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Physico-chemical properties of Seepage stream at Shripur area, eastern Nepal

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Abstract

Physico-chemical parameters of the Seepage stream of Shripur area were studied for two years from July, 2002 to June, 2004, once in every month at regular intervals. The maximum air temperature was recorded in rainy season during first year (July, 2002 to June, 2003) and second year study period (July, 2003 to June, 2004). Water temperature was maximum in summer and lowest in winter season. Transparency, total alkalinity, total hardness, chloride were maximum in winter season. Free CO_2 and BOD was maximum in summer season. The minimum transparency, total alkalinity, total hardness and chloride were recorded in rainy season. DO and pH were maximum in winter and minimum in summer season during the whole study period. Air temperature, water temperature, free CO_2, BOD showed positive and significant correlation with each other. Transparency showed positive and significant correlation with pH, DO, total alkalinity, total hardness and chloride. pH showed positive and significant correlation with DO and chloride. Similarly, DO, total alkalinity, total hardness and chloride showed positive and significant correlation with each other.

Key words: Koshi river, seepage stream, physic0-chemical properties of water, correlation, Nepal

Introduction

The physico-chemical parameters of water bodies influence directly or indirectly (the number, varieties, distribution, metabolic activities, growth, size, forms etc.) of the aquatic organisms in various ways. Functioning of the aquatic ecosystem is regulated by the interaction among the physico-chemical and biological components of the system. Hence, it is essential to have the knowledge of physico-chemical parameters for identifying suitability and fertility of an aquatic ecosystem. The physico-chemical parameters of a water body changes due to seasonal change, diurnal changes and pollutants. These bring significant seasonal and diurnal change in abundance of aquatic organisms. Among the physico-chemical parameters (factors) mainly air temperature, water temperature, transparency, pH, dissolved oxygen, free carbon dioxide, alkalinity, hardness, chloride and BOD mainly determine the hydrological condition of water body.

Though vast number of limnological investigations has been carried out in other countries, only a few works have been done in Nepal. Mc Eachern (1994), Aryal and Lacoul (1996), Ormerod *et al*. (1996) have contributed on limnological work.

Study area

The seepage stream is situated outside the Koshi Tappu Wildlife Reserve, east to the eastern embankment of Sapta Koshi river. It is a perennial, flow from Kushaha Village development committee (VDC) to south, Bhantabari area. The study was done on Shripur VDC area, lying between 26°35'55.3"N latitude and 87°00'46.2"E longitude (Fig. 1). The seepage stream at Shripur VDC area has 125 m to 250 m wide marshes on its fringe. The depth of water of seepage stream varies in different seasons. It is somewhat polluted due to the encroachment of human but rich in marshy plant and animal species.

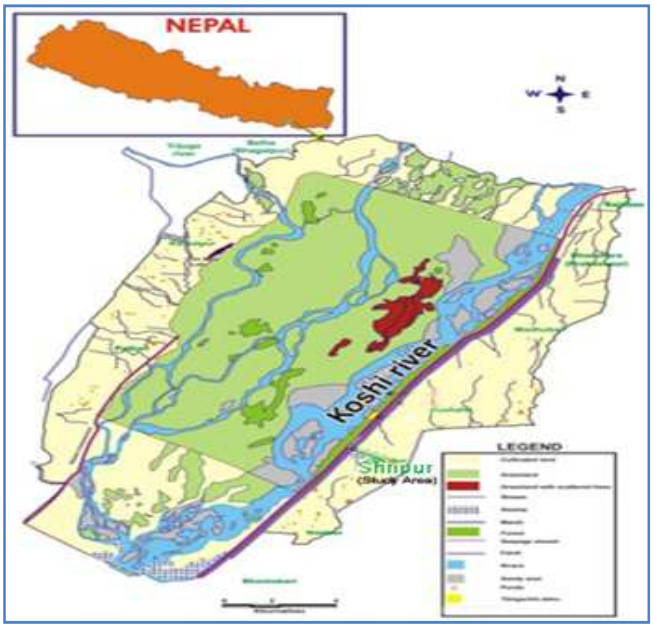

Figure 1. Map of the study area.

