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MONITORING WATER BODY: SEASONAL VARIATIONS IN PHYSICO-CHEMICAL PARAMETERS AND THEIR CORRELATION AMONGS THEM AT HIGH ALTITUDE YASHWANT LAKE OF TORANMAL (M.S.) INDIA.

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Short Profile

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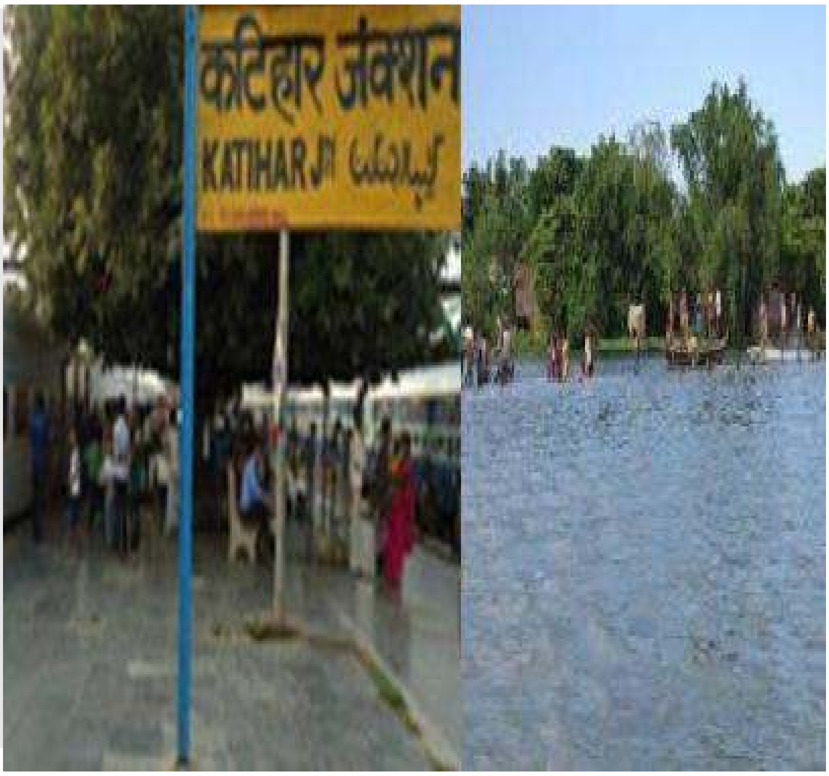

ABSTRACT:

Yashwant lake is located on Toranmal Plateau, one of the important plateaus in mid Satpura ranges. Extending between 21° 54´ North to 21° 61´ latitude and 74° 26´ to 74° 34´ East longitude. Surface water samples were collected from three selected stations of Yashwant lake namely YLA, YLB and YLC between 8 a.m. to 10 a.m. The study site was visited at an interval of fifteen days and monthly mean was taken for calculation (December 2006 to November 2008). The physical parameters such as Atmospheric Temperature (AT), Water Temperature (WT), Transparency (Trans.), Water Cover (WC), Total Solids (TS), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) and chemical parameters such as PH, Acidity (Aci), Alkalinity (Alk), Carbon-dioxide, Dissolved Oxygen (DO), Total Hardness (TH), Chlorides (Cl-), etc. were assessed in the laboratory. Significant positive or negative correlations were established among physico-chemical parameters.

KEYWORDS

Yashwant lake, Toranmal Plateau, High altitude, Physical parameters, Chemical parameters, Seasonal variations.

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INTRODUCTION

Fresh water is one of the basic needs of the mankind and is vital to all forms of life. For limnological studies understanding physico-chemical factors influencing the trophic dynamics of the aquatic system is fundamental. Each factor plays its unique role in the system but at the same time the final effect is the actual result of the interaction of these factors. All the physico-chemical variables influence gross primary productivity (GPP) of aquatic system but the magnitude of their influence differ significantly (Murugavel and Pandian, 2000). The metabolic activities of phytoplanktons-the primary producers depend on the physico-chemical factors of the aquatic environment (Hulyal and Kaliwal 2009), and the changes in physico-chemical parameters lead to changes in the plankton density which in turn influence faunal diversity and presence of some immigrant species in the lentic zone of reservoir (Ayoade *et al*., 2009). The physical and chemical properties of a fresh water body are characteristic of the climatic, geochemical, geomorphological and pollution conditions prevailing in the drainage basin and the underlying aquifer (Ramchandra *et al*., 2002). The monitoring of the surface water quality by hydrobiological parameters is among fundamental environmental priorities, because it also permits direct estimation of the conditions of the aquatic ecosystems exposed to deleterious anthropogenic factors.

The demand of water requirements has increased with burgeoning human population coupled with agricultural and industrial developments. Hence, the restoration, conservation and management of the water resources require thorough understanding of the system. Understanding of environmental changes is also necessary for the protection for remediation. Thus, monitoring and assessment of a system can provide basic information on the condition of the water bodies. With the help of study the interaction of all physical, chemical and biological components, one can design restoration methods towards conservation, management and sustainable use of a habitat. This may be useful in characterizing water bodies and their integrity too.

The physical parameters define those characteristics of water that respond to the sense of sight, touch, taste, odor and temperature; chemical parameters are related to the solvent capabilities like Total dissolved solids, Alkalinity, Hardness, Chlorides, Metals and nutrients while biological parameters Measures density and diversity of various biota. Though physico-chemical approach to monitor water pollution is most common and plenty of information is available on these aspects, it may not provide all the information required at the local level and thus assessment of water quality of all the water bodies becomes essential. Hence, a study of physical and chemical parameters was carried out at 'The Yashwant lake' of Toranmal area.

