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Physico-Chemical Profile of Three Freshwater Flood Plain Lakes of River Jhelum, Kashmir (India)

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Abstract
Kashmir valley lakes are facing a challenging effect of cultural eutrophication from the last few decades and it remains as the main water quality management problems. The physicochemical parametres of three flood plain lakes of river Jhelum, kashmir were studied for a period of two years from March 2012 to February 2014. The three lakes differed in terms of their abiotic features, with Anchar presenting very high nutrient levels followed by Wular and Manasbal. It has been observed that lake Manasbal is moderately eutrophic while the largest freshwater lake of Asia, Wular is marching towards high tropic nature as a result of heavy influx of silt load containing nutrients from the catchment area. Whereas, the semi-urban lake, Anchar operating under tremendous anthropogenic pressures, pumping load of autochthonus and allochthonus material leads to its rapid tropic evolution in the form of eutrophication.

Keywords: Physico-chemical Parametres; Flood plain lakes; eutrophication; Kashmir.

1. Introduction
The valley of Kashmir is located in the midst of Himalayan Mountains, experiencing a temperate-cum-mediterranean climate with four distinct seasons. The high altitude valley abounds in a vast array of fresh waterbodies and amongst these the lakes are of special ecological importance. These lakes categorized into glacial, alpine and valley lakes based on their origin, altitudinal situation and nature of biota, provide an excellent opportunity for studying the structure and functional process of an aquatic ecosystem system (Zutshi *et al*., 1972; Kaul, 1977; Kaul *et al*., 1977; Trisal, 1985; Khan 2006). However, the unplanned urbanization, deforestation, soil erosion and reckless use of pesticides for horticulture and agriculture have resulted in heavy inflow of nutrients into these lakes from the catchment areas (Baddar and Romhoo 2007). These anthropogenic influences not only deteriorate the water quality, but also affect the aquatic life in the lakes, as a result of which the process of aging of these lakes is hastened. As a consequence, most of the lakes in the Kashmir valley are exhibiting eutrophication (Kaul, 1979; Khan, 2008). It is now quite common that the lakes of Kashmir valley are characterized by excessive growth of macrophytic vegetation, anoxic deep water layers, and shallow marshy conditions along the peripheral regions and have high loads of nutrients in their waters (Koul *et al*., 1990; Khan, 2000; Jeelani and Shah 2006).
Though, quite a number of studies have been conducted to understand the hydrochemistry and hydrobiology of the Kashmir Himalayan lakes (Pandit, 1998; Jeelani and Shah 2007; Saini *et al*., 2008) however, most of the limnological investigations of the region have centered round Dal Lake (Zutshi *et al*., 1980; Trisal, 1987; Kundangar and Abubakr 2004; Jeelani and Shah 2006) and the other lakes though with equal ecological importance have received little attention. Available literature dealing with water quality of Anchar Lake is that of Bhat *et al*., 2001 and Pandit, 2002 and hardly any literature available on the water quality/pollution status of Manasbal Lake except that of Dar et., al 2013. Although all the three lakes are subject to anthropogenic disturbances, the varied human population in the catchment area, nature of immediate catchment and size of water body make them to respond differently to these pressures. Further, there is national and international focus on the conservation of Dal Lake, but any attention toward conservation of Wular, Manasbal and Anchar Lakes, which are equally under stress due to cultural eutrophication.
In this context an attempt has been made to determine the current trophic status of three different lake ecosystems of Kashmir valley viz, Wular lake, Manasbal lake and Anchar lake enjoying different ecological conditions, under the operative influence of wastewaters from the catchment areas.

