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Physico-chemical parameters of Seepage stream at Kushaha area

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Abstract

Physico-chemical parameters of the Seepage stream of Kushaha area were studied for two years from July, 2002-June, 2004, once in every month at regular intervals. The monthly data were pooled in seasonal value. The maximum air temperature was recorded in rainy season during first year study period (July, 2002 to June, 2003) but in the second year study period (July, 2003 to June 2004) it was maximum in summer season. Water temperature was maximum in summer and lowest in winter season. Transparency, PH, dissolved oxygen, total alkalinity, total hardness, chloride were recorded maximum in winter season. Free carbondioxide, and biological oxygen demand was maximum in summer season. The minimum transparency, total alkalinity, total hardness and chloride were recorded in rainy season. Dissolved oxygen, and PH, were minimum in summer season. The minimum carbondioxide and BOD were recorded in winter season. Air temperature, water temperature, free carbondioxide, biological oxygen demand showed positive and significant correlation with each other. Similarly, transparency, PH, total alkalinity, total hardness, chloride, showed positive and significant correlation with each other. Dissolved oxygen showed positive and significant correlation with pH, total alkalinity, total hardness and chloride.

Keywords: Physico- chemical parameters; seepage system

1. Introduction

The physico- chemical condition of a water body has a direct influence on the organisms. Seasonal fluctuations of various physico- chemical parameters have an important role in the distribution, periodicity, qualitative and quantitative composition of biota in aquatic ecosystem. The knowledge of all these parameters are essential for identifying the suitability and fertility of an aquatic ecosystem.

Several limnological studies have been done in the rivers and lakes of Nepal. Hickel [1], Lohaman *et al*. [2], Jones *et.al* [3], McEachern [4], Aryal and Lacoul [5], Ormerod *et al*. [6] 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 water body flowing from Kushaha Village development committee (VDC) to south, Bhantabari area. The study site - Kushaha VDC area, lies between 26°37' 10.6" N latitude and 87° 01' 38.2" E longitude (Fig. 1). The seepage stream at kushaha 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 human encroachment but rich in biodiversity.