MATERIALS AND METHODS

Study area

Yashwant lake is located on Toranmal Plateau, one of the important plateaus in mid Satpura. This plateau forms a table land on the summit, covering about 41 Sq.Km. area at 1155 meter altitude (AMSL) extending between 21° 54´ North to 21° 61´ latitude and 74° 26´ to 74° 34´ East longitude. With its extensive historical background as the capital of King Yuvanashav during Mahabharata period, it is a pre-eminent hill station and famous tourist spot in the North Western Maharashtra. It is situated 140

Km. North of Dhule, and 90 Kms East of Nandurbar, the district capitals of Maharashtra. Toranmal plateau is a quantum part of Satpura mountains forming the cultural transition with its trijunctional location between Maharashtra, Madhya Pradesh and Gujarat. Because of remoteness and inaccessibility, it is almost neglected and has remained as an isolated ecosystem. Hence, the attention of Environmentalists, Naturalists, Geographers, Ecologists, Geomorphologists and Biologists is required to identify its environment with biodiversity and scenic beauty. Located on a horst block between Narmada graban on north and Tapi in the south it is surrounded by many small residual hills with local relief of about 30 to 40 meters, surrounded by the plateau from all sides.

Yashwant lake has a perimeter of 2.75 Km. and spreads in 39 hectares. It was constructed during British period by damming the dip gorge. The gravel embankment around 400m on the north east side arrests the main flow of the stream.

Surface water samples were collected from three selected stations of Yashwant lake namely YLA, YLB and YLC between 8 a.m. to 10 a.m. The study site was visited at an interval of fifteen days and monthly mean was taken for calculation (December 2006 to November 2008). Total 24 visits were made per year and 48 visits during the study period. To collect water samples for analysis, plastic containers of two litre capacity were used. Containers were thoroughly cleaned, washed and rinsed before every collection. Separate containers were labeled station wise to indicate date and location and brought to the laboratory. The parameters such as Atmospheric Temperature (AT), Water Temperature (WT), Transparency (Trans.), Water Cover (WC) and Carbon-dioxide were analyzed at station itself and Dissolved Oxygen (DO) was fixed in separate BOD sample bottles. Analysis of other parameters such as Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Acidity (Aci), Alkalinity (Alk), Total Hardness (TH), Chlorides (Cl-) and pH, were carried out in the laboratory by using standard methods by APHA (1998), Michael (1984). To retain the chemical properties all the samples were protected from heat and direct sunlight during transportation until estimation.

RESULTS

For the convenience of presentation the physico-chemical parameters were divided into three groups:

Results are mainly considered for YLC and wherever required values for other sites are given.

Group I:

1) Atmospheric temperature (AT)

Atmospheric temperatures were same at all the three stations with minor differences in mean values (Table 3.1). They were minimum in winter around 17 ^{0}C and maximum in summer around 24 ^{0}C.

2) Water temperature (WT)

The water temperature followed same trend as that of atmospheric temperature (Table 3.1). However, during winter water temperature was about 1 ^{0}C higher than atmospheric temperature around 18.5 ^{0}C while during other seasons it was 1 to 3 ^{0}C lower around 22 ^{0}C in summer, 21 ^{0}C in monsoon and 19 °C in post monsoon. Seasonal variations for AT and WT were noted at $P < 0.0001$.

3) Water Cover (WC)

Percentage of water cover was recorded for whole Lake so the value for all stations was same (Table 3.1). It was Maximum in post monsoon (92.5 ± 1.1 %). It slightly decreased in winter (85.8 ± 1.5 %) and was recorded minimum in summer (66.67 ± 2.4 %). With the onset of monsoon it started increasing reaching mean value of 77.50 ± 3.5 % with seasonal variations at $P < 0.0001$.

Table: 3.1 Average seasonal variations in Atmospheric Temperature (AT) (°C), Water Temperature (WT) (°C) and Water Cover (WC) (%) at station YLA, YLB and YLC of Yashwant lake during November 2006 to December 2008

Sr. No	Parameters	Station with F-value	Winter	Summer	Monsoon	Pt.Mon.
1	AT °C	YLA $F_{3,20}$ 27.51	17.25 ± 0.55	24.50 ± 0.65	22.83 ± 0.38	20.75 ± 0.72
		YLB $F_{3,20}$ 22.57	17.67 ± 0.54	24.08 ± 0.75	22.92 ± 0.50	20.92 ± 0.52
		YLC $F_{3,20}$ 27.95	17.75 ± 0.62	24.50 ± 0.60	23.08 ± 0.32	20.58 ± 0.62
2	WT °C	YLA $F_{3,20}$ 12.47	18.42 ± 0.20	21.83 ± 0.45	20.42 ± 0.47	19.17 ± 0.49
		YLB $F_{3,20}$ 9.073	18.75 ± 0.21	21.58 ± 0.50	20.75 ± 0.44	19.67 ± 0.42
		YLC $F_{3,20}$ 18.85	18.75 ± 0.30	22.00 ± 0.46	21.17 ± 0.38	19.17 ± 0.24
3	Water Cover %	YL $F_{3,20}$ 21.95	85.83 ± 1.53	66.67 ± 2.47	77.50 ± 3.59	92.50 ± 1.11

Group II:

4) Transparency (Trans. meters)

With the nonsignificant differences among the three stations, maximum transparency was recorded at YLB (1.48 ± 0.01 m) in the winter and minimum at YLA (1.15 ± 0.01 m) in the monsoon (Table 3.2). Compared to winter it decreased marginally in the summer and post-monsoon. Transparency showed variations at $P < 0.0001$.

5) Total Solids (TS mg/L)

Total solids in water were higher at YLC as compared to YLA and YLB (Table 3.2) in all the seasons and fluctuated in accordance. They were maximum 170.8 ± 2.33 mg/L during monsoon that decreased to 146.3 ± 4.36 mg/L in post monsoon and further declined to 136 ± 1.7 mg/L in winter but increased to 160 ± 4.52 mg/L in summer at YLC.

6) Total Dissolved Solids (TDS mg/L)

TDS was maximum 133 ± 2.9 mg/L in summer and minimum 108.8 ± 2.79 mg/L in postmonsoon. While it was 112.3 ± 2.26 mg/L in winter and 128.3 ± 2.17 mg/L in monsoon at YLC (Table 3.2). The trends were same at other two stations but were nonsignificantly low.

7) Total Suspended Solids (TSS mg/L)

TSS levels showed same trend at all the three stations as that of TS (Table 3.2). However, at YLA and YLC minor differences were noted. At YLC it was maximum 42.5 ± 2.17 mg/L in monsoon and minimum 23.67 ± 1.14 mg/L in winter, while it was 26.5 ± 1.52 mg/L in summer and 37.5 ± 1.6 mg/L in post monsoon, with variations at $P < 0.0001$ across the season.