Materials and Methods

Physico-chemical parameters of the seepage stream at Shripur area were studied for two years from July, 2002 to June, 2004. The water samples were collected from three sites between 8 a.m. and 11 p.m., once in every month at regular interval. The air temperature and physico- chemical parameters of water were analyzed in the field. However, the BOD test after 5 days incubation in the incubator was done in the laboratory of Post Graduate Campus, Biratnagar. Transparency, air temperature and water temperature were recorded between 12 noon and 1 p.m. Air and water temperatures were recorded by centigrade mercury thermometer and pH with the help of pH meter. The transparency was measured by Secchi disc. Other parameters such as DO, free CO_2, alkalinity, hardness, chloride and BOD were measured according to Zobel *et al*. (1987) and APHA (1985). The monthly data were pooled in seasonal value and analyzed.

Results

Results of the air temperature and physico-chemical parameters of water of Seepage stream at Shripur area are shown in table 1 and table 2. Table 1 shows the results of air temperature and physico-chemical parameters of water of the first year (July, 2002-June, 2003) study period. Table 2 shows the results of air temperature and physico-chemical parameters of

Table 1. Air temperature and physico-chemical parameters of water of seepage stream at Shripur area from July 2002-June 2003 (Mean ± SD, N = 9).

Parameters	Months											
	Jul.	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**March**	**Apr.**	**May**	**Jun.**
Air temp (°c)	29.4 ±0.487	31.6 ±0.616	30.4 ±0.402	28.3 ±0.512	25.5 ±0.355	22.3 ±0.319	18.4 ±0.424	27.3 ±0.368	28.5 ±0.579	30.6 ±0.312	32.3 ±0.329	29.5 ±0.543
Water temp (°c)	25.6 ±0.721	27.1 ±0.408	27.6 ±0.480	24.6 ±0.410	21.5 ±0.781	18.6 ±0.473	16.4 ±0.518	24.3 ±0.368	26.2 ±0.377	28.3 ±0.551	28.5 ±0.539	26 ±0.520
Transparency (cm)	18.3 ±0.666	22.4 ±0.875	24.7 ±0.795	25.3 ±0.875	27.5 ±0.767	30.2 ±1.070	31.4 ±0.960	32.2 ±1.038	28.1 ±0.816	22.4 ±0.764	21.5 ±0.719	20.2 ±0.725
pH	7.5 ±0.221	7.6 ±0.188	7.8 ±0.194	7.9 ±0.176	8 ±0.149	8.1 ±0.141	8.3 ±0.149	7.5 ±0.176	7.2 ±0.205	7.3 ±0.210	7.5 ±0.221	7.8 ±0.163
DO (mg/ l)	6.34 ±0.211	6.25 ±0.270	6.36 ±0.242	6.56 ±0.272	6.67 ±0.237	7.18 ±0.292	7.8 ±0.238	7.11 ±0.264	6.1 ±0.274	5.4 ±0.258	5.3 ±0.221	5.92 ±0.234
Free CO_2 (mg/l)	5.43 ±0.230	5.62 ±0.193	5.45 ±0.242	5.33 ±0.274	5.25 ±0.216	5.17 ±0.219	5.15 ±0.188	5.67 ±0.171	5.73 ±0.253	5.93 ±0.266	6.33 ±0.258	5.83 ±0.221
Total alkalinity (mg/l)	75.34 ±0.847	72.41 ±0.821	77.32 ±0.745	86.6 ±0.835	103.42 ±1.109	115.3 ±1.209	125.59 ±1.138	111.34 ±1.128	102.67 ±1.085	98.56 ±0.800	95.32 ±0.799	85.56 ±0.890
Total hardness (mg/ l)	48.34 ±0.492	52.65 ±0.491	54.25 ±0.395	59.42 ±0.584	62.45 ±0.493	73.53 ±0.552	75.32 ±0.384	76.65 ±0.394	79.11 ±0.477	57.34 ±0.466	50.13 ±0.395	49.34 ±0.405
Chloride (mg/ l)	12.93 ±0.176	13.24 ±0.177	13.53 ±0.156	13.95 ±0.185	14.46 ±0.183	17.83 ±0.220	18.72 ±0.202	15.77 ±0.191	12.57 ±0.187	13.56 ±0.195	11.53 ±0.216	12.25 ±0.176
BOD (mg/ l)	0.93 ±0.058	0.91 ±0.045	0.88 ±0.034	0.81 ±0.029	0.78 ±0.069	0.72 ±0.048	0.69 ±0.054	0.98 ±0.045	1.55 ±0.027	1.91 ±0.053	2.1 ±0.066	1.27 ±0.046

