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Research Paper

WATER QUALITY STATUS OF HIGH ALTITUDE LAKE NACHIKETA TAL, GARHWAL HIMALAYA, UTTARAKHAND, INDIA

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Abstract

Water quality status of Nachiketa Tal was studied using various physico-chemical characteristics at four different selected sites for an interval of two years (June, 2008 to May, 2010). Results indicate variation in the water temperature between 4.0˚C to 27.0˚C. Transparency ranged between 38.00 cm to 198.00 cm. The minimum value of dissolved oxygen recorded was 3.00 mg l^{-1} and maximum 11.00 mg l^{-1}. Free CO_2 varied between 0.88 mg l^{-1} to 6.10 mg l^{-1}. pH value ranged between 6.8 to 7.9. The chloride level fluctuated between 5.96 mg l^{-1} to 22.57 mg l^{-1}. Values of nitrate varied from 0.061 mg l^{-1} to 0.129 mg l^{-1}, while, values of phosphate and silicate ranged between 0.014 mg l^{-1} to 0.098 mg l^{-1} and 0.0064 mg l^{-1} to 0.0110 mg l^{-1}, respectively. On the basis of physico-chemical parameters water of Nachiketa Tal represents a naturally occurring oligotrophic ecosystem.

Key words: Nachiketa Tal, Physiochemical characterstics, Garhwal Himalaya, Water quality.

INTRODUCTION

Freshwater habitats occupy a relatively small portion of the earth's surface, but their importance to man is far greater than their area (Odum, 1996). World oceans cover about three-fourth of earth's surface. According to UN estimates, the total amount of water on earth is about 1400 million cubic kilometers which is enough to cover the earth with a layer of 3000 meters depth. However, the freshwater constitute a very small proportion of this enormous quantity. About 2.7 percent of the total water available on the earth is fresh water of which about 75.2 percent lies frozen in polar regions and another 22.6 percent is present as ground water. The rest is available in lakes, rivers, atmosphere, moisture, soil and vegetation. (National Water Policy, 2002). Lakes in general, account for very small *viz.*, 0.009 % of the total freshwater and it has

been estimated that there are 12 million lakes on the earth with a total area of about 2.7 million km^2 and total volume of 1,66,000 km^3 (Heinonen *et al.,* 2000).

To undersatnd the ecology of freshwater systems, analysis of physico-chemical parameters are very essential. The physico-chemical methods are used to detect the effects of pollution on the water quality. Kaul et al. (1980) stated that dissolved oxygen has been used as a most reliable parameter of lake eutrophication. According to them a change in trophic status of a lake is associated with an increase in its nutrient status, so an increase in the conductivity values indicate a tendency towards higher level of trophication. Vestergaard and Sand-Jensen (2000) stated that alkalinity and trophic state regulate aquatic plant distribution in Danish lakes. Carvalho et al. (2002) investigated the physico-chemical conditions for supporting different levels of biological quality for fresh water. Adak et al. (2002) reported that different physico-chemical parameters of water are very important for effective maintenance of water quality through appropriate control.

In Uttarakhand 100 lakes have been documented (Uttarakhand Year book, 2011), while in the Garhwal region about 56 lakes have been enlisted (Rawat et al., 2007). The present communication deals with the water quality status of high altitude Lake Nachiketa Tal.

MATERIALS AND METHODS

Nachiketa Tal, situated at an altitude of 2475m asl lies between 30°22′- 31°25'N latitude and 75°51′-79°27'E longitude. It is small, somewhat oval shaped lake with an approximate length of 200m, width of 90m and depth of 3m with a catchment area of about 600 square meters, Nachiketa Tal receives water from precipitation and melting of snow. The lake, as such, has no inlet or outlet. The lake is approached by road from Uttarkashi up to Chaurangikhal, (27 Km) and thereafter a trek of 3 Km through dense mixed forest of *Rhododendron*, *Cedrus, Abies, Taxus, Quercus, Myrica* etc. The geographical location and directions were studied with the help of compass and GPS. Lake Nachiketa Tal is located in the Northern-Western part of Himalaya and South-East to Uttarkashi township.

