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Physico-Chemical Studies on Chimdi Lake of Sunsari District during its Restoration Stage

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Abstract
Chimdi Lake was ecologically a valuable site but due to the exploitation, almost all parts of the Lake changed into a terrestrial habitat. The issues of lake conservation have been brought into light recently and the work for rehabilitation; protection and conservation have been initiated by local peoples. Water quality plays an important role in determining the biodiversity of any water body. Various physico-chemical parameters such as atmospheric temperature, water temperature, transparency, total solids, total dissolved solids, total suspended solids, humidity, pH, dissolved oxygen, free carbon dioxide, total alkalinity, acidity, total hardness, calcium hardness, calcium, magnesium and chloride were estimated on monthly basis from March 2004 to February 2005. Physico- chemical values revealed that the lake is a suitable site for the habitat of aquatic lives.

Key words: Physico-chemical, restoration, Chimdi Lake, Nepal

Introduction

Chimdi Lake is located in eastern Nepal. It is about 12 km west from Nepal's main industrial city Biratnagar. The lake lies between 87^{O}10'51.3" E longitudes and 26^{O}29'23.5" N latitude at an elevation of 70m above the mean sea level. The total area of the lake is approximately 101.6 hectares.

The hydrological set up of any aquatic ecosystem plays a key role in determining the quality and productivity of any water body. Seasonal fluctuations of various physico–chemical factors have a crucial role in the distributions, periodicity, qualitative and quantitative composition of biota in aquatic ecosystem. The knowledge of all these factors is essential for identifying the suitability and fertility of an aquatic ecosystem.

The wetland serves as a habitat for a wide variety of waterfowls, fishes, wetland plants and vegetation. Chimdi Lake was also a rich habitat that supported rich biodiversity. In the absence of awareness on environmental issues, local people drained the water of this lake and converted a large part of it into paddy fields and wastelands.

Extensive works on different aspects of physico-chemical and biological parameters of fresh water body have been done in different parts of the world. Important works done outside of Nepal include the works of Ganpati (1943), Welch (1948), Mc. Combie (1953), Barret (1957), Spence (1964), Mc.Coll (1972), Jayaraman (1974), Swarup and Singh (1979), Weller

(1981), Trivedy and Goel (1984), Khan and Chaudhary (1994) and Rawat *et al*. (1995).

Though vast number of limnological investigations has been carried out in different parts of the world, only few works have been done in Nepal. Some of the works are those of Loffler (1969), Ferro (1976), Bhandari (1992), Chhetri (1992), Shrestha (1992), Thapa (1994) and Udash (1996).

Materials and Methods

Preliminary survey of the study site was made. Two different sub-sites as station A and B were selected in the lake for the analysis of physico-chemical parameters of the lake water. Station A is located towards the eastern part of the lake and consists of low number of aquatic macrophytes. Station B is located towards the western part of the lake and has luxuriant growth of macrophytes. The study was carried out for a period of 12 months (March 2004 to February 2005). It was generally done between 9 to 11 am in the morning

The lake area, latitude, longitude and altitude of Chimdi Lake were measured by using e-trex Vista GPS.

For each station sample, temperature, transparency, dissolved oxygen (DO_2), free carbon dioxide (FCO_2), Total alkalinity (TA), Total Hardness (TH), Calcium Hardness (Ca^{++}), Acidity, Chloride, Euphotic limit, calcium and magnesium were all analyzed in the field.

Total solids, total dissolved solids and total suspended solids were determined in the laboratory within 24 hours. Physico-chemical analysis of water was done as per standard methods recommended by Adoni (1985) and APHA (1998).

Statistical analysis was done by using computer software Genstat 5, Lawes Agricultural Trust (IACR- Rothamsted Experimental Station).

Results

Data on physico-chemical parameters have been tabulated in Table 1 and 2. Mean values along with ± S. D. of physico-chemical parameters have been presented in Table 3. Table 4 shows the coefficient of correlation values.

Physical Factors

(a) Temperature

Atmospheric temperature of the study area recorded were minimum 19 ± 0.00^{O}C (January) and maximum 34 ± 0.00^{O}C (September). The temperature started decreasing after September and reached minimum in January, after which it started increasing.