In short, transparency was higher at YLB and lowest at YLA where as TS, TDS and TSS were higher at YLC and lowest at YLB. TSS showed same results at YLA and YLB during winter and monsoon.

Table: 3.2 Average seasonal variations in Transparency (Trans.), Total Solids (TS), Total Disolved Solids (TDS) and Total Suspended Solids (TSS) at station YLA, YLB and YLC of Lake during November 2006 to December 2008

Sr. No.	Para-meters	Stations with F value	Winter	Summer	Monsoon	Postmonsoon
1	Trans. mts.	YLA $F_{3, 20}$ 20.12	1.38 ± 0.01	1.277 ± 0.008	1.155 ± 0.01	1.22 ± 0.03
		YLB $F_{3, 20}$ 34.34	1.48 ± 0.01	1.34 ± 0.017	1.19 ± 0.02	1.27 ± 0.02
		YLC $F_{3, 20}$ 24.85	1.44 ± 0.01	1.30 ± 0.01	1.168 ± 0.01	1.24 ± 0.03
2	TS mg/L	YLA $F_{3, 20}$ 22.28	131 ± 0.85	150.3 ± 3.48	161.2 ± 1.35	138 ± 4.16
		YLB $F_{3, 20}$ 11.89	126 ± 2.03	145.3 ± 3.94	152.8 ± 2.52	131.2 ± 5.06
		YLC $F_{3, 20}$ 19.50	136 ± 1.71	160 ± 4.52	170.8 ± 2.33	146.3 ± 4.36
3	TDS mg/L	YLA $F_{3, 20}$ 22.66	109.7 ± 1.74	126.8 ± 2.18	123.7 ± 1.94	105.7 ± 2.71
		YLB $F_{3, 20}$ 13.83	105.2 ± 2.38	120.2 ± 1.93	115.3 ± 1.70	101 ± 3.21
		YLC $F_{3, 20}$ 21.24	112.3 ± 2.26	133 ± 2.95	128.3 ± 2.17	108.8 ± 2.79
4	TSS mg/L	YLA $F_{3, 20}$ 23.74	21.33 ± 1.20	23.50 ± 1.33	37.50 ± 1.92	32.33 ± 1.64
		YLB $F_{3, 20}$ 14.70	20.83 ± 1.47	25.17 ± 2.16	37.50 ± 1.82	30.17 ± 1.93
		YLC $F_{3, 20}$ 29.16	23.67 ± 1.14	26.50 ± 1.52	42.50 ± 2.17	37.50 ± 1.60

Group III

8) pH : pH showed parallel fluctuations at the three stations but it was nonsignificantly higher at YLA and lower at YLC as compared to YLB (Table 3.3). However, seasonal variations at all the three stations were significant at $P < 0.0001$. pH of water at YLC was highest 8.2 ± 0.09 in summer which declined to 7.9 ± 0.06 in monsoon to 7.5 ± 0.04 in post-monsoon and decreased further in winter to 7.36 ± 0.05.

9) Acidity : Acidity also showed parallel fluctuations at the three stations (Table 3.3). It was non-significantly lower at YLB and YLC. Acidity was maximum 18.75 ± 0.3 mg $CaCO_3$/L in summer that declined to 16.17 ± 0.7 mg $CaCO_3$/L during monsoon to 10.5 ± 0.4 mg $CaCO_3$/L in post-monsoon and was maintained in winter at 10.83 ± 1.1 mg $CaCO_3$/L at YLA.

10) Alkalinity : Maximum 115.4 ± 1.6 mg $CaCO_3$/L alkalinity was reported in summer and minimum 85.4 ± 2.8 mg $CaCO_3$/L in post-monsoon at YLC with 89.58 ± 4.1 mg $CaCO_3$/L in winter and 107.9 ± 2.8 mg $CaCO_3$/L in monsoon which was lower than the other two sites (Table 3.3). The seasonal variations were significant at $P < 0.0001$ at the three stations.

11) Dissolved Oxygen (DO) : The DO was marginally non significantly higher at YLC compared to YLA and YLB (Table 3.3). It oscillated from maximum 12.93 ± 0.41 mg/L in winter to 9.73 ± 0.31 mg/L in summer, 11.6 ± 0.38 mg/L in monsoon and 10.63 ± 0.14 mg/L in post-monsoon. Dissolved oxygen also showed variations at all the three stations at $P < 0.0001$.

12) Carbon dioxide (CO_2) : CO_2 levels were also non-significantly higher at YLC compared to YLA and YLB with maximum 4.23 ± 0.3 mg/L in summer falling to 3.5 ± 0.1 mg/L in monsoon and further declining to 2.75 ± 0.2 mg/L in post-monsoon and reaching to minimum 0.96 ± 0.2 mg/L in winter with $P < 0.0001$ (Table 3.3).

13) Total Hardness (TH): Total hardness of water was lower at YLC as compared to YLA and YLB (Table 3.3). It was minimum 49.33 ± 2.1 mg/L in monsoon, which started increasing in postmonsoon with 52.33 ± 1.2 mg/L and winter with 58.67 ± 0.9 mg/L and reached to the maximum level at 65 ± 0.8 mg/L in summer. Total hardness showed significant variations at all the three stations across the seasons with $P < 0.0001$.

14) Chloride (Cl-) : At YLC maximum 27.17 ± 0.7 mg/L chloride was observed in summer that declined to 22.83 ± 0.9 mg/L in monsoon and reached to minimum level at 14.0 ± 0.6 mg/L in post- monsoon (Table 3.3). It started increasing in winter with 17.33 ± 1.1 mg/L. Though seasonal variations were in accordance to YLA and YLB, the chloride at YLC was lower than the other two stations. Chloride showed variations across the season at all the three stations with $P < 0.0001$.