Table 2. Air temperature and physico-chemical parameters of water of seepage stream at Shripur area from July, 2003-June, 2004 (Mean ± SD, N = 9).

Parameters	Months											
	Jul.	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**March**	**Apr.**	**May**	**Jun.**
Air temp. (°c)	30.2 ±0.424	32.1 ±0.397	31.1 ±0.374	28.4 ±0.359	25.6 ±0.503	22.5 ±0.416	18.2 ±0.432	27.3 ±0.385	29.5 ±0.476	31.2 ±0.426	33.6 ±0.290	30.3 ±0.359
Water temp. (°c)	24.6 ±0.501	28.3 ±0.359	28.2 ±0.377	25.3 ±0.487	21.2 ±0.418	17.3 ±0.394	16.6 ±0.485	24.2 ±0.418	26.7 ±0.531	28.6 ±0.312	29.5 ±0.535	25.4 ±0.388
Transparency (cm)	20.2 ±0.694	24.4 ±0.699	26.2 ±0.856	28.4 ±0.791	30.2 ±0.736	32.4 ±0.697	34.6 ±0.721	37.3 ±0.702	29.4 ±0.918	23.5 ±0.774	22.6 ±0.683	21.5 ±0.654
pH	7.6 ±0.163	7.7 ±0.216	7.8 ±0.163	7.9 ±0.182	8 ±0.176	8.1 ±0.226	8.2 ±0.191	7.6 ±0.176	7.3 ±0.182	7.4 ±0.194	7.5 ±0.202	7.8 ±0.169
DO (mg/l)	5.92 ±0.248	6.12 ±0.229	6.24 ±0.236	6.45 ±0.253	6.96 ±0.218	7.24 ±0.236	7.86 ±0.211	6.9 ±0.230	6.25 ±0.188	5.16 ±0.287	5.11 ±0.223	5.82 ±0.204
Free CO_2 (mg/ l)	5.63 ±0.188	5.72 ±0.233	5.56 ±0.202	5.43 ±0.249	5.36 ±0.183	5.25 ±0.202	5.17 ±0.165	5.73 ±0.258	5.92 ±0.204	6.14 ±0.206	6.24 ±0.226	5.72 ±0.154
Total alkalinity (mg/l)	73.34 ±0.736	71.43 ±0.763	79.63 ±0.851	87.67 ±0.676	105.57 ±0.952	113.67 ±1.186	123.54 ±1.239	110.44 ±1.012	104.35 ±0.819	99.37 ±0.765	97.62 ±0.935	86.34 ±0.786
Total hardness (mg/l)	49.34 ±0.615	52.52 ±0.586	53.64 ±0.403	57.34 ±0.494	61.52 ±0.470	72.35 ±0.413	77.34 ±0.516	78.24 ±0.403	79.25 ±0.422	58.62 ±0.436	51.5 ±0.402	50.25 ±0.602
Chloride (mg/l)	13.25 ±0.188	13.53 ±0.205	13.72 ±0.147	13.93 ±0.149	15.23 ±0.141	17.64 ±0.216	18.56 ±0.200	15.42 ±0.181	13.15 ±0.179	13.21 ±0.202	12.22 ±0.198	12.73 ±0.149
BOD (mg/l)	0.96 ±0.053	0.94 ±0.059	0.92 ±0.045	0.87 ±0.044	0.84 ±0.045	0.73 ±0.035	0.71 ±0.038	0.97 ±0.044	1.63 ±0.064	1.85 ±0.065	1.99 ±0.060	1.35 ±0.056

water of the second year (July, 2003-June, 2004) study period. Table 3 shows the correlation coefficient (r) of air temperature and physico-chemical parameters of water and table 4 shows the seasonal variations of air temperature and physico-chemical parameters of water.

