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Research Article

PHYSICO-CHEMICAL CHARACTERISTICS OF WATER IN WULAR LAKE –A RAMSAR SITE IN KASHMIR HIMALAYA

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ABSTRACT
An investigation was carried out to monitor the water quality over a period of one year on monthly basis at five study sites in the lake. Among the various parameters recorded, the overall surface water temperature ranged from 2.2^{0}C to 32.4^{0}C transparency from 0.2 m to 2.2 m; depth from 0.3 m to 5.5 m; pH from 7 to 8.8; dissolved oxygen from 3.4 mg/L to 11.5 mg/L; total alkalinity from 47mg/L to 257 mg/L; free CO_2 from 8 mg/L to 28mg/L; chloride from 8.4 mg/L to 29 mg/L; ammonical nitrogen from 49 µg/L to 542 µg/L; nitrate nitrogen from 146 µg/L to 483 µg/L, orthophosphate 13.0 µg/L to 36 µg/L and total phosphate from 102 µg/L to 297 µg/L. The high values of the physico-chemical parameters of water obtained in the present study sites indicate the eutrophic status of the lake.

Key Words*: Physico-chemical Parameters, Correlation, Eutrophic*

INTRODUCTION
Freshwater ecosystems are considered as one of the most important natural resources for the survivability of all the living organisms of the biosphere. The alarming rate of deterioration of water quality of fresh water resources like lakes, ponds, rivers etc. is now a global problem. Over-exploitation and pollution of water are responsible for making it scarce and unfit for consumption. For sustainable utilization of the water resources, periodic examination of the freshwater bodies are very much essential. Thus the present study has been undertaken to determine the physico-chemical characteristics of water samples in order to assess the water quality status of Wular lake, the largest freshwater lake in Indian subcontinent.

Study Area

Geographically the lake is situated at an altitude of 1,580 m (a.m.s.l), between 34°16´-34°20´N latitudes and 74°33´-74°44´E longitudes. Wular lake, an ox-bow type lake, is of fluviatile origin located in the north-west of Kashmir about 55 km from Srinagar city, being formed by the meandering of River Jhelum, which is the main feeding channel besides other tributaries. The lake is drained in the north-east by the only single outlet in the form of River Jhelum. The catchment of the lake is comprised of slopping hills of the Zanaskar ranges of the western Himalaya on the north eastern side and arable land around used for agriculture purposes.

Study Sites
Five sampling sites were chosen for the evaluation of various physico-chemical parameters of water within the lake (Fig.1)

SITE I: is located at a latitude 34^{0}21´ 51.5″N and longitude 74^0 39´ 42.0″E towards the eastern side of the lake. The water depth of this site ranges from 1to 4 m.

Site II:is located on the north western side of the lake with latitude 34^{0}24´ 14.8″N and longitude 74^{0}32´ 34.9″E, having good macrophytic growth. Its depth varies from 0.5 to 5.2 m.

Site III: located near the Watlab Ghat (latitude 34^{0}21´ 29.4″N and longitude 74^{0}31´ 48.2″E) on the western side of the lake, has profuse growth of macrophytes. Water depth at this site varies from 1 to 5.5 m.

Site IV: located on the south western side of the lake, situated in the centre of lake basin (latitude 34^{0}17´ 43.1″N and longitude 74^0 31´ 29.8″E).Water depth of this site varies from 0.7 to 4.9 m.

Site V: lies near the out let channel (Ningli) being adjacent to site IV (latitude $34^0$17´ 15. 8″N and longitude 74^0 30 ´24.9″E). Its depth ranges from 0.3 to 4.4 m.