Table: 3.3 Average seasonal variations in pH, Acidity (Aci.), Alkalinity (Alk.), Dissolved Oxygen (DO), Carbon-dioxide (CO_2), Total Hardness (TH) and Chlorides(Cl-) at station YLA, YLB and YLC of Yashwant lake during November 2006 to December 2008

Sr. No.	Param -eters	Stations with F value	Winter	Summer	Monsoon	Postmonsoon
1	pH	YLA $F_{3, 20}$ 31.53	7.51 ± 0.03	8.35 ± 0.10	8.03 ± 0.06	7.70 ± 0.04
		YLB $F_{3, 20}$ 19.93	7.48 ± 0.047	8.23 ± 0.11	7.9 ± 0.076	7.65 ± 0.04
		YLC $F_{3, 20}$ 28.56	7.36 ± 0.055	8.2 ± 0.096	7.9 ± 0.068	7.53 ± 0.049
2	Aci.	YLA $F_{3, 20}$ 28.08	11.92 ± 0.96	18.75 ± 0.72	17.42 ± 0.65	11.08 ± 0.49
		YLB $F_{3, 20}$ 31.28	11.17 ± 0.98	18.42 ± 0.56	16.75 ± 0.69	11.08 ± 0.23
		YLC $F_{3, 20}$ 25.87	10.83 ± 1.19	18.17 ± 0.38	16.17 ± 0.70	10.50 ± 0.46
3	Alk.	YLA $F_{3, 20}$ 14.86	96.25 ± 4.90	120 ± 1.44	113.3 ± 2.86	91.67 ± 3.85
		YLB $F_{3, 20}$ 12.09	94.58 ± 5.45	116.3 ± 1.67	110.4 ± 2.98	89.17 ± 3.57
		YLC $F_{3, 20}$ 23.19	89.58 ± 4.1	115.4 ± 1.6	107.9 ± 2.8	85.42 ± 2.8
4	DO	YLA $F_{3, 20}$ 21.16	12.23 ± 0.26	8.96 ± 0.38	10.80 ± 0.33	9.91 ± 0.17
		YLB $F_{3, 20}$ 18.13	12.63 ± 0.34	9.45 ± 0.33	11.28 ± 0.37	10.37 ± 0.18
		YLC $F_{3, 20}$ 17.00	12.93 ± 0.41	9.73 ± 0.314	11.60 ± 0.38	10.63 ± 0.14
5	CO_2	YLA $F_{3, 20}$ 26.13	0.716 ± 0.37	4.03 ± 0.28	3.35 ± 0.20	2.56 ± 0.22
		YLB $F_{3, 20}$ 33.79	0.73 ± 0.26	4.06 ± 0.32	3.38 ± 0.19	2.63 ± 0.18
		YLC $F_{3, 20}$ 32.81	0.96 ± 0.27	4.23 ± 0.3	3.51 ± 0.17	2.75 ± 0.21
6	TH	YLA $F_{3, 20}$ 26.41	60.33 ± 0.61	67.67 ± 1.40	51.00 ± 1.98	56.33 ± 1.08
		YLB $F_{3, 20}$ 47.06	60.67 ± 0.84	66.33 ± 0.95	50.0 ± 1.26	55.67 ± 0.95
		YLC $F_{3, 20}$ 25.54	58.67 ±0.98	65 ±0.88	49.33 ±2.1	52.33 ±1.2
7	Cl	YLA $F_{3, 20}$ 29.21	19.00 ± 1.31	29.5 ± 1.43	25.33 ± 0.95	15.83 ± 0.70
		YLB $F_{3, 20}$ 27.84	18.33 ± 1.40	27.83 ± 1.13	24.83 ± 1.13	14.83 ± 0.70
		YLC $F_{3, 20}$ 42.08	17.33 ± 1.14	27.17 ± 0.74	22.83 ± 0.94	14.0 ± 0.68

Acidity and Alkalinity are measured in terms of mg $CaCO_3$/L.

DO, CO_2, TH, and Cl- are measured in terms of mg/L.

Table 3.5 Intra Pearson Correlation between physico-chemical parameters of YLA at Yashwant lake during Dec. 2006 to Nov. 2008

	ACI	ALK	AT	Cl	CO_2	DO	NO_2^-	NO_3^-	pH	PO_4^{-3}	TDS	TH	TRANS	TS	TSS	WC	WT
ACI	1																
ALK	.942**	1															
AT	.813**	.707**	1														
Cl	.955**	.864**	.772**	1													
CO_2	.806**	.724**	.965**	.757**	1												
DO	-.574**	-.487*	-.844**	-.556**	-.871**	1											
NO_2^-	.547**	.417*	.670**	.443*	.672**	-0.347	1										
NO_3^-	-0.063	-0.146	0.124	-0.183	0.106	0.14	.749**	1									
pH	.883**	.770**	.897**	.886**	.885**	-.788**	.534**	-0.073	1								
PO_4^{-3}	.682**	.571**	.811**	.581**	.790**	-.488*	.942**	.597**	.701**	1							
TDS	.952**	.854**	.809**	.964**	.771**	-.546**	.570**	-0.013	.873**	.678**	1						
TH	0.304	0.323	0.177	.412*	0.194	-.453*	-.515*	-.885**	.411*	-0.315	0.254	1					
TRANS	-0.379	-0.34	-.620**	-0.228	-.641**	0.388	-.898**	-.750**	-0.386	-.853**	-0.372	.545**	1				
TS	.754**	.602**	.804**	.712**	.765**	-.475*	.910**	.515*	.738**	.919**	.828**	-0.238	-.743**	1			
TSS	0.029	-0.106	0.315	-0.061	0.298	-0.091	.832**	.932**	0.11	.700**	0.095	-.772**	-.808**	.637**	1		
WC	-.882**	-.767**	-.770**	-.848**	-.754**	.495*	-.687**	-0.167	-.815**	-.753**	-.907**	-0.068	.483*	-.857**	-0.273	1	
WT	.810**	.686**	.880**	.849**	.841**	-.764**	.479*	-0.113	.908**	.620**	.849**	0.377	-0.338	.712**	0.095	-.802**	1

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

Table 3.6 Intra Pearson Correlation between physico-chemical parameters of YLB at Yashwant lake during Dec. 2006 to Nov. 2008