Sampling was done at four sites (Table 1) in Lake Nachiketa Tal at monthly interval from June 2008 to May 2010 (I Year- June, 2008-May, 2009; II Year- June, 2009-May, 2010). The air and water temperature was measured by a thermometer and pH by portable Hanna pocket pH meter (H196-107). The turbidity was recorded by Systronics Digital Nephelo-Turbidity Meter (132), while conductivity and total dissolved solid by MAC soil and water analysis kit. Other parameters *viz.,* dissolved oxygen, free carbon dioxide, alkalinity, Total Suspended Solids (T.S.S.) and Total Solids (T.S.) were analysed following standard method outlined in Welch (1952), Trivedy and Goel (1986) and APHA (1995). For analysis of chloride, nitrate and phosphate water samples were collected in plastic bottles of 500 ml and were taken to laboratory.

Table 1. Sampling sites on Lake Nachiketa Tal.

Sampling Site	Location	Mean Depth (m)	Shore Characteristics
S1	North-West	2.5	*Rhododendron* trees; Chara; frequent bathing and washing of clothes; a temple is situated in the periphery of lake.
S2	North-East	2.5	*Rhododendron* trees; stone embankment; bottom clear with pebbles; hut of saint.
S3	South-East	1.0	Shrubby vegetation along *Rhododendron* trees; low depth due to deposition of litter and soil erosion; water turbid.
S4	South-West	1.5	*Rhododendron* trees, litter deposition and soil erosion.

RESULTS

The present study represents the limnological conditions of the high altitude Lake Nachiketa Tal. The water temperature in Nachiketa Tal was observed in accordance to the ambient temperature. The water temperature values varied between 4.0˚C in February'09 to 27.0˚C in June'09 (Fig 1). The transparency in Nachiketa Tal was recorded lowest (38.00 cm) in August'09 and highest (198.00 cm) in December'09 (Fig 1). The minimum value of dissolved oxygen recorded was 3.00 mg l^{-1} (September'09) and maximum 11.00 mg l^{-1} (December'08) (Fig 1). Free carbon dioxide in lake varied between 0.88 mg l^{-1} (June'09) to 6.10 mg l^{-1} to (December'08) (Fig 1).

Total alkalinity in lake Nachiketa Tal varied from 5.50 mg l^{-1} (December'08) to 35.00 mg l^{-1} (June'08) (Fig 1). The pH of water was observed to vary between 6.8 to 7.9 (Fig 1). The hardness of water in Nachiketa Tal varied from 22.40 mg l^{-1} (July'08) to 51.20 mg l^{-1} (June'09) (Fig 1). The chloride level fluctuated from 5.96 mg l^{-1} (July'08) to 22.57 mg l^{-1} (December'09) (Fig 1). The nitrate level in Nachiketa Tal varied from 0.061 mg l^{-1} (January'08) to 0.129 mg l^{-1} (March'09) (Fig 1). The phosphate was recorded minimum (0.014 mg l^{-1}) in September'08 and maximum (0.098 mg l^{-1}) in June'09 (Fig 1). The silicate in Nachiketa Tal varied from 0.0064 mg l^{-1} (June'08) to 0.0110 mg l^{-1} (March'09) (Fig 1).

Total solids was found to be absent in different month, whereas, it was recorded maximum 1.80 g l^{-1} in July'09 (Fig 1). The total dissolved solids in Nachiketa Tal was also not present at many sites during different months. However, the Total Dissolved Soilds was maximum 1.30 g l^{-1} during (July'09) (Fig 1). Total Suspended Solids in Nachiketa Tal was found to be absent at all the sites during different months, it was recorded highest (1.20g l^{-1}) (July'08, August'08) (Fig 1). Turbidity of water in the lake varied from 0.30 NTU (June'08) to 8.10 NTU (July'09) (Fig 1).

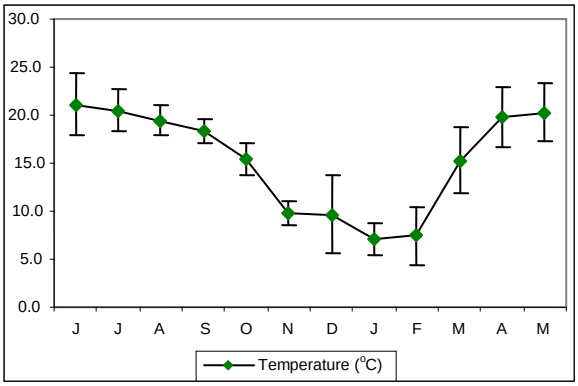
Table 2. Co-relation among the physico-chemical parameters of Lake Nachiketa Tal during I Year (June 2008–May 2009).