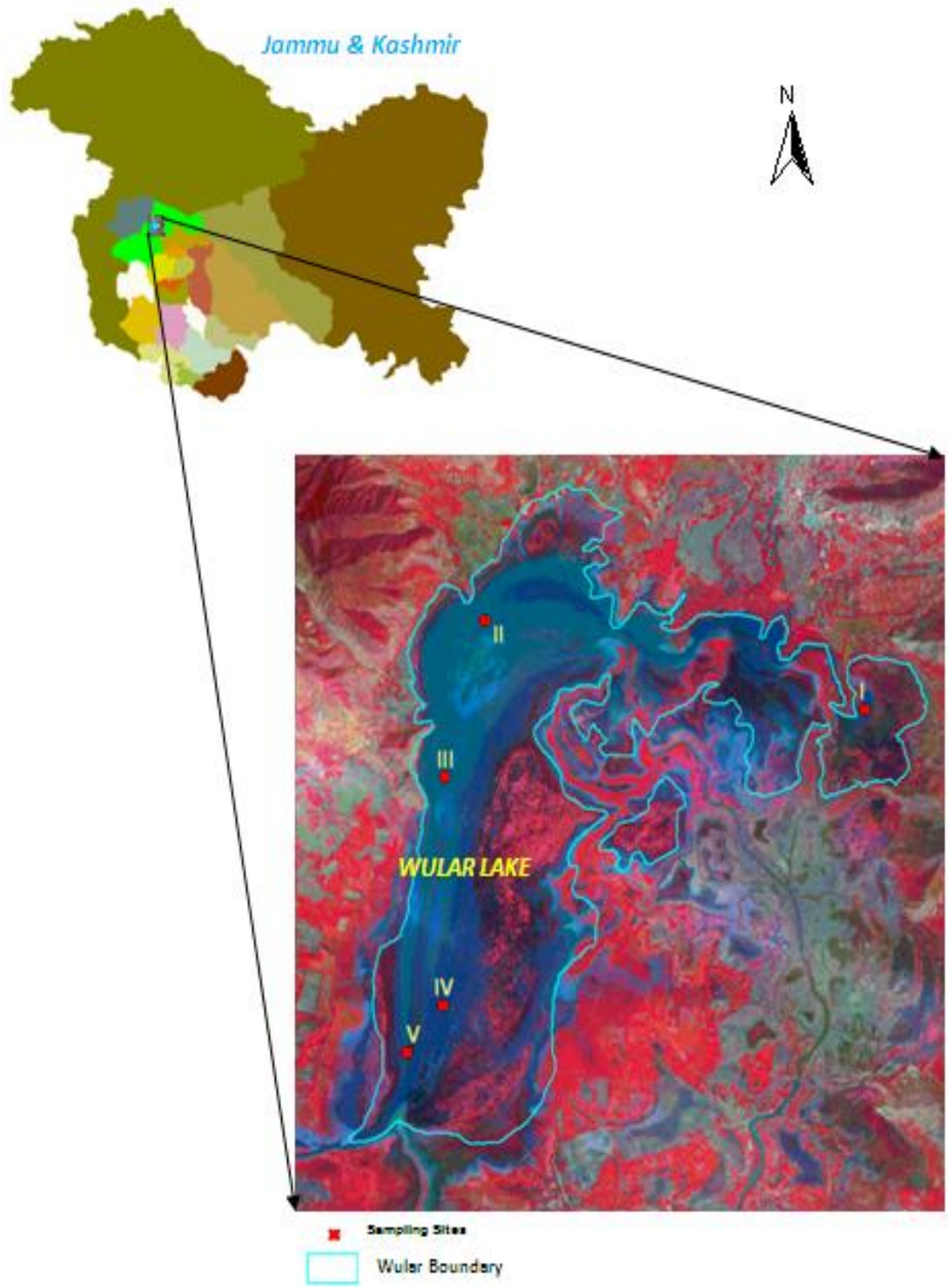

Figure 1: Locations of study sites within Wular lake

MATERIALS AND METHODS

The physico-chemical parameters of water were analyzed on monthly bases for a period of one year from September 2010 to August 2011. The parameters like pH, temperature, depth, and transparency were monitored on spot while the parameters like free carbon dioxide, chloride, and alkalinity values were determined by APHA (1998).Nitrogen and phosphorus were calculated by Spectrophotometric method (APHA, 1998; Wetzel and Lichens, 2000).

RESULTS AND DISCUSSION

In the present study water temperature fluctuated between a minimum of 2.2^0C in the month of January at site I to a maximum of 32.4^0C in August at site III. The variation in the temperature of the present study is in broad agreement with the findings of Rao *et al.* (1982) for Nainital lake (8^0C to 23^0C) and Billore and Vyas (1982) for Pichhola lake (0.6 to 26.3^0C).

Further, temperature was found negatively correlated with DO (Das, 2000) and transparency (Reid and Wood, 1976).