	ACI	ALK	AT	Cl	CO_2	NO_2^-	NO_3^-	DO	pH	PO_4^{-3}	TDS	TH	TRNS	TS	TSS	WC	WT
ACI	1																
ALK	.908**	1															
AT	.839**	.741**	1														
Cl	.955**	.890**	.745**	1													
CO_2	.832**	.713**	.974**	.725**	1												
NO_2^-	.408*	0.316	.548**	0.315	.539**	1											
NO_3^-	-0.244	-0.264	-0.098	-0.292	-0.098	.726**	1										
DO	-.638**	-.553**	-.824**	-.512*	-.864**	-0.15	.410*	1									
pH	.916**	.810**	.903**	.876**	.914**	0.371	-0.294	-.788**	1								
PO_4^{-3}	.623**	.513*	.795**	.523**	.776**	.921**	.483*	-.425*	.639**	1							
TDS	.872**	.822**	.723**	.923**	.715**	0.367	-0.178	-.489*	.820**	.554**	1						
TH	0.24	0.217	0.078	0.321	0.091	-.732**	-.918**	-0.369	0.311	-.481*	0.242	1					
TRNS	-0.365	-0.298	-.642**	-0.196	-.653**	-.891**	-.601**	.405*	-.420*	-.883**	-0.254	.631**	1				
TS	.708**	.593**	.729**	.715**	.736**	.751**	0.293	-0.389	.714**	.841**	.844**	-0.213	-.626**	1			
TSS	0.182	0.037	.407*	0.131	.427*	.890**	.749**	-0.087	0.257	.818**	0.266	-.686**	-.806**	.742**	1		
WC	-.895**	-.836**	-.708**	-.933**	-.693**	-0.139	.491*	.573**	-.867**	-0.399	-.848**	-.461*	0.077	-.592**	-0.005	1	
WT	.768**	.629**	.881**	.752**	.836**	0.38	-0.207	-.707**	.848**	.663**	.714**	0.207	-0.383	.670**	0.31	-.735**	1

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

Table 3.7 Intra Pearson Correlation between physico-chemical parameters of YLC at Yashwant lake during Dec. 2006 to Nov. 2008

	ACI	ALK	AT	CI	CO_2	DO	NO_2^-	NO_3^-	pH	PO_4^{-3}	TDS	TH	TRANS	TS	TSS	WC	WT
ACI	1																
ALK	.944**	1															
AT	.848**	.779**	1														
CI	.950**	.910**	.790**	1													
CO_2	.827**	.740**	.969**	.736**	1												
DO	-.630**	-.571**	-.769**	-.514*	-.849**	1											
NO_2^-	0.324	0.307	.525**	0.206	.527**	-0.16	1										
NO_3^-	-0.253	-0.27	-0.096	-0.36	-0.097	0.377	.738**	1									
pH	.919**	.869**	.915**	.883**	.908**	-.762**	0.332	-0.272	1								
PO_4^{-3}	.607**	.622**	.759**	.523**	.752**	-.469*	.726**	0.208	.667**	1							
TDS	.930**	.854**	.821**	.954**	.790**	-.516**	0.379	-0.155	.888**	.609**	1						
TH	0.377	0.347	0.181	.515**	0.182	-0.389	-.657**	-.926**	0.37	-0.22	0.36	1					
TRANS	-0.379	-0.346	-.658**	-0.211	-.669**	.413*	-.919**	-.602**	-.444*	-.729**	-0.363	.580**	1				
TS	.726**	.622**	.807**	.673**	.805**	-.428*	.781**	0.348	.747**	.755**	.835**	-0.151	-.745**	1			
TSS	0.004	-0.08	0.292	-0.124	0.333	-0.034	.880**	.852**	0.087	.502*	0.103	-.784**	-.833**	.633**	1		
WC	-.842**	-.809**	-.797**	-.830**	-.764**	.479*	-.587**	-0.06	-.821**	-.664**	-.884**	-0.124	.518**	-.838**	-0.274	1	
WT	.885**	.819**	.904**	.885**	.876**	-.652**	0.387	-0.201	.933**	.686**	.904**	0.339	-.438*	.788**	0.14	-.858**	1

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

DISCUSSION

1) Temperature: Water temperature is one of the most important factors which controls the physiological behavior and distribution of aquatic organisms and has effect on natural environment. This is reflected by lower water temperature at Yashwant Lake in monsoon due to cloudy weather and influx of rain water while in winter due to cold climatic conditions of higher altitude with shorter sunshine period. A pattern also observed by Zafar (1964); Munnawar (1970); Swarnalatha, (1994); Rajasegar (2003) and Singhai et al. (1990). A close correlation is evident between atmospheric and water temperature (Pearson correlation is significant at the 0.01 level Table 3.5, 3.6 and 3.7) with no significant differences in temperature at the three stations (YLA, YLB, YLC) of the Lake (Table 3.1). Temperature is also known to influence water chemistry-the parameters like Dissolved Oxygen, Solubility, pH, conductivity, etc. (Ramachandra and Solanki, 2007). In general water holds lesser oxygen as the temperature increases (Awasthi and Tiwari, 2004) hence an inverse relationship between the two, but a positive significant correlation with Alkalinity, Acidity, Atmospheric temperature, Chloride, CO_2, pH, Phosphate, TDS, TS and water cover is noted at 0.01 level in the present study.

With reference to thermal lag between AT and WT and annual variations in temperature, Jaychandra and Joseph (1988) recorded maximum difference of 2.7 ^{0}C between AT and WT at a tropical Vellayani Lake in Kerala while Kanan and Job (1980) have reported a difference of 5.5 ^{0}C, and Sreenivasan (1964) a difference of 6 ^{0}C in Bhavani Sagar reservoir. In the present study mean difference between AT and WT were between 2.56 ^{0}C to 1.42 ^{0}C respectively in summer and winter with Atmospheric temperature lower than Water Temperature in winter and vise a versa in summer.