The water temperature fluctuated according to the atmospheric temperature which ranged from 18.8 ± 0.00^{O}C (January) to 30.5 ± 0.42^{O}C (September). No marked variations were observed between the sampling stations.

(b) Humidity

Related humidity ranged from 53 ± 0.00% (December) to 88 ± 0.00% (June).

(c) Transparency

Monthly variations in the Secchi disc transparency ranged between 2.13 ± 0.00 cm (July) and 27.83 ± 0.00 cm (September), the minimum value in the monsoon and the maximum in the winter.

(d) Euphotic Limit

The Euphotic limit value varied from 5.34 ± 0.00 cm (July) to 69.58 ± 0.00cm (September).

(e) Total Solids

The concentration of total solid ranged from 200 ± 0.00 mg/L (May) to 960 ± 56.56 mg/L(August), the minimum value in the summer and the maximum in the monsoon.

The concentration of total solid ranged from 200 mg/L (May) to 920 mg/L (August) in site A. The value ranged from 200 mg/L (May) to 1000 mg/L (August) in site B.

(f) Total Dissolved solids.

The concentration of total dissolved solids ranged from 100 ± 0.00 mg/L (May) to 340 ± 28.28 mg/L (August).

The maximum value recorded in site A and site B was 320 mg/L (August) and 360 mg/L (August) respectively.

(g) Total suspended solids.

The concentration of total suspended solids ranged from 100 ± 0.00 mg/L (May) to 620 ± 28.28 mg/L (August).

The maximum value recorded in site A and site B was 600 mg/L (August) and 640 mg/L (August) respectively.

4.1.2 Chemical Factors

(a) Hydrogen ion concentration (pH)

pH values of the lake water remained almost alkaline throughout the study period and varied from 6.05 ± 0.028 (April) to 8 ± 0.70 (May). The variations in pH within sub sites were not considerable and ranged between 6.05 (April) to 8.5 (May).

(b) Dissolved Oxygen (DO2)

The dissolved oxygen contents showed its minimum value during summer (June) with its value of 4.82 ± 0.56 mg/L and maximum during winter (September) with its value of 19.92 ± 1.98 mg / L.

The minimum value of DO_2 in site A was 4.42 mg/L and site B was 5.22 mg /L. The maximum value of DO_2 in site A was 12.46 mg/L and in site B was 10.45 mg /L.

(c) Free Carbon dioxide (FCO2)

The value of FCO_2 ranged between 2.2 ± 3.11 mg/L (January) to 30.8 ± 0.00 mg/L (July).

Free carbon dioxide was found to be absent in the station B (January) and the lowest value recorded in station A was 4.4 mg/L in the same month.

(d) Total Alkalinity

Total alkalinity was due to bicarbonate only. The value ranged between 32 ± 0.00 mg/L (July) to 86 ± 33.9 mg/L (March). Considerable difference within sub-sites was observed in some months.

(e) Total acidity

The value of total acidity ranged between 2.5 ± 3.53 mg/L (January) to 35 ± 0.00 mg/L (July).

(f) Total Hardness

The minimum value of total hardness recorded in the lake water was 38 ± 7.07 mg/L (June) and the maximum value recorded in the lake water was 140 ± 26.62 mg/L (March).

The maximum value recorded in the

site A was 156 mg/L and minimum value recorded was 32 mg /L. Similarly, the maximum value recorded in site B was 124 mg/Land minimum value recorded was 44 mg/L.

(g) Calcium Hardness

The value of calcium hardness ranged from 23 ± 2.83 mg/L (June, October) to 84 ± 28.28 mg/L (March).

The value of calcium hardness in site A ranged from 18 mg/L (June) to 104 mg/L (March). The value of calcium hardness in site B ranged from 22 mg/L (September, October) 64 mg/L (March)

(h) Calcium (Ca++)

Calcium values obtained by calculation ranged between 9.21 ± 0.34 mg/L (June) to 33.66 ± 11.33 mg/L (March).