The depth of water at a particular site in a water body is one of the major physical factors which act as a controlling factor for determining the water quality. Among the different sites, a maximum depth of 5.5 m was maintained at site III in May and a minimum of 0.3 m at site V in January. The lowest mean depth is an indication of an evolutionary process coinciding with higher trophic status of the lake as also opined by Rawson (1953, 55), Hayes (1957) and Pandit (2002). The transparency of water fluctuated both spatially and temporally. In general, the highest transparency values were recorded in winter season (1.7 m at site III) and lowest in summer season (0.6 m at site V). Higher transparency values during the winter season may be due to sedimentation of suspended soil particles (Singh, 1990) and low suspended organic matter with poor planktonic growth (Sinha *et al.,* 2002).On the basis of inter-correlation matrix transparency showed positive correlation with dissolved oxygen (Sharma *et al.*,2010)

In the present study, the pH value was found to fluctuate from 7 to 8.8 at sites II and III in the months of December and May respectively, indicating that the waters were neutral to alkaline at various sites. Further, pH showed significantly positive correlations with water temperature. This is in conformity with the observations of Zutshi and Khan (1977) and Zutshi and Vass (1978). Further more, Inverse relationship of pH with nitrate as recorded in the present study agrees well with the study of Ali *et al*., 1985.

In any aquatic ecosystem, dissolved oxygen is of paramount importance because it is critical to the survival of most forms of aquatic life besides being the most reliable criterion in assessing the trophic status and the magnitude of eutrophication (Edmondson, 1966). Dissolved oxygen revealed a definite seasonal trend registering high values in winter (11.1 ± 0.4 mg/L at site III and low in summer 5.0 ± 2.0 mg/L at site II Low values of DO implies higher trophic status (Naz and Turkmen,2005). Dissolved oxygen showed inverse relationship with water temperature (Ali, 1999; Gurumayum *et al.*, 2000). Similar type of results were observed in present study as dissolved oxygen decreased with increase in temperature. The monthly values for alkalinity did not depict any definite trend, although the maximum value (257 mg/L) was registered of at site V in December and a minimum value of 47 mg/L at site III in August. However, total alkalinity in the lake followed a trend of decrease from winter to summer months. Agarwal and Thapliyal (2005) also obtained maximum alkalinity during winter months in Bhilangana. Further, the values of alkalinity above 90mg/L can be categorized as hard water type of Moyle (1945). However, Alikunhi (1957) has found that alkalinity > 100mg/L is suggestive of highly productive waters. As per Spence (1964) the lake falls in the category of nutrient rich (> 60.00mg/L).

During the present study dateable concentrations of free CO_2 were noticed throughout year at all the sites and it ranged between 8 mg/L to 28 mg/L respectively in the month of July at site II and in January at site III. The free CO_2 depicted well marked seasonal fluctuations at all the sites, registering a minimum values (11 ± 3.5 mg/L at site III) in summer and a maximum in winter (23.3 ± 1.5 mg/L at site I). The minimum values were, thus, recorded during July when the macrophytes attained luxuriant growth. The

Table 1.1: Monthly variations in the physico-chemical parameters of water in Wular lake during Oct.2010 to Sep.2011.