	A.T.	W.T.	R.H.	Trans	D.O.	F CO_2	T.A.	pH	Hard.	Cl.	NO_3^-	PO_4	T.S.	T.D.S.	T.S.S.	Turb.
A.T.	1.000															
W.T.	0.719	1.000														
R.H.	0.307	0.392	1.000													
Trans	-0.466	-0.815	-0.685	1.000												
D.O.	-0.211	-0.486	0.125	0.374	1.000											
F CO_2	-0.427	-0.419	-0.521	0.499	-0.226	1.000										
T.A.	0.474	0.283	0.221	-0.308	-0.081	-0.490	1.000									
pH	0.056	-0.316	-0.228	0.366	0.133	0.461	-0.291	1.000								
Hard.	0.213	0.096	-0.654	0.352	-0.331	0.324	-0.089	0.485	1.000							
Cl.	-0.057	-0.400	-0.732	0.739	0.108	0.516	-0.507	0.480	0.593	1.000						
NO_3^-	-0.332	-0.266	-0.816	0.532	-0.424	0.469	-0.390	-0.028	0.531	0.632	1.000					
PO_4	0.346	0.067	-0.512	0.351	-0.085	0.173	0.034	-0.018	0.539	0.679	0.474	1.000				
T.S.	0.232	0.609	0.671	-0.741	-0.089	-0.239	-0.176	-0.173	-0.393	-0.548	-0.480	-0.475	1.000			
T.D.S.	0.594	0.744	0.067	-0.543	-0.198	-0.469	0.492	-0.273	0.101	-0.341	-0.220	0.006	0.367	1.000		
T.S.S.	0.224	0.440	0.799	-0.683	0.178	-0.338	0.073	-0.339	-0.664	-0.632	-0.674	-0.358	0.854	0.242	1.000	
Turb.	-0.162	0.406	0.202	-0.483	-0.471	0.218	-0.266	-0.248	-0.185	-0.426	0.051	-0.428	0.738	0.263	0.491	1.000

Table 3. Co-relation among the physico-chemical parameters of Lake Nachiketa Tal during II Year (June 2009–May 2010).

	A.T.	W.T.	R.H.	Trans	D.O.	F CO_2	T.A.	pH	Hard.	Cl.	NO_3^-	PO_4	T.S.	T.D.S.	T.S.S.	Turb.
A.T.	1.000															
W.T.	0.776	1.000														
R.H.	0.193	0.020	1.000													
Trans	-0.715	-0.814	-0.107	1.000												
D.O.	-0.638	-0.584	0.018	0.539	1.000											
F CO_2	0.636	0.579	-0.424	-0.577	-0.260	1.000										
T.A.	0.281	0.527	-0.369	-0.259	-0.137	0.696	1.000									
pH	-0.493	-0.812	-0.108	0.803	0.278	-0.515	-0.460	1.000								
Hard.	0.264	0.221	-0.210	0.133	0.117	0.439	0.662	0.044	1.000							
Cl.	-0.434	-0.667	-0.146	0.697	0.067	-0.468	-0.504	0.673	-0.302	1.000						
NO_3^-	-0.659	-0.593	-0.529	0.361	0.260	-0.122	-0.025	0.424	-0.058	0.301	1.000					
PO_4	0.608	0.241	-0.066	-0.033	-0.554	0.231	0.037	0.285	0.377	0.232	-0.278	1.000				
T.S.	0.431	0.447	-0.178	-0.534	0.099	0.830	0.576	-0.642	0.325	-0.622	-0.113	-0.186	1.000			
T.D.S.	0.230	0.375	-0.314	-0.412	0.035	0.621	0.435	-0.538	0.085	-0.327	0.072	-0.125	0.752	1.000		
T.S.S.	0.448	0.329	0.006	-0.425	0.109	0.691	0.464	-0.463	0.412	-0.622	-0.230	-0.141	0.819	0.238	1.000	
Turb.	0.488	0.534	-0.247	-0.548	0.058	0.889	0.651	-0.659	0.412	-0.637	-0.177	-0.110	0.980	0.725	0.815	1.000