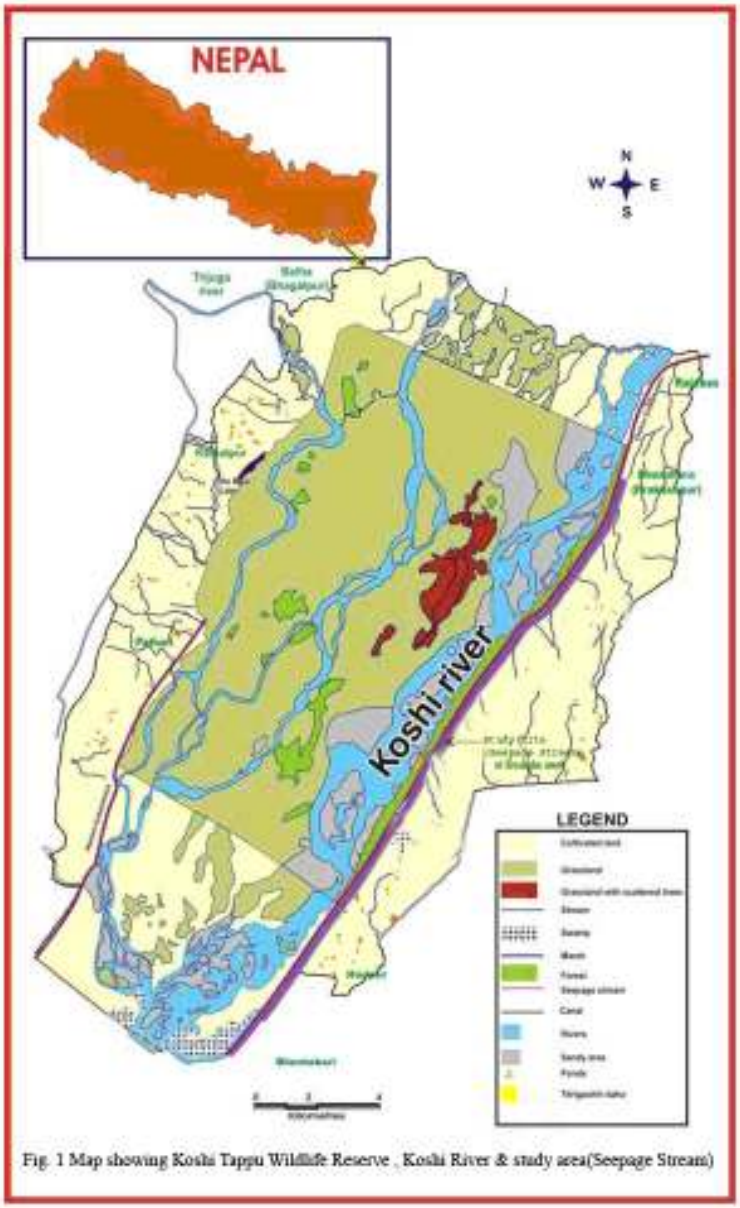

Fig. 1 Map showing Koshi Tappu Wildlife Reserve , Koshi River & study area(Seepage Stream)

2. Materials and Methods

Physico-chemical parameters of the seepage stream were studied for two years from July, 2002-June, 2004. The water samples were collected from three sites between 8 a.m. and 11 p.m., once in every month. The air temperature and physico- chemical parameters of water were analysed 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 dissolved oxygen, free carbon dioxide, alkalinity, hardness, chloride, and BOD were measured according to Michael (7) Zobel *et al*. (8) and APHA (9).

3. Results

3.1 Air temperature

The minimum air temperature was 18.5 ±0.656 °C in the month of January and maximum 32.4± 0.421 °C in August during the first year study period. The air temperature increased from July to August and decreased from September to January. Again it increased from February to May then a slight decrease was recorded in June during the first year study period (Table 1). During the second year study period, 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 in June and July (Table 2). The maximum air temperature was 33.2 ± 0.559 °C in May and minimum 19.3 ± 0.382 °C in January during the second year study period. Air temperature showed positive and significant correlation with water temperature ($r = 0.9794$, $P<0.01$), free carbon dioxide ($r = 0.6677$, $P<0.01$) and biological oxygen demand ($r = 0.6062$, $P<0.01$) but it had inverse and significant correlation with transparency ($r= - 0.452$, $P<0.05$), pH ($r = -0.908$, $P<0.01$), dissolved oxygen ($r = - 0.8994$ $P<0.01$), total alkalinity ($r = - 0.6713$, $P<0.01$), total hardness ($r = - 0.6239$, $P<0.01$) and chloride ($r = - 0.6759$, $P<0.01$) (Table 3).
Seasonally, the highest air temperature was recorded in rainy season and minimum in winter season during the first year study period but it was highest in summer during the second year study period (Table 4).

3.2 Water temperature

The water temperature increased from July to August then decreased from September to January. Again it increased from February to May and a slight decrease was recorded in June during the first year (Table 1) and the second year study periods (Table 2). The maximum water temperature was recorded in May and minimum in January during the whole study period. The water temperature showed positive and significant correlation with free carbon dioxide ($r = 0.7319$, $P<0.01$) and biological oxygen demand ($r = 0.6960$ $P<0.01$) but it showed inverse and significant correlation with transparency ($r = -3893$, $P<0.10$), P^H ($r = - 0.917$, $P <0.01$), dissolved oxygen ($r = -0.9229$, $P<0.01$), total alkalinity ($r = -0.5613$, $P<0.01$), total hardness ($r = - 0.5167$, $P<0.01$) and chloride ($r = -0.6645$, $P<0.01$) (Table 3).

Seasonally, the maximum water temperature was in summer followed by rainy and winter seasons during the first and the second year study periods (Table 4).