In both the sites the minimum value was obtained in summer and maximum in winter.

(i) Magnesium (Mg++)

Magnesium values obtained by calculation ranged between 3.65 ± 0.93 mg/L (June) to 13.66 ± 1.38 mg/L (March).

The value in site A ranged between 3.41 mg/L (June) to 12.68 mg/L (March). The value of magnesium in site B ranged between 3.41 mg/L (August) to 14.64 mg/L (March)

(j) Chloride

The concentration of chloride ranged from 4.92 ± 1.004 mg/L (November) to 15.62 ± 4.01 mg/L (March).

The value of chloride in site A ranged between 5.68 mg/L (November) to 12.78 mg/L (March).

The value of chloride in site B ranged between 4.26 mg/L (November) to 18.46 mg/L (March).

Discussion

The meteorological factors such as ambient temperature sunshine, rainfall, humidity exert a considerable influence on the physico-chemical dynamics of water body. The physico-chemical characteristic of water largely determines the structure and composition of biotic community of an aquatic ecosystem. Reid (1961) has stated that the successful development and maintenance of a population of organisms depends upon harmonious ecological balance between environmental conditions and tolerance of the organisms to variations in one or more of these conditions.

In the present study a strong positive and significant correlation ($r = + 0.94$, $P < 0.05$) was found between atmospheric temperature and water temperature. Similar observations were made by Kant and Anand (1978) and Rawat. *et al.* (1995) . Welch (1952) and Munawar (1970) have observed that shallower the water body more quickly it reacts to the change in the temperature.

Transparency of water was higher after rainy season and lower values were observed during rainy season. Mc.Combie (1953) recorded that the transparency shows a direct relationship with the suspended organisms and non-living particles in the water. During winter the higher value of transparency may be related with the settling rate of the suspended particles, absence of rain, run off, flood water and gradual decrease in plankton growth due to low temperature. Similar trend was observed by Rawat. *et al.* (1995) in Deoria Tal.

The mean value of total solids was higher during rainy season due to rain, run

Table 1. Physico-chemical parameters of water of Chimdi lake of sampling site A.

Parameters	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
Atm temp.(^{0}c)	26	31	33	31	32	32	34	30	30	21	19	24
Water temp(^{0}c)	25	29.8	29.6	30	29	29.4	30.2	26.2	23.4	20	18.8	21.2
Transparency(cm)	27	11.5	6.56	6.93	2.13	2.6	27.83	20.12	16.66	4.66	5.68	6.12
Euphotic limit (cm)	67.5	28.75	16.4	17.34	5.34	6.5	69.58	50.31	41.66	10	13.63	15.3
Total solid (mg/l)	290	380	200	340	600	920	400	450	600	560	510	490
Dissolved solid(mg/l)	140	180	100	200	240	320	200	190	200	180	190	200
Suspendend solid(mg/l)	150	200	100	140	360	600	200	260	400	380	320	290
Humidity (%)	64	58	79	88	72	81	62	64	72	53	85	80
pH	7.8	6.05	7.5	6.94	7.08	7.29	7.1	7.11	7.24	7.8	7.9	7.82
DO_2 (mg/l)	5.22	5.22	8.04	4.42	6.03	6.43	12.46	6.43	6.83	8.8	10.05	6.43
FCO_2(mg/l)	17.6	13.2	26.4	22	30.8	26.4	8.8	13.2	8.8	22	4.4	22
TA (mg/l)	110	62	60	62	32	40	50	56	54	58	60	48
Total Acidity (mg/l)	20	15	30	25	35	30	10	15	10	25	5	25
Total Hardness (mg/l)	156	90	52	32	46	48	46	48	52	50	56	48
Ca Hardness (mg/l)	104	50	30	18	26	28	26	24	24	32	34	28
Ca++ (mg/l)	41.68	20.04	12.02	7.21	10.42	11.22	13	9.61	9.61	12.8	13.62	11.22
mg++ (mg/l)	12.68	9.76	5.36	3.41	4.88	4.88	4.88	5.85	6.83	4.39	5.36	4.88
Chloride (mg/l)	12.78	11.36	8.52	8.52	9.94	11.36	14.2	9.94	5.68	14.2	7.1	8.52

Table 2. Physico-chemical parameters of water of Chimdi lake of sampling site B.