Air temperature

The air temperature increased a little in August then decreased from September to January. Again it increased from February to May then a slight decrease was recorded from June to July during the first year (Tab. 1) and the second year study periods (Tab. 2). The maximum air temperature was recorded 32.3±0.329°C in May and minimum 18.4±0.424°C in January during the first year study period. During the second year study period, the maximum air temperature was recorded 33.6±0.290°C in May and minimum 18.2±0.432°C in January. The air temperature showed positive and significant correlation with water temperature (r = 0.9696, P<0.01), free CO_2 (r = 0.7654, P<0.01) and biological oxygen demand (r=0.6035, P<0.01) but inverse and significant correlation with transparency (r = -0.7033, P< 0.01), pH (r = -0.74,<0.01), DO (r = -0.8941, P<0.01), total alkalinity (r = -0. 7660, P<0.01), total hardness (r = -0.6767, P<0.01) and chloride (r = - 0. 9281, P< 0.01) (Tab. 3).

Table 3. Pearson's correlation coefficient (r) for air temperature and physico-chemical parameters of water of seepage stream at Shripur area during July, 2002-June, 2004. N = 24, d.f. = 22.

Parameters	**Water temp °C**	**Transparency (cm)**	**pH**	**DO (mg/l)**	**Free CO_2 (mg/l)**	**Total alk. (mg/l)**	**Total har. (mg/l)**	**Chloride (mg/l)**	**BOD (mg/l)**
Air temp (°c)	0.9696*	-0.7033*	-0.74*	-0.8941*	0.7654*	-0.7660*	-0.6767*	-0.9281*	0.6035*
Water temp (°c)		-0.6383*	-0.788*	-0.8786*	0.7934*	-0.6907*	-0.5834*	-0.9052*	0.6593*
Transparency (cm)			0.4012***	0.7641*	-0.4549**	0.7693*	0.8790*	0.7662*	-0.4295**
pH				0.7216*	-0.784*	0.3356	0.1448	0.7251*	-0.738*
DO (mg/ l)					-0.8555*	0.5676*	0.6571*	0.8915*	-0.8230*
Free CO_2 (mg/l)						-0.2505	-0.3375	-0.7339*	0.9215*
Total alkal (mg/ l)							0.8231*	0.7280*	-0.0559
T. hardness (mg/l)								0.6685*	-0.2243
Chloride (mg/ l)									-0.6393*

* Significant at 1% level (P<0. 01), ** significant at 5% level (P<0. 05), *** significant at 10% level (P<0.10), Values not marked denote non-significant correlation.

Water temperature

The water temperature increased from August to September then decreased from October to January. Again it increased from February to May then decreased from June to July during the first year study period (Tab. 1). The maximum water temperature was 28.5±0.539°C in May and minimum 16.4±0.518°C in January during the first year study period. During the second year study period, it increased a little in August then decreased from September to January. Again it increased from February to May then decreased from June to July (Tab. 2). The maximum water temperature was 29.5±0.535°C in May and minimum 16.6±0.485°C in January during the second year study period. The water temperature showed positive and significant correlation with free CO_2 (r = 0.7934, P< 0.01), and BOD (r = 0.6593, P<0.01) but inverse and significant correlation with transparency (r = -0.6383, P<0.01), pH (r = -0.788, P<0.01), DO (r = -0.8786, P<0.01), total alkalinity (r = -0. 6907 P< 0.01), total hardness (r = -0.5834, P<0.01) and chloride (r = - 0.9052, P<0.01) (Tab. 3).