3.3 Transparency

The transparency increased from August to December then decreased a little in January. Again it increased from February to March then decreased a little in April and again increased a little in May then decreased from June to July during the first year study period (Table 1). The maximum

transparency was 37.34 ± 0.650 cm in December and minimum 19.2 ± 0.419 cm in July during the first year study period. In the second year study period, the transparency increased from August to December then decreased a little in January. Again it increased from February to March then decreased from April to July (Table 2). The maximum transparency was 33.2 ± 1.001 cm in March and minimum 20.2 ± 0.986 cm in July during the second year study period. Water transparency showed positive and significant correlation with pH ($r = 0.5196$, $P < 0.01$), total alkalinity ($r = 0.5621$, $P<0.01$), total hardness ($r = 0.8032$, $P<0.01$) and chloride ($r = 0.4667$, $P<0.05$) (Table 3).

The maximum value of transparency was in winter season followed by summer and rainy seasons during the first and second year study periods (Table 4).

3.4 pH

The pH increased from July to December then decreased from January to May. Again it increased a little in June during the first year study period (Table 1). The maximum pH was 8.3±0.221 in December and minimum 7.2 ± 0.211 in May during the first year study period. During the second year study period, pH increased from July to January then decreased from February to April. Again a slight increase was recorded in May then decreased a little in June (Table 2). The maximum pH was 8.3 ± 0.205 in January and minimum 7.1mg/l ±0.163 and 7.1 ± 0.240 in April and June, respectively. pH showed positive and significant correlation with dissolved oxygen ($r = 0.887$, $P<0.01$), total alkalinity ($r = 0.5583$, $P<0.01$) total hardness ($r = 0.6099$, $P<0.01$) and chloride ($r = 0.6314$, $P<0.01$) but inverse and significant correlation with free carbon dioxide ($r = -0.712$, $P< 0.01$) and biological oxygen demand ($r = -0.67$, $P<0.01$) (Table 3).

The maximum pH was in winter and minimum in summer season during the first and the second year study period (Table 4).

3.5 Dissolved oxygen

The dissolved oxygen decreased from July to September then increased from October to January. Again it decreased from February to May and a slight increase was recorded in June during the first year study period (Table 1). The maximum dissolved oxygen was 6.96 ±0.268 mg/l in January and minimum 5.73 ± 0.287 mg/l in May during the first year study period. During the second year study period, the dissolved oxygen decreased from July to August then increased from September to January. Again it decreased from February to May and a slight increase was recorded in June (Table 2). The maximum dissolved oxygen was 7.3 ± 0.301 mg/l in January and minimum 5.92 ± 0.219 mg/l in May. The dissolved oxygen showed positive and significant correlation with total alkalinity ($r = 0.5241$, $P<0.01$), total hardness ($r = 0.4430$, $P<0.05$) and with chloride ($r = 0.6643$, $P<0.01$) but inverse and significant correlation with free carbon dioxide ($r = -0.7342$, $P<0.01$) and biological oxygen demand ($r = -0.7237$, $P<0.0.01$) (Table 3).

The maximum dissolved oxygen was in winter season followed by rainy and summer seasons during the first and the second year study periods (Table 4).