2) Water Cover: Large lakes are typically repositories of the greatest numbers of species, because their greater surface area provides more opportunities for colonization. They contain a greater variety of microhabitats and their internal environmental conditions are more stable compared to smaller water bodies (Pip, 1987). However, ponds are the examples of a patchily distributed habitat whose biodiversity has to cope up with conditions and events such as the physico-chemical changes, resource availability, biotic interactions, etc. The potential of surrounding landscape also influences the conditions within a patch and effects the dispersal between patches (Andrew and Michael, 2009).

The high DO in the reservoirs compared to the tanks are related to slightly lower temperatures, more water level, larger surface area (water cover) and therefore, more dissolution of atmospheric oxygen (Hegde and Hudder, 1995). Hence, water cover was positively correlated to DO at Yashwant Lake. At Yashwant Lake water cover starts increasing in monsoon due to rain water and continues to rise slowly upto post-monsoon as water is brought to Lake via streams present in the forest surrounding the Lake (Table 3.1). It is minimum in summer due to the evaporation, percolation of water as well as due to the usage for domestic purpose by the people of Toranmal village. This creats an irregular shoreline that encompasses more littoral formations at the area of land and water interface. A high value of shoreline development index is believed to be indicative of productive nature of the water body (Sugunan, 2000).

3) Transparency: The transparency of water reflects seasonal variations with maximum transparency in winter when water level has stabilized and (Table 3.2) minimum in monsoon when the rain water run off brings soil particles like silt and mud with other inorganic matter from catchment area making the water turbid. This is a common phenomenon noted for several waterbodies especially in Indian climatic

condition. (Zafar, 1964; Kanungo and Naik, 1987; Singhai *et al*., 1990; Kaur *et al*.,1995). The area around Yashwant lake receives around 1600 mm annual rainfall during South West monsoon (June to August). The heavy rains, deforestation, human activities, etc. are main causes of soil runoff that lowers transparency of water (Coker, 1954). This is reflected by high total solids in monsoon, obstructing light penetration in water. The transparency and total solids are negatively significantly correlated at YLA, YLB and YLC (Table 3.5, 3.6 and 3.7). The turbidity of this type is temporary as the particles settle down due to gravitation of their own weight. Low transparency affects the aquatic ecosystem influencing its productivity, as the rate of photosynthesis by submerged macrophytes decreases. Further, the excess amount of hardness in water also reduces the penetration of light (Welch, 1986; Shukla and Bais, 1990). The water of the Yashwant Lake is soft (At YLA: Maximum 67.6 ± 1.4 mg $CaCO_3$/L and Minimum 51 ± 1.9 mg $CaCO_3$/L). Here, the transparency is positively correlated with total hardness at 0.05 levels, while it is negatively correlated with Atmospheric Temperature, CO_2, NO_{2-}, NO_{3-}, PO_4^{-3}, TS and TSS at 0.01 level.

Non-significant increase in transparency was observed from post-monsoon onwards as the silt started settling down increasing transparency to maximum level in winter. Decrease in transparency during summer may be attributed to increase in hardness noted in present study. Increased hardness during summer indicates increase in amount of dissolved solids that decreases light penetration leading to decrease in transparency.

Studies of Eggermont, *et al.*, (2007) using redundancy analysis (RDA) showed that the transparency is also affected due to different types of vegetation in catchment area. However, in the present study the Lake is surrounded by deciduous forest for which the correlation is still to be evaluated.

4) Total Solids (TS), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS): As discussed earlier higher concentration of TDS increases water turbidity which in turn decreases the light penetration in water. This affects the photosynthesis thereby suppressing the primary production in the form of algae and microphyte. Positive significant correlation is expected between TDS, TS and TSS as is noted at all the three stations YLA, YLB and YLC (Table 3.5, 3.6 and 3.7). However, the significantly negative correlations between TDS and DO at YLA and YLC and positively significant correlation with CO_2 at all the three stations indicate decline in photosynthetic activity due to lower light penetrance. The TDS is positively significantly correlated with Acidity, Alkalinity, AT, Cl-, NO_{2-}, NO_{3-}, pH, PO_4^{-3} and WT at all the three stations except NO_2- at YLB and YLC.

The highest TDS recorded in summer at all the three stations may be due to decaying vegetation (Table 3.2). The products of decaying vegetation at the surface when starts sinking may increase the TSS as well as TDS (Khan and Khan, 1985; Iqbal and Kataria, 1995). The wetlands acts as sinks for nutrient deposition hence, the high TDS values may also depend on the age of the Lake (Anitha *et al*., 2005) as a result of gradual salt deposition, an observation not always applicable for monsoonal wetlands. However, at Yashwant Lake all the values of TDS were within the permissible limits of 500 mg/L (BIS, 1991).

The higher TSS during monsoon reflects the addition of suspended solids from the runoff water, which starts settling down slowly in post-monsoon and results in minimum TSS during winter (Table 3.2). Increased level of suspended solids, result in increased turbidity and decreased photosynthesis, rise in water temperature and decreased dissolved oxygen (Sharma, *et al.*, 2008). The TSS at Yashwant Lake of the three stations ranged between 20.8 ± 1.4 to 42.5 ± 2 mg/L which are within the permissible limits of WHO standards i.e. below 500 mg/L. Total solids being TSS + TDS correspond to changes in both these parameters too.

5) pH: Natural waters are usually alkaline due to presence of high concentration of carbonates. However, considerable fluctuations in pH can be observed in natural waters during day, as well as over the month and the year, caused by exposure to air and biological activities. In present investigation pH varied between 7.3 ± 0.05 at YLC to 8.3 ± 0.1 at YLA (Table 3.3). The higher value of pH during summer may be due to increased photosynthetic activity by phytoplankton and macrophytes decreasing CO_2 levels that are known to lower the pH towards acidity. Higher the photosynthesis more O_2 production and more CO_2 utilization, increasing the pH (Satpathy *et al.*, 2007). According to Boyd and Pillai (1984) photosynthetic activity leads to following reaction,

$$2HCO_3 \rightarrow CO_2 + CO_3^{2-} + H_2O$$

As plants remove CO_2 from water for use in photosynthesis, carbonates accumulate and subsequently undergo hydrolysis as follows:

$$CO_3^{2-} + H_2O \rightarrow HCO_3- + OH-$$

With reference to accumulation of OH- that causes the pH to rise, (Sarwar and Wazir, 1991), Yashwant Lake can be categorized as 'slightly alkaline' due to the predominance of calcium, carbonates as well as bicarbonates, the ions that influence the pH of water (Pearsall, 1930 and Zafar, 1966).