A.T = Air Temperature, W.T = Water Temperature, R.H= Relative humidity, Trans = Transparency, D.O = Dissolved oxygen, F CO_2 = Free Carbon dioxide, T.A = Total Alkalinity, Hard. = Hardness, Cl^- = Chloride, NO_3^- = Nitrate, PO_4 = Phosphate, SiO_2 = Silicate, T.S. = Total Solids, T.D.S. = Total Dissolved Solids, T.S.S. = Total Suspended Solids, Turb. = Turbidity.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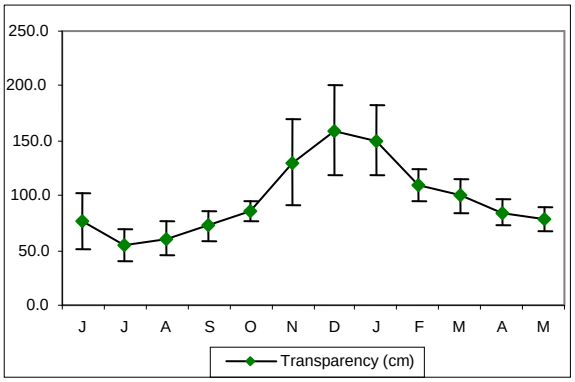
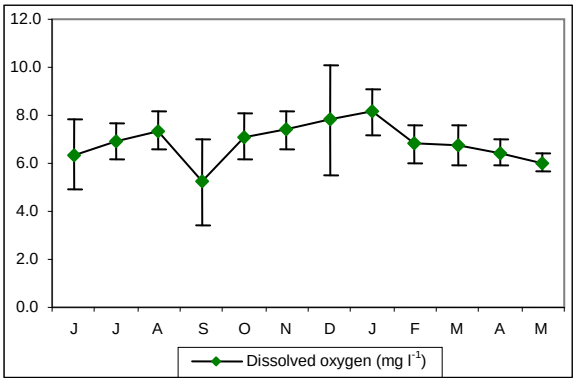
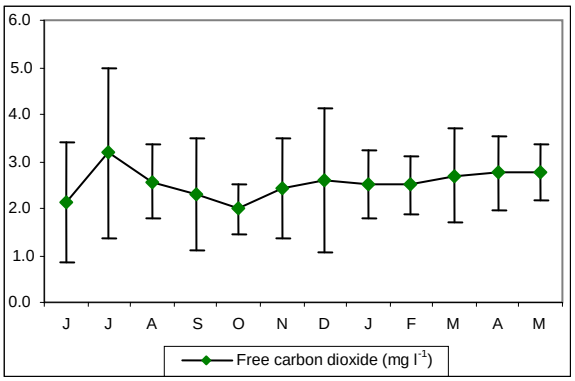
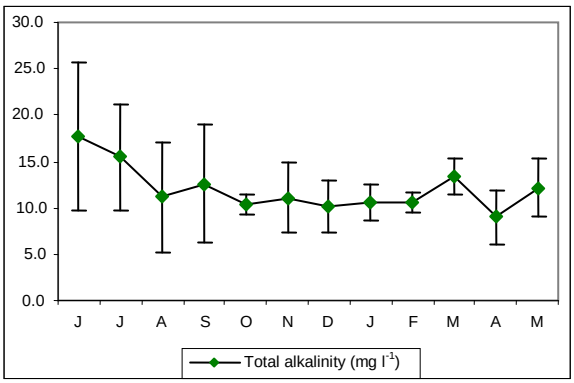
25.0
20.0
15.0
10.0
5.0
0.0
J J A S O N D J F M A M
Temperature (°C)


250.0
200.0
150.0
100.0
50.0
0.0
J J A S O N D J F M A M
Transparency (cm)


12.0
10.0
8.0
6.0
4.0
2.0
0.0
J J A S O N D J F M A M
Dissolved oxygen (mg l-1)