Transparency

The transparency of water increased from August to February and decreased from March to July during the first year (Tab. 1) and the second year study periods (Tab. 2). The maximum transparency was 32.2±1.038 cm in the month of February and minimum 18.3±0.666 cm in the month of July during the first year study period. During the second year study period, the maximum water transparency was recorded 37.3±0.702 cm in the month of February and minimum 20.2±0.694 cm in the month of July. Transparency showed positive and significant correlation with pH ($r = 0.4012$, $P<0.10$), DO ($r = 0.7641$, $P<0.01$), total alkalinity ($r = 0.7693$, $P<0.01$), total hardness ($r = 0.8790$, $P<0.01$) and chloride ($r = 0.7662$, $P<0.01$) but inverse and significant correlation with free CO_2 ($r = -0.4549$, $P<0.05$) and BOD ($r = -0.4295$, $P<0.05$) (Tab. 3).

The pH increased from August to January and decreased a little from February to March. Again it increased from April to June then decreased a little in July during the first year (Tab. 1) and the second year study periods (Tab. 2). The maximum pH was 8.3±0.149 in January and minimum 7.2±0.205 in March during the first year study period. During the second year study period, the maximum pH was 8.2±0.191 in January and minimum 7.3±0.182 in March. pH showed positive and significant correlation with DO ($r = 0.7216$, $P<0.01$) and chloride ($r = 0.7251$, $P<0.01$) but inverse and significant correlation with free CO_2 ($r = -0.784$, $P<0.01$) and BOD ($r = -0.738$, $P<0.01$) (Tab. 3).

Dissolved oxygen

The DO decreased a little in August then increased from September to January. Again it decreased from February to May then increased a little from June to July during the first year study period (Tab. 1). The maximum DO was 7.8±0.238 mg/l in January and minimum 5.3±0.221 mg/l in May during the first year study period. But in the second year study period, the DO increased from August to January then decreased from February to May. Again it increased a little from June to July (Tab. 2). The maximum DO was 7.86±0.211 mg/l in January and minimum 5.11±0.223 mg/l in May during the second year study period. DO showed inverse and significant correlation with free CO_2 ($r = -0.8555$, $P<0.01$) and BOD ($r = -0.8230$, $P<0.01$) but positive and significant correlation with total alkalinity ($r = 0.5676$, $P<0.01$), total hardness ($r = 0.6571$, $P<0.01$) and chloride ($r = 0.8915$, $P<0.01$) (Tab. 3).

Free carbon dioxide

The free CO_2 increased a little in August then it decreased from September to January. Again it increased from February to May then decreased a little from June to July during the first year (Tab. 1) and the second year study periods (Tab. 2). The maximum free CO_2 was 6.33±0.258 mg/l in the month of May and minimum was 5.15±0.188 mg/l in the month of January during the first year study period. During the second year study period, the maximum free CO_2 was 6.24±0.226 mg/l in May and minimum 5.17±0.165 mg/l in January. Free CO_2 showed positive and significant correlation with BOD ($r = 0.9215$, $P<0.01$) but inverse and significant correlation with chloride ($r = -0.7339$, $P<0.01$) (Tab. 3).

Total alkalinity

The total alkalinity decreased a little in August then increased from September to January and decreased from February to July during the first year (Tab. 1) and the second year study

periods (Tab. 2). The maximum total alkalinity was 125.59±1.138 mg/l in January and minimum 72.41±0.821 mg/l in August during the first year study period. During the second year study period, the maximum total alkalinity was 123.54±1.239 mg/l in the month of January and minimum 71.43±0.763 mg/l in August. Total alkalinity showed positive and significant correlation with total hardness (r = 0. 8231, P<0.01) and chloride (r = 0.7280, P<0.01 (Tab. 3).

Total hardness

The total hardness increased from August to March then decreased from April to July during the first year (Tab. 1) and the second year study periods (Tab. 2). The maximum total hardness was 79.11±0.477 mg/l in March and minimum 48.34±0.492 mg/l in July during the first year study period. During the second year study period, the maximum total hardness was 79.25±0.422 mg/l in March and minimum 49.34±0.615 mg/l in July. Total hardness showed positive and significant correlation with chloride (r = 0.6685, P<0.01) (Tab. 3)

Chloride

The chloride increased from August to January then decreased from February to March. Again it increased a little in April then a slight decrease was recorded in May followed by a gradual increase from June to July during the first year (Tab. 1) and the second year study periods (Tab. 2). The maximum chloride was 18.72±0.202 mg/l in January and minimum 11.53±0.216 mg/L in May during the first year study period. During the second year study period, the maximum chloride was 18.56±0.200 mg/l in January and minimum 12.22±0.198 mg/l in May. Chloride showed inverse and significant correlation with BOD (r = -0.6393, P>0.01), (Tab. 3).