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

Parameters	Months											
	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	Jun.
Air temperature (°C)	31.3	32.4	28.3	27.6	22.7	21.2	18.5	27.6	29.4	30.3	31.3	29.2
	±0.487	±0.421	±0.483	±0.609	±0.394	±0.397	±0.656	±0.586	±0.459	±0.385	±0.501	±0.294
Water temperature (°C)	27.3	28.2	24.2	23.3	19.2	18.1	16.2	25.4	27.4	28.3	29.3	25.3
	±0.485	±0.283	±0.427	±0.616	±0.326	±0.569	±0.343	±0.416	±0.639	±0.464	±0.589	±0.383
Transparency (cm).	19.2	22.3	24.2	25.4	31.6	37.34	25.3	31.5	34.3	22.7	23.4	22.3
	±0.419	±0.604	±0.721	±0.678	±0.548	±0.650	±0.512	±0.863	±0.818	±0.467	±0.705	±0.803
PH	7.4	7.5	7.5	7.7	7.9	8.3	8.1	7.7	7.4	7.3	7.2	7.3
	±0.176	±0.182	±0.216	±0.210	±0.194	±0.221	±0.188	±0.156	±0.216	±0.149	±0.211	±0.176
Dissolved oxygen (DO_2), (mg/l)	6.18	6.15	6.13	6.29	6.61	6.91	6.96	6.26	5.98	5.92	5.73	6.25
	±0.236	±0.216	±0.231	±0.222	±0.223	±0.277	±0.268	±0.165	±0.260	±0.253	±0.287	±0.205
Free carbon dioxide (CO_2), (mg/l)	5.12	5.63	5.75	5.33	4.92	4.83	5.23	5.46	5.79	5.84	5.75	5.35
	±0.215	±0.221	±0.222	±0.156	±0.154	±0.211	±0.188	±0.240	±0.214	±0.236	±0.170	±0.221
Total alkalinity (mg/ l)	71.33	67.64	60.35	72.53	95.45	108.34	110.64	96.56	94.67	91.58	89.6	79.63
	±0.725	±0.634	±0.683	±0.812	±1.023	±1.107	±1.040	±0.820	±0.728	±1.014	±0.805	±0.783
Total hardness (mg/ l)	50.52	56.34	61.25	63.52	75.56	76.33	78.65	79.34	81.22	63.65	53.34	52.56
	±0.539	±0.389	±0.437	±0.475	±0.405	±0.349	±0.391	±0.368	±0.535	±0.321	±0.585	±0.435
Chloride (mg/ l)	13.24	13.83	14.23	14.45	15.26	18.73	17.27	16.36	14.84	13.14	14.45	17.23
	±0.142	±0.156	±0.149	±0.163	±0.169	±0.205	±0.196	±0.157	±0.171	±0.134	±0.188	±0.216
Biological Oxygen Demand (BOD), (mg/ l)	0.99	0.98	0.93	0.91	0.87	0.82	0.79	1.14	1.61	1.81	2.11	1.13
	±0.033	±0.036	±0.049	±0.041	±0.045	±0.056	±0.052	±0.058	±0.075	±0.030	±0.055	±0.057