Variation in pH may also be due to the human activities (addition of sewage and industrial effluent etc.) as well as natural processes such as ground water leaching of carbonate minerals (Skoulikidis et al., 1998).

The pH of Lake water is positively correlated with hardness as is also reported by Rao, (1955); Zafar, (1964); David and Savita, (1995). The pH was observed to decline during winter and increase during summer as is evident from the observations. Studies on the pH under present investigation did not reveal much variation at different sampling stations and alkaline trend was maintained all throughout the year.

The water which has a pH value of more than 9.6 or less than 4.5 becomes unsuitable for most living organisms and for other uses (Dwivedi and Sonar, 2004a). In the present study the pH levels were within the limits set for the protection of aquatic life i.e. 6.5 to 9 (U.S. EPA, 2002), irrigation 5.5 to 9 and for drinking water ISB standard 6.5 to 8.5. This indicates that the pH of the Yashwant lake is well in the permissible limit for various uses.

6) Acidity: Higher acidity at irrigation reservoirs has been proposed due to initial acidic rains as well as agricultural runoff during monsoon (Deshkar, 2008). However, at Yashwant lake acidity was minimum during post-monsoon at all the three stations as this is the period immediately after precipitation which leads to dilution. The maximum acidity recorded was 18.7 mg $CaCO_3$/L at YLA in summer much below the threshold value (Table 3.3). Hence, the acidity in water of Yashwant lake is very low. Here a positive significant correlation of acidity is established with Alkalinity, AT, Chloride, Carbon dioxide, pH, NO_2-, PO_4^{-3}, TDS, TS, WT and negative correlation with DO and WC (Table 3.5, 3.6 and 3.7).

Alkalanity: In the present study, alkalinity ranged from 120 ± 1.4 mg $CaCO_3$/L at YLA in summer to 85.4 ± 2.8 mg $CaCO_3$/L at YLC in post monsoon (Table 3.3). Seasonal variations in alkalinity with higher values in summer and lower in post-monsoon indicate the concentration of salts in water as a result of evaporation and dilution respectively. As the area is surrounded by forest erosion from rocks is probably low as is also reported by Agrawal and Kanchan (2004) and Radhika *et al*., (2004). Low values of alkalinity conform to the lower pH. There is no standard set for total alkalinity. Alkalinity and pH are the factors responsible for determining the amenability of water to biological treatment (Manivasakum, 1980). Spence (1964) suggested that a water body with alkalinity values above 60 mg/L is nutrient rich and is good for the production of fish-food organisms, while Sugunan (1989) observed that reservoirs having total alkalinity value between 40 – 90 mg/L were medium productive and above 90 mg/L were highly productive. Accordingly, the average total alkalinity of the Lake studied indicates its good productive nature.

Further, positively significant correlations of alkalinity are established with AT, Cl-, CO_2, Acidity, pH, PO_4^{-3}, TDS, TS, WT and negative significant correlation with Dissolved Oxygen and water cover at all the three sampling stations. The alkalinity is also contributed from the soaps and detergents. Results of present study confirm this at YLA where because of domestic washing activities, maximum alkalinity is noted compared to YLB and YLC. Some amount of alkalinity is used by phytoplankton as carbon source (Ahmad and Singh, 1993 and Wani, 1998).

8) Dissolved Oxygen: Survival of aquatic organisms especially fishes depend upon levels of Dissolved Oxygen in the water. During present study, the dissolved oxygen of surface water varied from 12.9 ± 0.4 mg/L to 9.7 ± 0.3 mg/L at YLC in winter and summer respectively (Table 3.3). The maximum dissolved oxygen in winter may be due to higher solubility of oxygen at relatively lower temperature while higher level in monsoon (11.6 ± 0.3 mg/L at YLC) may be attributed to circulation and mixing of water and atmospheric oxygen due to agitation of surface water Vise a versa, the lower values of dissolved oxygen during summer may be attributed to the fact that the warm water holds less oxygen as well as increases the mineralization of non living matter which demands more oxygen (Kumar et al., 2005) decreasing oxygen levels. Tape and Mutlu (2005) have linked the increase in dissolved oxygen in a reservoir in turkey to high run-off occurring during rainy season.

In Yashwant lake positive correlation of dissolved oxygen is noted with NO_3-, Transparency and Water Cover with non significant level at 0.05 level while negative correlation is established with pH, PO_4^{-3}, TDS, WT, Acidity, Alkalinity, Atmospheric temperature, Chloride and CO_2 at all the three stations (Table 3.5, 3.6 and 3.7). The level of oxygen concentration in aquatic ecosystem is dependent on temperature, photosynthetic activity, respiration of biotic communities and organic loading.

Further, with increasing altitude, there is a decrease in atmospheric pressure, implying that oxygen saturation will be lower. However, compensation occurs, because decreasing temperature due to high altitude enhances the solubility of oxygen. Hence, the observed dissolved oxygen level in the Lake is probably the result of these opposing trends, besides biological and other interacting factors as discussed by Green et al. (1996) and Murugavel and Pandian, (2000). The annual mean dissolved oxygen differed non-significantly. Similar trends are observed for a series of Indonesian Lakes situated from 10 to 2125 m altitudes (Green *et al.*, 1996).

Ideal dissolved oxygen for the fish, the final stage of productivity in the fresh water ecosystem is assumed to be between 6 and 7 mg/L (Edmondson, 1960). Water with dissolved oxygen concentration below 2 mg/L is not able to support the life. Low oxygen concentration will also affect the types of fish and invertebrates that inhabit the area (Anonymous, 2005a). It is important to note that low oxygen conditions are common in many lakes during summer when winds that promote mixing are absent and water at the bottom of the lake is slowly depleted of oxygen over the course of the summer (Anonymous, 2005b). Mixing of the water column, as full turnover occurs, typically restores oxygen throughout the Lake to healthy levels. Oxygen in the water is vital for the respiration of the organisms living at the bottom as well as near the surface. When the consumed oxygen is not replaced by new oxygen, insufficiency of oxygen caused is dangerous in terms of the survival of the living beings.