Biological oxygen demand

The BOD decreased from August to January then increased from February to May. Again it decreased a little from June to July during the first year (Tab. 1) and the second year study periods (Tab. 2). The maximum BOD was 2.1±0.066 mg/l in May and minimum 0.69±0.054 mg/l in January during the first year study period. During the second year study period, the maximum BOD was 1.99±0.060 mg/l in May and minimum 0.71±0.038 mg/l in January. BOD was positive and significantly correlated with air temperature (r= 0. 6035 P< 0.01), water temperature (r= 0.6593 P< 0.01) and free CO_2 (r = 0.9215, P< 0.01) but inverse and significantly correlated with transparency (r= -0.4295, P<0.05), pH (r= -0.738, P <0.1), DO (r = -0. 8230) and chloride (r = - 0. 6393, P< 0.01) (Tab. 3).

Seasonal variations in air temperature and physico-chemical parameters of water at Shripur area during the first year and second year study period are presented in table 4. The maximum air temperature of the area was in rainy season and minimum in winter season but the water temperature was maximum in summer and minimum in winter during the first and the second year study periods. The maximum value of transparency, total alkalinity, total hardness and chloride were in winter season followed by summer and rainy seasons during the first and the second year study periods. The pH was maximum in winter season and minimum in summer season during the first and the second year study periods. The maximum DO was in winter season and minimum in summer season during the first and the second year study periods. The maximum value of free CO_2 and BOD were in summer season followed by rainy and winter during the first and second year study periods.

Discussion

The highest air temperature was recorded in the month of May (Tabs. 1, 2). When data on monthly air temperature were pooled in seasonal values, the rainy season showed highest air temperature (Tab. 4). The summer temperature (30.04°C) was moderate in this region due to its geographical location. Air temperature showed positive and significant correlation with water temperature (Tab. 3). Rawat *et al*. (1995) also obtained strong positive significant correlation between air and water temperatures.

Generally, water temperature is influenced by air temperature and intensity of solar radiation. It was highest in summer and lowest in winter (Tab. 4). Highest value was recorded in summer might be due to high air temperature and greater light penetration. Though the high air temperature appeared in rainy season, a little lower water temperature was recorded at that time in comparison to summer season. It might be due to high turbidity, high volume of water and greater velocity of water in rainy season. The water temperature showed positive and significant correlation with free CO_2 and BOD but had inverse and significant correlation with transparency, pH, DO, total alkalinity and total hardness. Bose and Gorai (1993) reported negative significant correlation between water temperature and DO.

Table 4. Seasonal variations in air temperature and physico-chemical parameters of water of seepage stream at Shripur area during the first year (July, 2002-June, 2003) and the second year (July, 2003-June, 2004) study periods.

Parameters	Year I			Year II		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Air temperature (°C)	29.68	30.23	23.63	30.4	30.93	23.68
Water temperature(°C)	26.83	26.58	20.28	27.25	26.63	20.1
Transparency (cm)	26.05	21.4	28.6	28.2	23.08	31.4
pH	7.38	7.68	8.08	7.45	7.73	8.05
Dissolved oxygen (mg/l)	5.98	6.22	7.05	5.86	6.03	7.13
Free Carbon dioxide (mg/)	5.92	5.58	5.23	6.01	5.66	5.30
Total alkalinity (mg/)	101.97	77.66	107.73	102.95	77.69	107.61
Total hardness (mg/l)	65.81	51.15	67.68	66.90	51.44	67.14
Chloride (mg/l)	13.36	12.99	16.24	13.5	13.31	16.34
BOD (mg/l)	1.64	1	0.75	1.61	1.04	0.79