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

Parameters	Months											
	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	Jun.
Air temperature (°C)	30.3	31.4	29.3	28.3	23.5	22.4	19.3	28.4	30.3	31.4	33.2	30.3
	±0.457	±0.416	±0.489	±0.410	±0.421	±0.402	±0.382	±0.571	±0.487	±0.405	±0.559	±0.485
Water temperature (°C)	27.2	28.2	25.4	24.6	19.4	18.2	16.5	25.6	28.6	29.1	29.3	26.4
	±0.346	±0.437	±0.346	±0.336	±0.480	±0.391	±0.249	±0.461	±0.336	±0.294	±0.489	±0.489
Transparency (cm).	20.2	23.4	26.5	27.4	28.6	32.3	24.2	29.4	33.2	24.5	23.4	22.3
	±0.986	±0.820	±0.890	±0.804	±0.909	±1.141	±0.653	±0.819	±1.001	±0.870	±0.857	±0.671
PH	7.3	7.5	7.6	7.7	7.9	8.2	8.3	7.6	7.4	7.1	7.3	7.1
	±0.176	±0.188	±0.163	±0.176	±0.176	±0.187	±0.205	±0.206	±0.230	±0.163	±0.226	±0.240
Dissolved oxygen (DO_2), (mg/ l)	6.19	6.15	6.26	6.75	6.85	6.9	7.3	6.14	6.12	6.1	5.92	6.24
	±0.224	±0.286	±0.254	±0.197	±0.156	±0.240	±0.301	±0.216	±0.239	±0.274	±0.219	±0.206
Free carbon dioxide (CO_2), (mg/ l)	5.23	5.57	5.92	5.14	5.1	4.73	5.23	5.9	6.2	5.93	5.89	5.87
	±0.230	±0.257	±0.261	±0.216	±0.258	±0.258	±0.230	±0.210	±0.194	±0.235	±0.207	±0.240
Total alkalinity (mg/ l)	69.45	66.78	61.52	74.52	98.72	107.83	111.73	98.64	94.57	93.52	87.65	77.76
	±1.005	±0.931	±0.944	±0.929	±0.858	±1.003	±0.953	±0.916	±0.843	±1.098	±0.841	±0.810
Total hardness (mg/ l)	51.45	54.35	60.65	63.52	65.34	69.89	77.65	78.34	82.49	56.34	54.11	53.54
	±0.434	±0.307	±0.343	±0.415	±0.449	±0.373	±0.623	±0.408	±0.430	±0.655	±0.395	±0.279
Chloride (mg/ l)	14.56	14.83	15.14	15.17	15.34	18.63	18.34	17.24	15.54	14.32	15.26	17.13
	±0.221	±0.258	±0.206	±0.278	±0.283	±0.282	±0.236	±0.254	±0.240	±0.257	±0.233	±0.230
Biological Oxygen Demand (BOD), (mg/ l)	1	0.98	0.89	0.85	0.84	0.78	0.72	1.1	1.56	1.79	2.14	1.1
	±0.036	±0.048	±0.043	±0.042	±0.044	±0.048	±0.040	±0.042	±0.071	±0.055	±0.040	±0.048

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

Parameters	Water temperature (°C)	Transparency (cm).	P^H	Dissolved oxygen (Do_2), (mg/L)	Free carbon dioxide (Co_2) (mg/L)	Total alkalinity (mg/L)	Total hardness (mg/L)	Chloride (mg/L)	Biological Oxygen Demand (BOD), (mg/L)
Air temperature (°C)	0.9794*	-0.452**	-0.908*	-0.8994*	0.6677*	-0.6713*	-0.6239*	-0.6759*	0.6062*
Water temperature (°C)		-0.3893***	-0.917*	-0.9229*	0.7319*	-0.5613*	-0.5167*	-0.6645*	0.6960*
Transparency (cm).			0.5196*	0.3216	-0.1971	0.5621*	0.8032*	0.4667**	-0.1251
P^H				0.887*	-0.712*	0.5583*	0.6099*	0.6314*	-0.67*
Dissolved oxygen (DO_2),(mg/ l)					-0.7342*	0.5241*	0.4430**	0.6643*	-0.7237*
Free carbon dioxide (CO_2) (mg/l)						-0.2834	-0.1117	-0.3789***	0.6473*
Total alkalinity (mg/L)							0.6943*	0.6284*	0.0548
Total hardness (mg/l)								0.4786**	-0.2052
Chloride (mg/l)									-0.3984***

(i) * Significant at 1% level (P<0. 01), ** significant at 5% level (P<0. 05), * significant at 10% level (P<0. 10)**

(ii) Values not marked denote non-significant correlation.

Table 4 Seasonal variations in air temperature and physico-chemical parameters of water of Seepage stream at Kuhasha 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)	29.65	30.3	22.5	30.83	30.33	23.38
Water temperature(°C)	27.6	26.25	19.2	28.15	26.8	19.68
Transparency (cm).	27.98	22	29.91	27.63	23.1	28.13
P^H	7.4	7.43	8	7.35	7.38	8.03
Dissolved oxygen (DO_2), (mg/l)	5.97	6.18	6.69	6.07	6.21	6.95
Free carbon dioxide(CO_2) (mg/l)	5.71	5.46	5.08	5.98	5.65	5.05
Total alkalinity (mg/l)	93.10	69.74	96.74	93.60	68.88	98.2
Total hardness (mg/l)	69.39	55.17	73.52	67.82	55	69.1
Chloride (mg/l)	14.70	14.63	16.43	15.59	15.42	16.87
Biological Oxygen Demand (BOD), (mg/l)	1.67	1.01	0.85	1.65	0.99	0.80