Parameters	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Atm temp.(^{0}c)	26	31	33	31	32	32	34	30	30	21	19	24
Water temp(^{0}c)	25	29	29.6	30	29	29.2	30.8	27.3	24	20	18.8	21.2
Transparency(cm)	25	11.5	10.68	20.37	2.13	2.6	27.83	29.5	27.66	28.33	16	14.25
Euphotic limit (cm)	62.5	28.75	26.7	50.93	5.34	6.5	69.57	73.75	69.15	70.83	48	35.62
Total solid (mg/l)	310	380	200	260	600	1000	360	370	400	410	530	550
Dissolved solid(mg/l)	150	180	100	140	200	360	240	130	160	230	220	310
Suspendend solid(mg/l)	160	200	100	120	400	640	120	240	240	180	310	240
Humidity (%)	64	58	79	88	72	81	62	64	72	53	85	80
pH	7.2	6.09	8.5	7.27	7.06	7.43	7.12	7.16	7.38	7.6	7.66	7.49
DO_2 (mg/l)	5.63	5.22	7.24	5.22	6.43	6.83	9.65	6.83	5.63	9.65	10.45	7.64
FCO_2(mg/l)	17.6	17.6	26.4	22	30.8	22	4.4	8.8	8.8	17.6	0	17.6
TA (mg/l)	62	62	72	80	32	40	52	56	60	64	66	52
Total Acidity (mg/l)	20	20	30	25	35	25	5	10	10	20	0	20
Total Hardness (mg/l)	124	104	66	44	44	48	54	52	58	54	64	44
Ca Hardness (mg/l)	64	42	42	28	26	34	22	22	28	30	36	26
Ca+ +(mg/l)	25.65	16.8	16.83	11.22	10.42	13.62	8.81	8.81	11.22	12.02	14.42	10.42
mg++(mg/l)	14.64	15.12	5.85	3.9	4.39	3.41	7.8	7.32	7.32	5.68	6.83	4.39
Chloride (mg/l)	18.46	8.52	7.1	9.84	9.94	11.36	14.2	7.1	4.26	8.52	5.68	5.68

Table 3. Mean ± S.D. Value of Physico-chemical parameters of water of Chimdi lake