	Sites	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Temperature (^{0}C)	**I**	20.4	12.2	9.2	3.5	2.2	5.5	10	14	19	26	28	30.3
	II	22	12.7	10	3.2	2.9	6	10.6	15	20	27	28.4	32
	III	22.6	12.3	9	4	3	6.5	11.5	12	22	25	30	30.4
	IV	19.7	11.4	8.1	3	2.7	5.2	10	10.5	19	24.6	29.4	30.1
	V	19.2	11	7	3	2.7	5.1	10	10	19	24.4	29	29
Depth(m)	**I**	2	1.7	1.3	1.1	1	1.5	2.3	3.2	4.2	4	3.2	2.4
	II	2.2	1.9	1.5	1	0.5	1.7	2.7	3.5	5.2	4.7	3.5	2.9
	III	2.9	2.6	2.1	1.5	1	2.4	3.3	4	5.5	4.1	3.9	3
	IV	2.3	2.1	2	1.4	0.7	2.1	2.5	3.1	4.9	3.7	2.3	2
	V	1.9	1.7	1.5	1.1	0.3	1.6	2	2.7	4.4	3.2	2.1	1.7
Transparency(m)	**I**	1.2	0.8	1	1.1	1.3	1.2	1	0.7	0.4	1.1	0.4	0.8
	II	1.3	0.9	1	1.3	1.4	1.1	0.9	0.7	0.2	1	0.7	0.5
	III	1.1	1.2	1.3	1.6	1.9	1.7	1.3	0.6	0.7	1.3	0.7	0.9
	IV	1.5	0.9	1.2	1.4	1.1	2.2	1.1	0.4	0.5	1.3	0.4	0.5
	V	1.1	0.4	1	1	1.2	1.2	1	0.5	0.4	1	0.3	0.4
pH	**I**	7.4	7.7	8.3	7	7.3	7.2	7.9	7.4	8.4	7.8	7.9	7.9
	II	7.7	7.9	8.7	7.3	7.5	7.3	8.2	7.8	8.8	7.6	7.7	8.2
	III	7.8	7.9	8.6	7.3	7.2	7.1	8.3	7.9	8.8	7.9	7.8	8.1
	IV	7.5	7.8	8.5	7.1	7.4	7.2	8.4	7.4	8.7	7.7	7.9	7.9
	V	7.4	7.7	8.3	7.2	7.4	7.1	8.2	7.5	8.2	7.7	7.8	7.8
Dissolved oxygen (mg/L)	**I**	8.9	8.4	9.5	9.7	10.5	9.4	8.7	8.4	7.7	8	4.2	6.4
	II	8.4	9.1	8.8	9.1	9.7	9.9	9.4	7.5	8.2	7.2	3.4	4.3
	III	9.2	9.9	10.4	11.5	11.1	10.7	9.7	8.9	8.6	7.9	5.4	5.9
	IV	7.9	9.7	9.3	10.7	10.4	10.1	8.9	7.4	7.5	6.4	4.9	5.1
	V	7.4	8.3	8.3	9.6	9.2	9.7	8.2	7.3	7.1	5.3	3.9	4.7
Total alkalinity (mg/L)	**I**	99	117	139	172	147	131	135	121	105	82	71	75
	II	89	153	132	158	116	105	107	84	63	62	49	59
	III	67	116	147	194	171	132	174	119	87	75	59	47
	IV	79	138	157	219	159	147	187	141	92	88	63	54
	V	92	124	162	257	192	144	153	157	73	79	72	67
Free carbon dioxide(mg/L)	**I**	14	16	22	25	23	22	17	14	10	14	12	14
	II	17	15	16	19	21	25	15	10	7	17	8	12
	III	19	16	14	19	28	21	13	13	8	9	9	15
	IV	21	13	17	22	18	27	11	15	9	15	12	17
	V	18	10	15	19	22	19	13	12	6	18	7	14
Chloride((mg/L))	**I**	22	17	26	15	17	19	15	19	13	29	22	17
	II	18	14	21	14	22	24	17	21	17.4	26	24	19

	III	19	13	23	10	15	17	13	15	14.8	21	19	17
	IV	17	14	22	9	14	19	14	17	14	29	23	14
	V	26	22	27	8.4	15	21	17	19	13	27	22	16
Ammonical nitrogen (µg/L)	**I**	218	376	363	406	287	217	327	135	94	79	87	103
	II	321	283	351	357	393	227	232	174	126	87	74	87
	III	175	193	298	542	152	286	176	210	183	110	49	92
	IV	198	217	369	393	258	196	183	167	139	142	97	124
	V	210	167	317	371	392	254	219	321	131	167	87	110
Nitrate nitrogen(µg/L)	**I**	284	422	465	400	388	365	263	254	309	165	215	387
	II	298	407	445	483	465	378	278	264	204	176	211	376
	III	305	472	476	460	421	342	243	287	343	184	193	394
	IV	321	437	456	465	394	369	213	245	321	146	186	365
	V	311	451	460	479	417	374	265	279	365	169	217	398
Ortho phosphate(µg/L)	**I**	28	16	13	17	21	27	18	36	23	24	27	22
	II	32	19	15	16	24	29	19	29	27	25	21	27
	III	35	23	18	19	18	32	23	34	31	32	19	21
	IV	29	14	22	21	23	25	21	27	24	34	32	32
	V	31	20	17	25	22	28	17	32	32	29	29	29
Total phosphate(µg/L)	**I**	237	212	153	246	267	285	189	175	190	145	137	162
	II	167	198	167	292	253	176	121	145	185	127	102	121
	III	184	281	219	274	218	297	173	123	159	174	126	149
	IV	131	165	180	198	292	264	197	186	192	181	173	174
	V	232	167	131	241	197	251	217	132	153	175	139	192