The maximum Secchi disc transparency was recorded in winter followed by summer and rainy seasons (Tab. 4). The maximum transparency was in winter due to lesser amount of suspended organic and inorganic materials and absence of rain. Transparency is influenced mainly by suspended organic matter (Green, 1974). Higher transparency during winter months was recorded by Rawat *et al*. (1995). In this study minimum transparency recorded in the rainy season may be due to more sand and colloidal particles carried by the rain water. Similar trends were observed by Rawat *et al*. (1995). The maximum pH of present study was in winter season followed by rainy and summer seasons (Tab. 4). The maximum pH in winter season may be attributed to algal blooms because the higher pH is associated with the phytoplankton maxima. The minimum pH recorded in summer may be due to low photosynthesis. Several workers have reported low pH during the low photosynthetic period due to the formation of carbonic acid (Gautam, 1990). The pH showed positive and significant correlation with DO.

The maximum DO was recorded in winter season followed by rainy and summer season (Tab. 4). The maximum DO found in winter season may be due to low temperature. Similar observations were made by Moitra and Bhattacharya (1965). The minimum DO was found in summer due to high temperature, and higher microbial demand for oxygen in decomposition of suspended organic matter (Palharya & Malvia, 1988). DO content showed positive and significant correlation with total alkalinity and total hardness. It showed inverse and significant correlation with water temperature, free CO_2 and BOD. Bose and Gorai (1993) also reported inverse and significant correlation of DO with water temperature. Jindal and Kumar (1993) reported inverse correlation of DO with water temperature. According to McColl (1972) the relation between water temperature and DO is not so significant because the production and consumption of oxygen takes place simultaneously.

The maximum free CO_2 was recorded in summer season followed by rainy and winter season (Tab. 4). The maximum free CO_2 was recorded in summer, it may be due to high temperature, high rate of decomposition of organic matter, low volume of water etc. Michael (1969) stated that the concentration of CO_2 is directly correlated with the amount and nature of biological activity in water. In this study the minimum free CO_2 was found in winter season. Ray and David (1966) and Gautam (1990) also found minimum free CO_2 in winter season. Free CO_2 of water showed positive and significant correlation with water temperature and BOD, and inverse and significant correlation with CO_2 (Tab. 4).

The total alkalinity was found maximum in the month of January. Seasonally the maximum total alkalinity was found in winter season followed by summer and rainy seasons (Tab. 4). It was found maximum in winter season due to high pH. Ray and David (1966) also reported maximum total alkalinity during winter. Water bodies having total alkalinity from 40 to 90 mg/l is considered as medium productive and above 90 mg/l as highly productive (Jhingran, 1991). This investigation showed that the study area is suitable for aquatic production. Total alkalinity showed positive and significant correlation with total hardness and chloride.

The maximum total hardness was in winter season followed by summer and rainy seasons (Tab. 4). The maximum total hardness in winter season might be due to low volume of water and slow current of water. Minimum quantity in rainy season may be due to more dilution of water (Patralekh, 1994). Ruttner (1953) also recorded similar relationship. It showed positive and significant correlation with total alkalinity (Tab. 3).

The maximum chloride was recorded in winter season which might be due to more contamination by organic matters. Chloride concentration indicates the presence of organic waste of animal origin. Munawar (1970) has suggested that higher concentration of chloride in water is an index of pollution of animal origin and there is a direct relation between chloride concentration and pollution level. Chloride showed positive and significant correlaton with total alkalinity (Tab. 3).

The maximum BOD was recorded in summer followed by rainy and winter season (Tab. 4). The maximum BOD obtained in summer may be due to low volume of water and high content of organic matter whereas minimum obtained in winter may be due to low temperature and retarded microbial activity for the decomposition of organic matters. Ray and David (1966) opined that high BOD value indicates organic waste pollution. BOD showed positive and significant correlation with air temperature, water temperature and free

CO_2 and inverse and significant correlation with pH and DO (Tab. 4). Ray and David (1966) also reported inverse correlation of BOD with DO.

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