Parameters	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Atm temp.(^{0}c)	26 ± 0.0	31 ± 0.0	33 ± 0.0	31 ± 0.0	32 ± 0.	32 ± 0.0	34 ± 0.0	30 ± 0.0	30± 0.0	21 ± 0.0	19 ± 0	24 ± 0
Water temp(^{0}c)	25 ± 0.0	29.8 ± 0.5	29.6 ± 0.0	30 ± 0.0	29 ± 0.0	29.3 ± 0.1	30.5 ± 0.4	26.7 ± 0.7	23.7 ± 0.4	20 ± 0.0	18.8 ± 0	21.2 ± 0
Transparency(cm)	26 ± 1.4	11.5 ± 0.0	8.6 ± 2.9	13.7 ± 23.7	2.1 ± 0.0	2.6 ± 0.0	27.8 ± 0.0	24.8 ± 6.6	22.1± 7.7	16.4± 16.7	10.8 ± 7.3	10.1 ± 6
Euphotic limit (cm)	65 ± 3.5	28.7± 0.0	21.5 ± 7.2	34.1 ± 56.5	5.3± 0.0	6.5 ± 0.0	69.5 ± 0.0	62.03 ± 16.5	55.4± 19.4	41.2± 43.0	27.1 ± 24.3	25.4 ± 14
Total solid (mg/l)	300 ± 14.1	380 ± 0.0	200 ± 4.2	300 ± 42.4	600 ± 0.0	960 ± 56.5	380 ± 28.2	410 ± 56.5	500 ± 141.4	485 ± 106.07	520 ± 14.1	520 ± 42
Dissolved solid (mg/l)	145 ± 7.07	180 ± 0.0	100 ± 0.0	170 ± 14.1	220 ± 28.2	340 ± 28.2	220 ± 28.2	160 ± 42.4	180 ± 28.2	205 ± 35.3	205 ± 21.2	255 ± 78
Suspended solid (mg/l)	155 ± 7.07	200 ± 0.0	100 ± 0.0	130 ± 0.0	380 ± 28.2	620 ± 28.2	160 ± 56.5	250 ± 14.1	320 ± 113.1	280 ± 141.4	315 ± 7.07	265 ± 35
Humidity (%)	64 ± 0.0	58 ± 0.0	79 ± 0.0	88 ± 0.0	72 ± 0.0	81 ± 0.0	62 ± 0.0	64 ± 0.0	72 ± 0.0	53 ± 0.0	85 ± 0	80 ± 0
pH	7.5 ± 0.4	6.05 ± 0.03	8 ± 0.7	7.1 ± 0.2	7.07 ± 0.01	7.3 ± 0.1	7.1 ± 0.01	7.13 ± 0.0	7.3± 0.1	7.1 ± 0.1	7.1± 0.1	7.6 ± 0
DO_2 (mg/l)	5.42 ± 0.2	5.2 ± 0.0	7.6± 0.5	4.8 ± 0.5	6.2 ± 0.2	6.6 ± 0.2	10.9 ± 1.9	6.6± 0.2	6.2± 0.8	9.2± 0.6	10.2± 0.2	7.03 ± 1
FCO_2 (mg/l)	17.6 ± 0.0	15.4 ± 3.1	26.4 ± 0.0	22 ± 0.0	30.8 ± 0.0	24.2 ± 3.1	6.6 ± 3.1	11 ± 3.1	8.8 ± 0.0	19.8 ± 3.1	2.2 ± 3.1	19.8 ± 3
TA (mg/l)	86 ± 33.9	62 ± 0.0	66 ± 8.4	71 ± 0.0	32 ± 0.0	40 ± 0.0	51 ± 1.4	56 ± 0.0	57 ± 4.2	61 ± 4.2	63 ± 4.2	50 ± 3
Total Acidity (mg/l)	20 ± 0.0	17.5 ± 3.5	30 ± 0.0	25 ± 8.4	35 ± 0.0	27.5 ± 3.5	7.5 ± 3.5	12.5 ± 3.5	10 ± 0.0	22.5 ± 3.5	2.5 ± 3.5	22.5 ± 4
Total Hardness (mg/l)	140 ± 22.6	97 ± 9.9	59 ± 9.9	38 ± 7.07	45 ± 1.4	48 ± 0.0	50 ± 5.6	50 ± 2.8	55 ± 4.2	52 ± 2.8	60 ± 5.6	46 ± 3
Ca Hardness (mg/l)	84 ± 28.2	46 ± 5.6	36 ± 8.4	23 ± 2.8	26 ± 0.0	31 ± 4.2	24 ± 2.8	23 ±1.4	26 ± 2.8	31 ± 1.4	35 ± 1.4	27 ± 1
Ca++ (mg/l)	33.6 ± 11.3	18.6 ± 2.2	14.4 ± 3.4	9.2 ± 0.35	10.4 ± 0.0	12.4 ± 1.7	10.9 ± 2.9	9.2± 0.5	10.4± 1.1	12.4± 0.5	14.02 ± 0.5	10.8 ± 1
mg++ (mg/l)	13.6± 1.3	12.4 ± 3.7	5.6 ± 0.3	3.6 ± 0.93	4.6 ± 0.3	4.1 ± 1.04	6.3 ± 2.06	6.5± 1.04	7.07 ± 0.3	5.03 ± 0.9	6.09 ± 1.04	4.6± 0
Chloride (mg/l)	15.6 ± 4.02	9.4 ± 2.01	7.8 ± 1.0	9.2 ± 0.0	9.4 ± 0.0	11.3 ± 0.0	14.2 ± 0.0	8.5± 2.01	4.9± 1.0	11.3± 4.02	6.3± 1	7.1± 2

