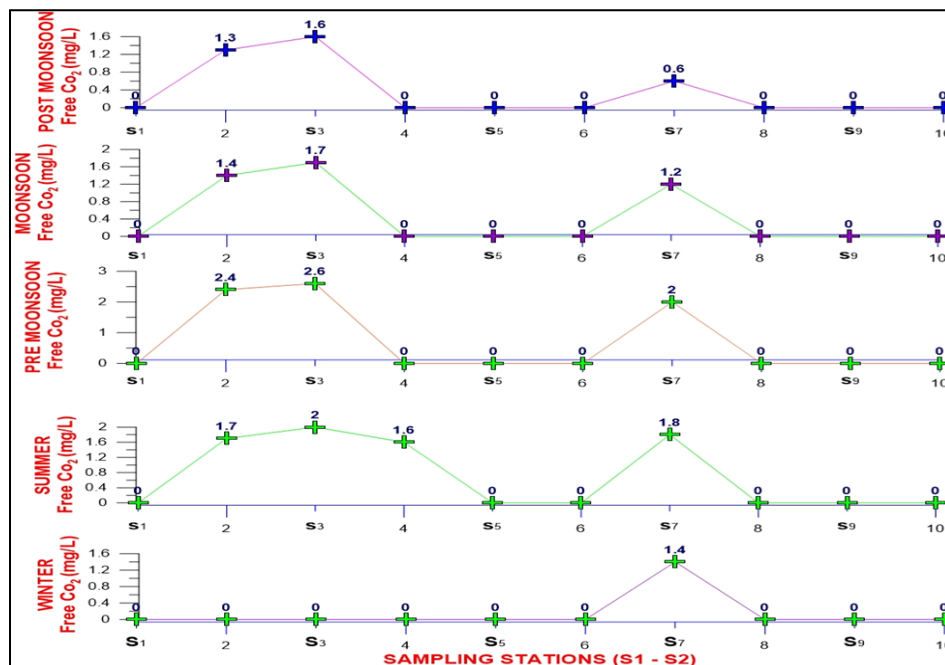


Fig 14: Showing seasonal variation of FreeCO₂ mg/l in Upper Lake Bhopal

Free Carbon Dioxide (mg⁻¹)

During pre-monsoon season Free carbon dioxide was absent in most of sampling sites and maximum content of 2.6mg⁻¹ at

S3 was recorded. On an average basis a value of 0.7mg⁻¹ were recorded for free carbon dioxide with SD±1.13 and a variance of 0.29 was observed.

Tolerance Limits

Table 16: Tolerance limits for inland surface waters

S. No.	Characteristic	Tolerance	Observed Values in Upper Lake
(i)	pH	6.5 to 8.5	7.5 - 9.3
(ii)	Dissolved Oxygen, mg/l,	6	5.2 - 13.8
(viii)	Total Dissolved Solids, mg/l, Max	500	110 - 168
(ix)	Total Hardness (as CaCO ₃), mg/l, Max	300	
(x)	Calcium Hardness (as CaCO ₃), mg/l, Max	200	50 - 124.8
(xi)	Magnesium (as CaCO ₃), mg/l, Max	100	1.1 - 7.2
(xv)	Chlorides (as Cl), mg/l, Max	250	19 - 69

Conclusion

The majority of aquatic organisms prefer a pH range of 6.5-9.0, although some organisms can thrive well in water with pH outside these limits. In general any deviation from this limit (high or low) is having deleterious effects on aquatic organisms and reduces the survival rate as well as hatching period. Further deviation from the prescribed limits of optimum pH increases mortality rate and more specifically sensitive species are bound to be effected. In addition of biological effects, extreme pH level increases the solubility of compounds which enhances the mobility of toxic chemicals and ultimately increases its absorption by aquatic organisms. Humans can tolerate wide range of pH from 4 - 11 without substantial gastrointestinal irregularities. pH greater than 11 can cause eye and skin irritation. In Upper Lake Bhopal observed pH ranges from 7.5 -9.3 during summer season which shows the tendency of Lake to mobilize the toxic chemicals.

Dissolved oxygen is one of the most widely used indicator of water quality indicator apart from coliform, DO content

approaching 5mg/l puts aquatic life under stress. In general, lower the dissolved oxygen concentration in water higher the stress level is found in aquatic fauna and results in a condition called anorexia which ultimately causes death of an organism. Higher level of DO is good indicator of aquatic life, but increases metal corrosion. Biochemical oxygen demand is a measure of oxygen quantity utilized by aerobic bacteria when large quantity of organic matter is present for decomposition caused by death of plants, leaf fall, runoff, untreated sewage, leakage, septic tanks and floods. These aerobic bacteria compete for oxygen and decrease its concentration, If DO approaches 5ppm causes visual effects in fishes which cannot tolerate it for long duration. This whole process results in transition in diversity where sensitive species are replaced by tolerant ones. The observed value of DO in Upper Lake, Bhopal ranges fluctuates from 5.2-13.8 mg/L. According to Environment Protection Agency drinking water standard there is no category of water Hardness. Hard water increases the demand of detergents and more quantity of soaps. On the other hand National Academy of Science ardently states that

an average calcium level in Fairfax Water Hardness Scale could contribute 5-10 percent daily requirement of daily allowance of calcium for population. The average water condition in Upper Lake, Bhopal fluctuates from moderately Hard to Hard waters.

As is evident from Indian drinking water standard, the values observed from Upper Lake, Bhopal are either crossing the limits of maximum allowable concentration limits or remain below the permissible limits. Hence, it is inferred that no value matches with standard table which depicts the disturbed ecological status and deteriorating water quality.

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