6.0
5.0
4.0
3.0
2.0
1.0
0.0
J J A S O N D J F M A M
Free carbon dioxide (mg l-1)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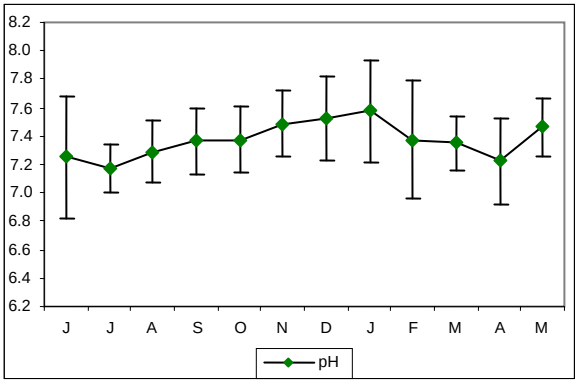
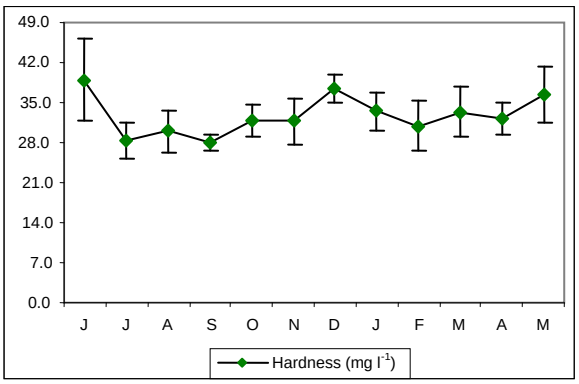
25.0
20.0
15.0
10.0
5.0
0.0
J J A S O N D J F M A M
Total alkalinity (mg l-1)


8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
J J A S O N D J F M A M
pH


49.0
42.0
35.0
28.0
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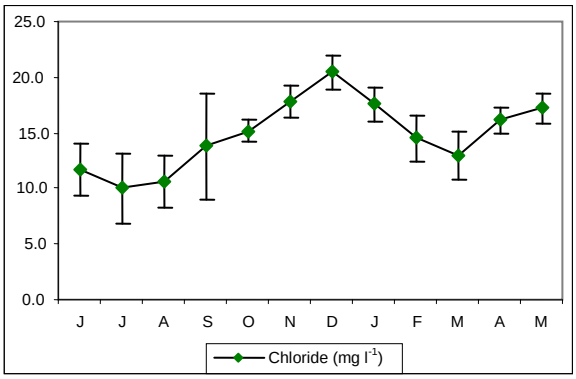
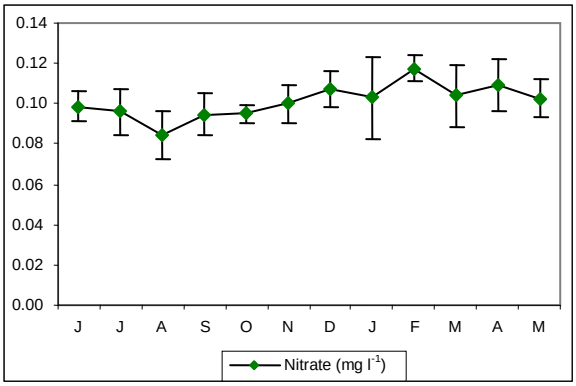
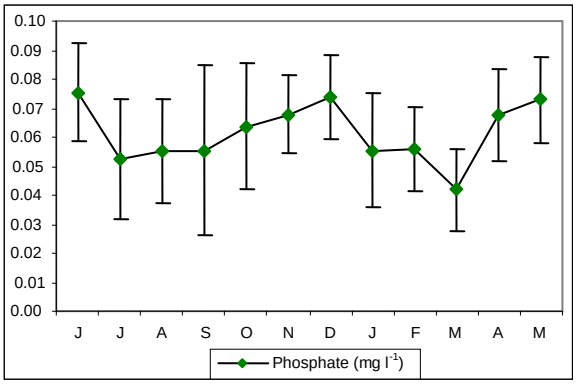
14.0
7.0
0.0
J J A S O N D J F M A M
Hardness (mg l-1)


25.0
20.0
15.0
10.0
5.0
0.0
J J A S O N D J F M A M
Chloride (mg l-1)