Table 4. Coefficient correlation between various physico-chemical parameters

	Atm temp(^{0}c)	Water temp(^{0}c)	Humidity (%)	pH	DO_2 (mg/l)	FCO_2 (mg/l)	TA (mg/l)	Total Acidity (mg/l)	Total Hardness (mg/l)	Ca Hardness (mg/l)	Ca++ (mg/l)	Mg++ (mg/l)	Chloride (mg/l)
Atm temp (^{0}c)	-	0.94	0.006	-0.07	-0.32	0.32	-0.29	0.32	-0.14	-0.20	-0.19	-0.03	0.15
Water temp(^{0}c)	0.94	-	0.009	-0.19	-0.35	0.38	-0.17	0.38	-0.03	-0.08	-0.06	0.03	0.31
Humidity (%)	0.006	0.009	-	0.45	-0.12	0.14	-0.08	0.14	-0.39	-0.26	-0.28	0.51	0.46
pH	-0.07	-0.19	0.45	-	0.16	0.22	0.08	0.22	-0.14	0.02	0.01	-0.36	0.07
DO_2 (mg/l)	-0.32	-0.35	-0.12	0.27	-	-0.48	-0.16	-0.48	-0.29	-0.27	-0.24	-0.29	0.08
FCO_2 (mg/l)	0.32	0.38	0.14	0.22	-0.48	-	-0.25	1	-0.10	0.02	0.0007	-0.25	0.12
TA (mg/l)	-0.29	-0.17	0.08	0.08	-0.16	-0.25	-	-0.25	0.64	0.65	0.65	0.57	0.21
Total Acidity (mg/l)	0.32	0.38	0.14	0.92	-0.47	1	-0.25	-	-0.10	0.02	0.0007	-0.25	0.12
Total Hardness (mg/l)	-0.14	-0.03	0.39	-0.14	-0.29	-0.10	0.64	-0.10	-	0.96	0.97	0.94	0.48
Ca Hardness (mg/L)	-0.20	-0.08	0.26	0.02	-0.27	0.02	0.65	0.02	0.96	-	0.99	0.83	0.52
Ca ++(mg/l)	-0.18	-0.06	0.28	0.01	-0.24	0.0007	0.65	0.0007	0.97	0.99	-	0.84	0.55
mg++(mg/l)	-0.03	0.03	0.51	-0.36	-0.21	-0.25	0.57	-0.25	0.94	0.83	0.84	-	0.37
Chloride (mg/l)	0.15	0.31	0.46	0.07	0.08	0.12	0.21	0.12	0.48	0.52	0.55	0.37	-

off and sediment deposition. During summer minimum value was obtained. The same trend was obtained regarding total dissolved solid and total suspended solids. Rawat *et al*. (1995) has also computed maximum value of total dissolved solid in the month of August. The value of total dissolved solids (100 ± 0.00mg/L to 340 ± 28.28 mg / L) was very less in comparison to the value obtained by Leghari *et al*. (2001) in Dhabeji springs, Malir, Karachi (1943 – 2732 mg /L).

In the present investigation pH showed insignificant inverse correlation with water temperature, total hardness and magnesium. Other physico-chemical parameters showed insignificant positive correlation with pH.

Rawat *et al*. (1995) obtained positive significant correlation with total alkalinity ($r = + 0.52$, $P < 0.05$) but such correlation was not obtained in the present study.

Bist (1993) opined that variation in DO_2 could be due to one or more factors such as temperature, light intensity, turbidity, photosynthesis and respiration. The values of DO_2 are higher in winter and lower in summer. However in present study higher value was obtained in the month of September. This may be due to luxuriant growth of macrophyte thus increase in photosynthesis rate than respiration.

The dissolved oxygen showed inverse but insignificant correlation with water temperature ($r = - 0.3$), such observation was also shown by Jindal and Kumar (1993) and Thapa (1994). According to McColl (1972) the relation between temperature and dissolved oxygen is not so significant because the production and consumption of oxygen takes place simultaneously.

The value of FCO_2 decreased from summer to rainy and then increased. The permitted level of FCO_2 is 4 to 25 mg/L.