high value of the free carbon dioxide content is an indication of high degree of pollution, a fact also supported by Todda (1970) and Coole (1979) which related high value of free carbon dioxide content to high degree of pollution. An inverse relation between pH and carbon dioxide was found which is in consonance with the observations made by Jindal and Rumana (2000) from River Yamuna (Table1.2). Chloride content in water is regarded as an indication of organic load of animal origin from the catchment area (Kumar *et al.,* 2004). The concentration of chloride during the present study showed less variations. A range of 8.4 mg/L (at site V in January) and 29 mg/L (at sites I and IV in June) was registered during the course of study. Jana (1973) and Govindan and Sundaresan (1979) observed that higher concentration of chloride in the summer period could be also due to sewage mixing, increased temperature and evaporation by water.

Phosphorous, is generally recognized as one of the key nutrients in the productivity of freshwaters as it is essential element determining fertility of lakes. The concentration orthophosphate phosphorus (OPP) during the study period ranged from a minimum of 13.0 µg/L at site I in November to a maximum of 36 µg/L, being recorded at site I in April. The low orthophosphate-phosphorous content in waters is due to the formation of an insoluble calcium-phosphate complex. Such a phenomenon functions as scavenger of some inorganic nutrients and also acts as a removal agent of dissolved organic matter by absorption (Otsuki and Wetzel, 1974). Thornton and Nduku (1982) suggested values >30µg/L as indicative of eutrophic status in temperate lakes. The spatial and temporal fluctuations regarding the total phosphate phosphorous (TPP) were very irregular. In general, lower concentrations were maintained in the warmer months (i.e. during summer) at all sampling sites. On the other hand, monthly concentration depicted a

maximum of 297 µg/L and a minimum of 102 µg/L at sites III and II in the month of February and July respectively. The total phosphorus as also the orthophosphate content in the Wular lake fluctuated greatly during the course of the year. However, the average concentration of both total phosphorus and orthophosphate phosphorus revealed the waterbody belonging to the hypertrophic category of Wetzel (1983). This is substantiated by the fact that almost the whole waterbody is infested by the macrophytes, which is possible only when this important nutrient is available in ample quantities. Bandela *et al*. (1999) observed an increase in phosphate concentration in those water bodies that received domestic waste. NH_4-N showed great fluctuations throughout the year at all the sites and ranged between 49 µg/L and 542 µg/L. From April onwards there was a gradual decrease in the concentrations of the ion at the sites till a minimum value (49 µg/L) was noticed in July at site III. After attaining the minimum values the concentrations once again depicted an increasing trend. Such fluctuations in the values of ammonical nitrogen may be due to decomposition of organic matter and bird droppings into the lake as it is visited by many aquatic birds (Zuber, 2007). Prasad (1990) pointed out that ammonical nitrogen increases during rainy seasons. Nitrate nitrogen (NO_3-N) was higher in the winter months (with maximum value of 483µg/L in December at site II) while the lower values were recorded in the summer months (146 µg/L in June at site IV). Trisal (1977) opined that the increase in nitrate- nitrogen content during winter is the cumulative effect of nitrification in the water column and the mud water interface. Ganapati (1960) pointed out that the concentration of nitrate-nitrogen (>150µg/L) is an indicative of eutrophication and as such the Wular lake falls in eutrophic category.

Table 1.2: Correlation coefficient values among various physico-chemical parameters in Wular lake