3.6 Free carbon dioxide

The free carbon dioxide increased a little from August to September then decreased from October to December. Again it increased from January to April then decreased from May to July during the first year study period (Table 1). The maximum free carbon dioxide was recorded 5.84 ± 0.236 mg/l in April and minimum 4. 83 ± 0. 211 mg/l in December during the first year study period. During the second year study period, the free carbon dioxide increased from August to September then decreased from October to December. Again it increased from January to March then decreased from April to July (Table 2). The maximum free carbon dioxide was 6. 2 ± 0.194 mg/l in March and minimum 4.73 ±0.258 mg/l in the month of December during the second year study period. Free carbon dioxide showed positive and significant correlation with biological oxygen demand (r =0. 6473, P<0.01) and inverse and significant correlation with chloride (r = -0.3789, P<0.10) (Table 3).

The free carbon dioxide was maximum in summer season followed by rainy and winter seasons during the first and the second year study periods (Table 4).

3.7 Total alkalinity

The total Alkalinity decreased from July to September then increased from October to January. Again it decreased from February to June during the first year (Table 1) and the second year study periods (Table 2). The maximum total alkalinity was recorded 110.64 ± 1.040 mg/l in January and minimum 60.35 ± 0.683 mg/l in September during the first year study period. During the second year study period, the maximum total alkalinity was recorded 111.73 ± 0.953 mg/l in January and minimum 61.52 ± 0.944 mg/l in September. The total alkalinity showed positive and significant correlation with total hardness (r = 0.6943, P<0.01) and chloride (r = 0.6284, P< 0.01) (Table 3).

The maximum value of total alkalinity was in winter season followed by summer and rainy seasons during the first and second year study periods (Table 4).

3.8 Total hardness

The total hardness increased from August to March then decreased from April to July during the first year (Table 1) and the second year study periods (Table 2). The maximum hardness was 81.22 ± 0.535 mg/l in March and minimum 50.52 ±0.539 mg/l in July during the first year study period. During the second year study period, the maximum total hardness was 82.49 ± 0.430 mg/l in March and minimum was 51.45 ± 0.434 mg/l in July. Total hardness showed positive and significant correlation with chloride (r = 0.4786, P<0.05) (Table 3).

The maximum value of total hardness was in winter season followed by summer and rainy seasons during the first and second year study periods (Table 4).

3.9 Chloride

The chloride increased from August to December then decreased from January to April. Again it increased from May to June then a slight decrease was recorded in July during the first year (Table 2) and the second year study periods (Table 2). The maximum chloride was 18.73 ± 0.205 mg/l in December and minimum 13.14 ± 0.134 mg/l in April during the first year study period. During the second year study period, the maximum chloride was 18.63 ± 0.282 mg/l in December and minimum 14.32 ± 0.257 mg/l in April. Chloride showed inverse and significant correlation with biological oxygen demand (r = -0.3984, P< 0.10) (Table 3).

The maximum value of chloride was in winter season followed by summer and rainy seasons during the first and second year study periods (Table 4).

3.10 Biological oxygen demand

The biological oxygen demand decreased from July to January then increased from February to May. Again it decreased a little in June during the first year (Table 1) and the second year study periods (Table 2). The maximum biological oxygen demand was 2.11 ±0.055 mg/l in the month of May and minimum 0.79 ± 0.052 mg/l in the month of January during the first year study period. During the second year study period, the maximum biological oxygen demand was 2.14 ±0.040 mg/l in the month of May and minimum 0.72 ± 0.040 mg/l in the month of January. Biological oxygen demand showed positive and significant correlation with air temperature ($r = 0.6062$ $P<0.01$), water temperature ($r =0.6960$ $P< 0.01$) and free carbon dioxide ($r = 0.6473$ $P < 0.01$) but it had inverse and significant correlation with P^H ($r = - 0.67$, $P< 0.01$), dissolved oxygen ($r = -0.7237$, $P< 0.01$), and chloride ($r = - 0.3984$ $P < 0.10$) (Table 3).