0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
J J A S O N D J F M A M
Nitrate (mg l-1)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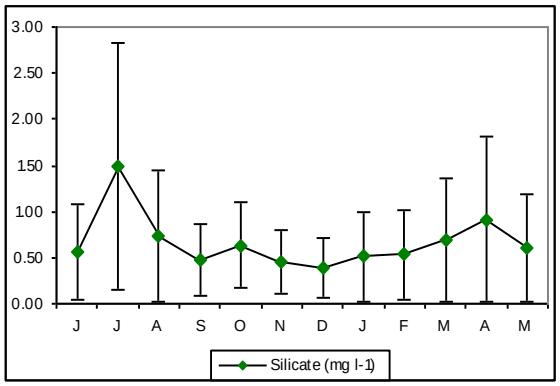
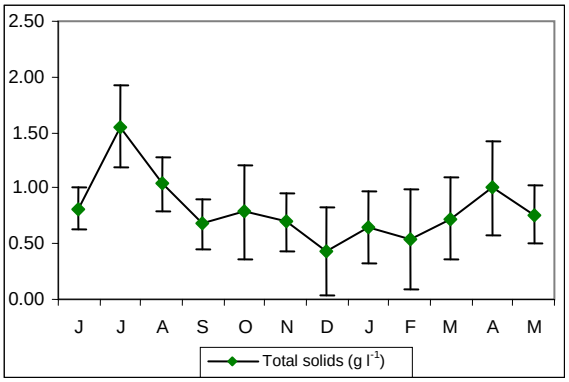
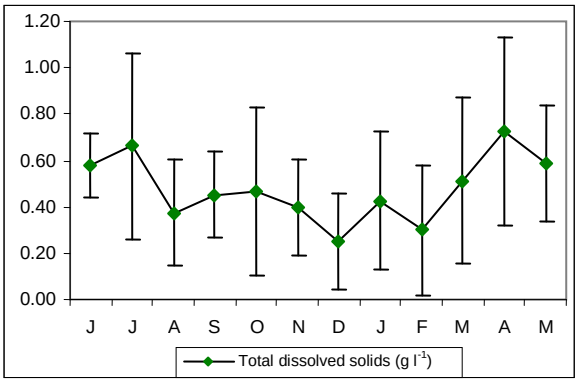
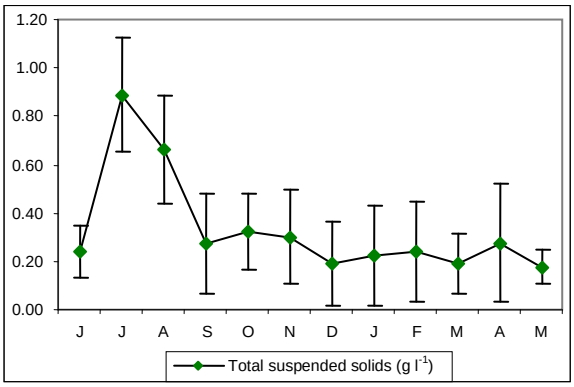
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
J J A S O N D J F M A M
Phosphate (mg l-1)


3.00
2.50
2.00
150
100
0.50
0.00
J J A S O N D J F M A M
Silicate (mg l-1)


2.50
2.00
1.50
1.00
0.50
0.00
J J A S O N D J F M A M
Total solids (g l-1)


1.20
1.00
0.80
0.60
0.40
0.20
0.00
J J A S O N D J F M A M
Total dissolved solids (g l-1)


1.20
1.00
0.80
0.60
0.40
0.20
0.00
J J A S O N D J F M A M
Total suspended solids (g l-1)

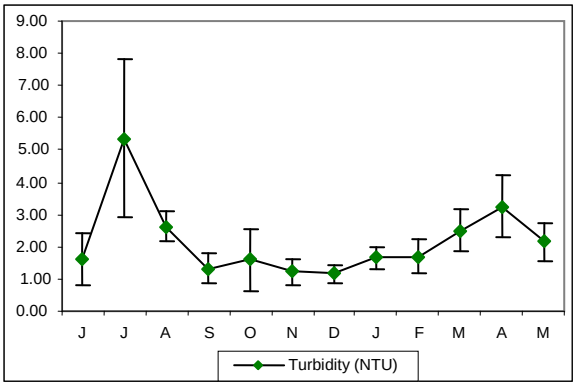


Fig.1. Monthly average fluctuation of physico-chemical parameters of Lake Nachiketa Tal during June 2008–May 2010.

DISCUSSION

Water temperature in Lake Nachiketa Tal ranged from 4˚C to 27˚C during the study period. In general, the water temperature was maximum during summer months, while, the minimum was observed during winter (Fig 1). The values more or less varied in accordance with the air temperature. The oxygen cycle in water involves a rapid decrease during summer and a steady increase through autumn till maximum content reached in winter, following the well known solubility of gases (Kaul *et al.* 1980).