The highest dissolved oxygen recorded at YLC was a good pointer to the fact that the station is most productive with the high water quality parameters and will support diverse organisms.

9) Carbon-Dioxide: Phytoplankton use CO_2 in photosynthesis, the pH of pond water increases as carbonic acid (i.e. CO_2) is removed. Phytoplankton and other plants can also combine with bicarbonates (HCO_3) to form CO_2 for photosynthesis and carbonates (CO_3^{-2}) are released.

$$2HCO_3 + (\text{Phytoplankton}) \rightleftharpoons CO_2(\text{photosynthesis}) + CO_3^{-2} + H_2O$$
$$CO_3^{-2} + H_2O \rightleftharpoons HCO_3^{-} + OH^{-}(\text{Strong base})$$

High pH could also be viewed as a decrease in hydrogen ions (H+).

$$CO_3^{-2} + H^{+} \rightleftharpoons HCO_3^{-} \text{ or}$$
$$HCO_3^{-} + H^{+} \rightleftharpoons H_2O + CO_2$$

As expected inverse relationship between carbon dioxide and dissolved oxygen was noted in waters of Yashwant lake (Table 3.5, 3.6 and 3.7). When carbon dioxide content increases, oxygen content decreases (Mathew, 1978; Mahopatra, 1987; Shivkumar and Kuruppasomy, 2008). Carbondioxide, pH, alkalinity and temperature are directly related to each other since the pH depends upon the free carbon dioxide and bicarbonate-carbonate levels (Mathew, 1975; Michael, 1984). Kudari et al., (2006) have correlated high pH of Hanamapur and Gudgur water bodies to the presence of algal blooms, which use free CO_2 for photosynthesis and increase the pH of the water body as is also suggested by Wurts and Durborow (1992). Organic decomposition, respiration, photosynthesis, diffusion and run-offs could also account for the variations seen in the CO_2 levels. Higher CO_2 in the dry season agrees with Renn's (1968) observation that CO_2 is released at high levels during low oxygen production.

Carbondioxide rarely cause direct toxicity to fish. However, its high concentrations with lower pond pH can limit the capacity of fish blood to carry O_2 by lowering blood pH at the gills. Hence, at a given DO concentration (e.g. 2 mg/L) fish may suffocate when CO_2 levels are high and appear unaffected when CO_2 is low (Wurts and Durborow, 1992). The mean range of CO_2 in Yashwant Lake is within tolerable limit for fish production since it did not exceed the limit proposed by APHA, (1985) 10 mg/L.

10) Total Hardness (TH): The desirable limit of hardness in drinking water according to BIS standards is 300 mg/L. According to Durfor *et al*., (1964) waters with hardness below 60 mg $CaCO_3$/L are soft, between 61 to 120 mg $CaCO_3$/L are moderately hard; between 121 to 180 mg $CaCO_3$/L are hard and more than 181 mg $CaCO_3$/L are very hard. Considering this the water of Yashwant lake having hardness between 49.3 mg $CaCO_3$/L. to 67.6 mg $CaCO_3$/L. changes from soft to moderately hard seasonally (Table

3.3, Fig. 3.13).

Total hardness is highest during summer at all the three stations, when water cover decreases due to evaporation of water and concentration of calcium and magnesium salts (Bagde and Verma, 1985; Moundiotiya *et al*., 2004; Lentz –Ciplani and Dunson, 2006). According to Spence (1964), waters with more than 60 ppm which may be equivalent to 60 mg $CaCO_3$/L hardness are classified as 'nutrient rich' waters. According to this classification the Yashwant lake can be categorized as 'nutrient rich'.

The total hardness is significantly positively correlated with the Chloride (Table 3.5, 3.6 and 3.7). The ecological significance of major cations or hardness of calcium and magnesium in the biotic dynamics of aquatic flora and fauna is a well established fact. Calcium is essential mainly for fauna while, magnesium is essential for flora for chlorophyll biosynthesis and enzymatic transformations, particularly for phosphorylation in algae, fungi and bacteria.

11) Chloride: The ecological significance of chloride lies in its potential to regulate salinity of water and exert consequent osmotic stress on biotic communities. Thrash *et al*. (1949) pointed out that high chloride concentrations are indicator of large amount of organic matter in the water and is suggestive of eutrophication. The maximum concentration of chlorides recorded in summer at all the three stations with 29.5 ± 1.4 mg/L at YLA, (Table 3.3), can be attributed to the rise in temperature and evapotranspiration, low water level and water cover as is reported by Gonzalves and Joshi, (1946); Prasad et al. (1985); Moundiotiya et al. (2004); Kumar et al. (2006). In addition, numerous studies have confirmed that ground water inputs tend to increase the concentrations of chlorides (Allen *et al*., 1999; Cengiz Koc, 2008). The draining of domestic organic waste of animal origin and industrial wastes without treatment and the agricultural fertilizers and pesticides used in agricultural land surrounding the lake also contribute to increase in chloride concentration. This is reflected by the second maxima of chloride concentration at Yashwant Lake recorded in monsoon. The nearby human population and grazing animals might also be responsible for the higher load of organic matter entering in the lake during rainy season leading to rise in chloride content. The seasonal variations may be accounted for the additions from precipitations and evaporation and human activities (especially by washerman). The contribution of rains in increasing the chloride content in water has also been reported by Hutchinson (1957), Sehgal (1980) and Purohit and Saxena (1990). Further, the chloride values at YLA are nonsignificantly high (29.5 mg/L) as compared to YLB (27.8 mg/L) that reflects the anthropogenic activities such as washing, bathing, etc. at YLA. The present findings confirms the findings of Zafar (1964), Munawar (1970) and Singhai et al. (1990).

In the present study chloride is negatively significantly correlated with water cover and DO at all the three stations whereas positively significantly correlated with CO_2, pH,PO_4^{-3}, TDS, TS, WT, AT, Acidity and Alkalinity at all the three stations (Table 3.5, 3.6 and 3.7).

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