Seasonally, biological oxygen demand was maximum in summer season followed by rainy and winter seasons during the first and the second year study periods (Table 4).

4. Discussion

The rainy season showed highest air temperature in the first year study period because gradual increase in air temperature was noticed during summer months (February, March, April and May). Air temperature showed positive and significant correlation with water temperature. Chakaraborty *et al*. (10), Kant and Anand (11) and Rawat *et al*. (12) also obtained strong positive 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. 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 in the first year study period, a little lower water temperature was recorded at that time in comparison to that of 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 inverse and significant correlation with dissolved oxygen. Bose and Gorai (13) also reported inverse and significant correlation between water temperature and dissolved oxygen. Welch (14) and Munawar (15) have observed that shallower the water body more quickly it reacts to the change in the temperature.

The maximum secchi disc transparency was recorded in winter followed by summer and rainy seasons. The maximum transparency was in winter due to lesser amount of suspended organic and inorganic materials and absence of rain. Higher transparency during winter months was recorded by Singh (16), Rawat *et al*. (12), and Mishra *et al*. (17). In this study minimum transparency was recorded in rainy season might be due to more sand particles and colloidal soil carried by the rain water. Similar trends were observed by Singh (18), Rawat *et al*. *(*12), and Mishra *et al*. (19).

The maximum pH was in winter season may be attributed to algal blooms because Hutchinson *et al*. (20) and Roy (21) have shown that 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 photosynthesis due to the formation of carbonic acid (Hannan and Yong (22) Cabecadas and Brogueira (23) Bais *et al*.(24).

The maximum dissolved oxygen found in winter season may be due to low temperature. Similar observation were made by Moitra and Bhattacharya (25). The minimum dissolved oxygen was found in summer due to high temperature, and higher microbial demand for oxygen in decomposition of suspended organic matter (Bhowmick and Singh (26) Dissolved oxygen content showed inverse and significant correlation with water temperature. Bose and Gorai (13) also reported similar result.

The maximum free carbon dioxide was recorded in summer, it may be due to high temperature, high rate of decomposition of organic matter, low volume of water etc. Michael (27) stated that the concentration of carbon dioxide is directly correlated with the amount and nature of biological activity in water. The minimum free carbon dioxide was found in winter season. Pahwa and Mehrotra (28), Ray *et al*. (29) also found minimum free carbon dioxide in winter season.

The maximum total alkalinity was found in winter season due to high pH. Chakraborty *et al*. (10), Singh (16) and Mishra *et al*. (19) also reported maximum total alkalinity during winter. Jhingran (30) reported water bodies having total alkalinity from 40 to 90 mg/l as medium productive and above 90 mg/l as highly productive. This investigation showed that the study area is suitable for aquatic production. Total alkalinity showed positive and significant correlation with total hardness. Barat and Jha, (31) also reported similar result.

The maximum total hardness in winter season might be due to low volume of water and slow current of water. Similar results were obtained by Misra *et al*. (17). Patralekh (32) pointed minimum quantity in rainy season may be due to more dilution of water. Ruttner (33) also recorded similar relationship.

Maximum chloride recorded in winter season might be due to more contamination by organic matters. Klein (34) pointed out a direct relationship between amount of chloride and level of pollution.

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. Similar observations were also made by Singh (18). Ray and Devid (35) opined that high BOD value indicates organic waste pollution. BOD showed inverse and significant correlation with dissolved oxygen. Ray and David (35) also reported similar relationship.

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