Parameters	1	2	3	4	5	6	7	8	9	10	11
1	1										
2	.646(**)										
3	-.649(**)	-.652(**)									
4	.560(*)	.761(**)	-.680(**)								
5	-.909(**)	-.513(*)	.768(**)	-.411							
6	-.918(**)	-.616(**)	.619(**)	-.571(**)	.824(**)						
7	-.713(**)	-.871(**)	.860(**)	-.861(**)	.680(**)	.657(**)					
8	.603(**)	.028	-.423	.202	-.642(**)	-.687(**)	-.269				
9	-.890(**)	-.797(**)	.691(**)	-.538(*)	.845(**)	.824(**)	.766(**)	-.417			
10	-.780(**)	-.834(**)	.783(**)	-.553(*)	.781(**)	.711(**)	.789(**)	-.207	.884(**)		
11	.536(*)	.429	-.454(*)	.245	-.557(*)	-.457(*)	-.404	.096	-.588(**)	-.611(**)	
12	-.798(**)	-.765(**)	.756(**)	-.750(**)	.755(**)	.743(**)	.879(**)	-.450(*)	.744(**)	.711(**)	-.308

*** Correlation at 0.01(2-tailed):...* Correlation at 0.05(2-tailed):...*
1=Temperature, 2=depth, 3=transparency, 4= pH, 5=dissolved oxygen, 6= total alkalinity, 7= free carbon dioxide, 8= chloride, 9= ammonical nitrogen 10= nitrate nitrogen, 11= orthophosphate, 12= total phosphate

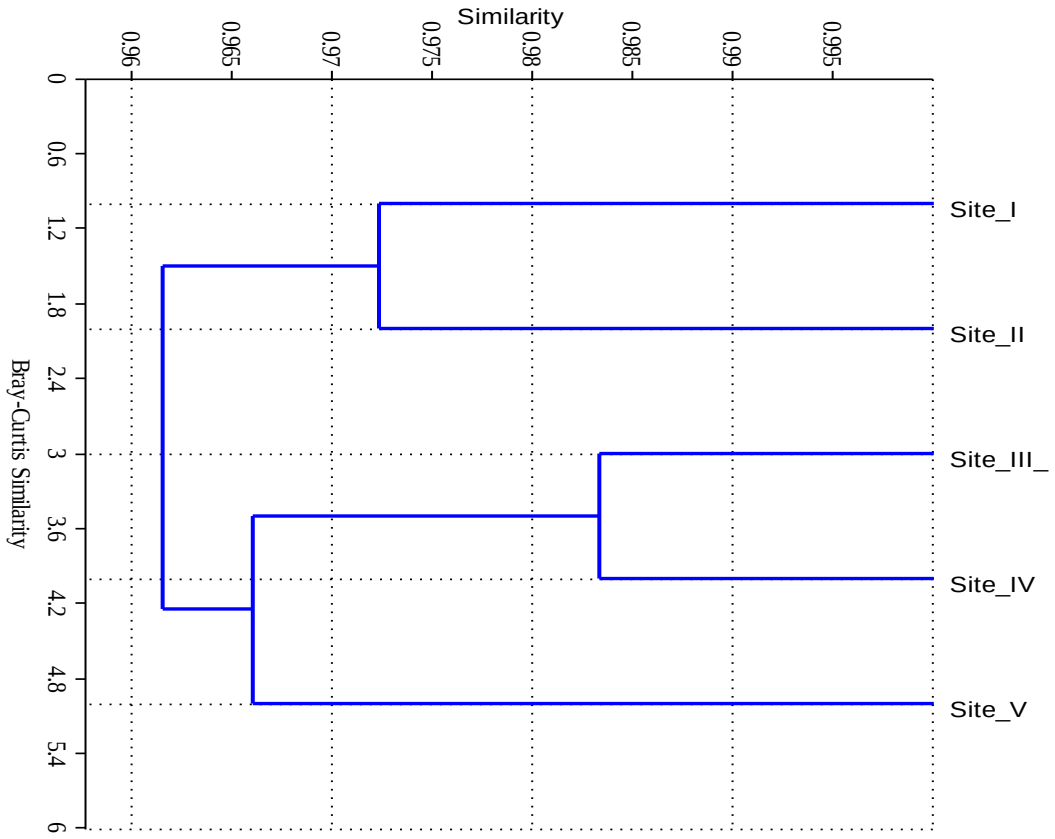

Figure 2: Bray-Curtis cluster analysis of five study sites

Bray-Curtis cluster analysis shows great similarity between sites III and IV (0.98%).Contrary to these sites, site V showed maximum dissimilarity during the entire study period because it represents the outlet of the lake. In Figure 2, Sites I and II showed immediate similarity.

In conclusions all the physico-chemical characteristics of water in Wular lake depict that the lake gets eutrophicated day-by- day due to increased human population stress.

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