The absence of CO_2 during January on site B may be chiefly due to its complete consumption in carbon assumption or its complete conversion into carbonic acid and ultimately into stable carbonate and bicarbonate.

Maximum FCO_2 was observed during monsoon may be accounted by the reduced photosynthesis during these months. The increase concentration of FCO_2 at this time also indicates its influx through rain water in the form of carbonic acid, Chakraborty (1959) also supports his agreement.

In the present investigation free carbon dioxide shows inverse correlation ($r = + 0.4$) with DO_2 and the same was observed by Ganpati (1943) and Pandey and Lal (1995). FCO_2 shows positive but insignificant correlations with water temperature ($r = + 0.3$, $P < 0.05$) as by Rao (1955). However in the present investigation FCO_2 does not show any distinct correlation with other physico-chemical parameters.

In the present investigation the mean value of alkalinity obtained ranged between 32 ± 0.00 mg/L to 86 ± 33.9 mg/L which was lower than those reported by Pandey and Lal (1995). Total alkalinity showed positive and significant correlation with total hardness ($r = 0.6$, $P < 0.05$), positive and significant correlation with calcium hardness ($r = 0.6$, $P < 0.05$), positive and significant correlation with calcium ($r = 0.65$, $P < 0.05$) and magnesium

($r = 0.5704$, $P < 0.05$). Total alkalinity does not show any significant correlation with pH as observed by Rawat *et al*. (1995).

Spence (1964) working on the south Scottish lakes categorized lakes with more than 60ppm alkalinity as nutrient rich. Alkalinity in itself is not harmful to human beings; still the water suppliers with less than 100 mg/L are desirable for domestic use, Trivedy and Goel (1984). The present investigation shows that the lake water is suitable for aquatic life. In the present investigation acidity showed strong positive and significant correlation with free carbon dioxide ($r = 0.99$, $P < 0.05$). Other physico-chemical parameters showed no any significant correlation with acidity.

Higher value of total hardness was recorded in the month of March and lower value in the month of June. Dead Molluscan shell also releases chemical contents which increase the concentration of total hardness (Khan and Chowdhary,1994). In the present investigation total hardness showed positive and significant correlation with total alkalinity ($r = 0.64$, $P<0.05$), positive and significant correlation with calcium hardness ($r = 0.96$, $P < 0.05$), positive and significant correlation with calcium ($r = 0.97$, $P < 0.05$) and positive and significant correlation with magnesium ($r = 0.94$, $P < 0.05$).

A water body having more than 25 mg/L of calcium content has been regarded as rich by Ohle (1956). Calcium forms a principal component of shells of molluscs. The lake showed richness in calcium content thus suitable for molluscs which are good food for waterfowls.In the present investigation calcium hardness showed positive and significant correlation with total alkalinity ($r = 0.65$, $P < 0.05$), positive and significant correlation with magnesium ($r = 0.83$, $P < 0.05$), positive and significant correlation with chloride ($r = 0.52$, $P < 0.05$).

Magnesium occurs in all kinds of natural waters with calcium, and its concentration remains generally lower than calcium (Trivedy and Goel, 1984). The same trend was found in present investigation. The importance of magnesium lies with the chlorophyll bearing algae and plants. In the present investigation magnesium showed significant and positive correlation with total alkalinity ($r = 0.57$, $P < 0.05$) and positive and significant correlation with total hardness ($r = 0.94$, $P < 0.05$).

Chlorides are usually present in low concentration in water and play metabolically active role in photolysis of water and phosphorylation reactions in autotrophs. Higher chloride values were recorded during summer however no definite pattern of fluctuations, Swarup and Singh (1976) also reported an increase in Chloride during summer. The chloride concentration of lake water depends upon the amount of pollution causing matter entering into the lakes. The value obtained in the present study indicates that the lake is not polluted and lies within the tolerance limit (28 mg/L). In the present investigation chloride showed positive correlation with water temperature ($r = 0.32$) but the relation is not significant. Chloride showed positive and significant correlation with calcium hardness ($r = 0.52$, $P < 0.05$).

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