Free CO_2 was present through out the study period at all sampling sites and ranged from 0.88 to 6.1 mg l^{-1}. Earlier, Sorgensen (1948) and Moyle (1949) classified waters and grouped into three different nutrient status groups on the basis of alkalinity as follows (a) 1 to 15 mg l^{-1} as nutrient poor (b) 16 to 60 mg l^{-1} as moderately rich and (c) more than 60 mg l^{-1} as nutrient rich. ake Nachiketa Tal showed lower value of alkalinity as compared to the other Indian lakes. Considering the limits of alkalinity reported by different researchers Nachiketa Tal can be conveniently categorised as nutrient poor to moderate rich lake.

A significant negative correlation was recorded between dissolved oxygen and water temperature in both the years of study ($r= -0.486$, $p<0.05$ in I year; $r= -0.584$, $p<0.05$ in II year) (Table 2). Free carbon dioxide was inversely correlated to dissolve oxygen in both the years ($r= -0.226$, $p<0.05$, I year; $r= -0.260$, $p<0.05$, II year) (Table 3). Similar inverse relationship has also been reported by other in different lakes (Pearsall, 1923; Ganapati, 1940; Gonzalves and Joshi 1946; Rao 1955; Shastree et al., 1991 and Rawat, 1992).

In general, hardness was maximum during summer months, while, the minimum values were observed during monsoon. The present study is in corroboration with Harrison (1999) who reported that the chloride concentration depends on the water level. He stated that when the water level decreases, the chloride concentration increases. He further observed that when water level rises due to rain, the consequent dilution decreases the chloride concentration.

Reid (1961) found that average of nitrate in unpolluted freshwater is 0.30 ppm. According to Sawyer (1947, 1952) and Vollenweider (1968) limiting value of nitrate for the process of eutrophication as 300 μl^{-1}. During the present study, the value of nitrate ranged from 0.061 to 0.129 mg l^{-1} (Fig 1), thus on the basis of above classification Nachiketa Tal is considered as an oligotrophic water body.

In Lake Nachiketa Tal phosphorous value ranged between 0.020 to 0.098 mg l^{-1} during the study period (Fig 1). Low phosphate value observed during spring was due

to the high phytoplankton density. Low concentration 50 and 52 µg l^{-1} of phosphorous is characteristic of high altitude Lakes (Pandit, 1999). The silicate concentration in Nachiketa Tal was recorded to be very low (0.0064 mg l^{-1} to 0.0110 mg l^{-1}) (Fig 1). In general, the silicate was maximum during spring months, while, the minimum was observed during summer. Pant *et al.* (1985) also reported decreased silicate concentration during spring and summer. Liss and Spencer (1970) and Aston (1980) stated that silicate concentration decrease due to biological removal by phytoplankton, especially by diatoms and silicoflagellates.

In Lake Nachiketa Tal, Total Solids ranged from being absent to 1.80 g l^{-1}, Total Dissolved Solids varied from 0.00 to 1.30 g l^{-1} and total suspended solids ranged from nil to 1.20 g l^{-1} (Fig 1). The Total Solid and Total Suspended Solids were observed higher during monsoon season while least during winter season. In Lake Nachiketa Tal Total Solid and Total Suspended Solids was observed higher during monsoon season while least during winter season, similar to the findings of Tripathi and Pandey (1990) and Patil *et al.* (2011). The total solid and total suspended solids recorded low during winter which is due to the sedimentation and high during monsoon due to high surface run off, silt from catchment area of Lake.

In Lake Nachiketa Tal the turbidity was minimum 0.30 N.T.U. and maximum 8.10 N.T.U. (Fig 1). High turbidity during monsoon was observed in Lake Nachiketa Tal during the present study period. During monsoon season silt, clay and other suspended particles contributes to the turbidity values, while during winter season settlement of silt, clay results low turbidity. Dagaonkar and Saksena (1992) and Garg *et al.* (2006b) have also reported high turbidity during rainy season (monsoon).

A significant negative correlation between transparency and turbidity was recorded in both the years ($r= -0.483$, $p<0.05$ in I year; $r= -0.548$, $p<0.05$ in II year) (Table 2). On the other hand, a positive correlation between total dissolved solids and turbidity was recorded in both the years ($r= 0.263$, $p<0.05$ in I year; $r= 0.725$, $p<0.05$ in II year) (Table 3).

CONCLUSION:

On the basis of various parameters studied Nachiketa Tal represents a naturally occurring ecosystem that is oligotrophic Although the nutrient level too is still near moderate, nonetheless, the trend is towards assuming moderate condition.

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