2. Materials and Methods
2.1 Study Area
The valley of Kashmir is situated in the middle of the Himalayas between the northwest and southeast (33°01′–35°00′N latitude and 73°48′–75°30′ E longitude) at an altitude ≥1500 m above sea level. The study was carried out in 3 valley lakes, viz., Wular Lake (34°20′ N, 74°44′ E), Manasbal Lake (34°15′ N, 74°40′E) and Anchar Lake (34°01′ N, 74°02′ E).
Wular Lake, an ox-bow type mono-basined lake, with fluviatile origin is situated at 34 km to the northwest of Srinagar city at an altitude of 1,530 m above m. s. l, within the geographical coordinates of 34°17´-34°20´N latitudes and 74°33´-74°44´E longitudes. Wular lake, the largest freshwater lake of Asia within river Jhelum basin, plays a significant role in the hydrographic system of the Kashmir valley by acting as predominant absorption basin for the annual flood water besides playing a vital role in sustaining agriculture, hydropower generation, sports activities and climate regulation. In ancient times, its surface area was 202 km^2 (Stein, 1961), which at the turn of 20th century got reduced to 189 km^2, with an open water area of 24 km^2 (Pandit, 2002). The shrinkage in lake area is mainly due to continuous siltation brought about by various tributaries (Erin, Madhumati, Ashtung, Hartal, etc.), besides River Jhelum. The lake is an open drainage type and hence experiences moderate eutrophication (Pandit, 2002). It is

surrounded by pir pangal mountains (locally known as Baba Shakur-ud-din mountains) towards north, northeast and northwest which drain their runoff through various streams, prominent being Erin, Madhumati apart from river Jhelum (which emerge from verinag spring and drains whole kashmir valley). The lake was included in 1986 as a wetland of national importance under the wetland programme of the Ministry of Environment and forests, Govt of India for intensive convention management purposes. Recognising the importance of the wetland for its biodiversity and socioeconomic values, the lake in 1990 was designated by India as a wetland of international importance under the Ramsar convention (MOEF 1986, 1990).

Manasbal lake, the deepest freshwater valley lake of Kashmir, is located at the mean geographical coordinates of 74°39' 07" to 74°41' 20" E longitude and 34° 14' 40" N to 34°15' 20" N latitude at an altitude of 1584 m amsl, at a distance of about 30 km to the north-west of Srinagar, the summer capital of Jammu and Kashmir state. It is a semi drainage rural lake, having an area of about 2.83 sq. km, oblong in outline and extends in north east- southwest direction with the maximum length and breadth of 3.5 km and 1.5 km, respectively. It is the deepest of all valley lakes with a depth of 12.5m.

The lake is bounded by the Karewas on the northeast and northwestern sides below which lies the Manasbal village. Above and beyond are the ruins of Badshah Bagh, now called Jarooka Bagh, consisting of an old incomplete palace and a garden built by Mughal Emperor Jehangir. There is a Fish Farm on the northern side of the lake and a Drug Research Farm on its northwest side. On the eastern side are hill tops, extending upto Limestone Mountain called Ahateng in the southeast. At the foot of this range on the banks of lake lies Kondabal village where there are many lime kilns used for limestone extraction. On the eastern side bare rugged high mountains are present.

The lake inflow is chiefly derived from underground springs, in addition to which a small irrigation stream (Laar Kuhl) on the eastern side also drains water into the lake during spring-autumn. The Laar kuhl stream takes off water from the Sindh Nallah (a tributary of river Jhelum) and irrigates the agricultural fields throughout its course in the neighbourhood of the lake, thus bringing in allochthonous material into the lake including major and minor nutrients, polythene, bottles and other material. The lake is connected to the river Jhelum by a permanent channel which leaves the lake on its western side and runs in southwest direction to join the river at a place about 0.7 km below the village Sumbal. It is semi drainage, warm monomictic lake, which receives stratification from March till November, followed by mixing in early December (Zutshi and Khan, 1978; Yousuf, 1979).

Anchar Lake, a shallow basin lake with fluviatile origin is situated at an altitude of 1,583 m above m.s.l, within the geographical coordinates of 34º 20´ to 34º 26´N latitude and 74º 28´ to 74º 85´E longitude, at a distance of 12 km to the North-west of Srinagar city. The lake is mono-basined with surface area of 6.6 km2. The lake has a total area of 6.80 km^2 of which about 1.69 km2 at present represent open water and the remaining portion has been transformed into a marshland due to increased human perturbations of the ecosystem. The lake receives water from the Sind stream on the northern side and a channel from Khushalsar Lake on its southern side. The excess water of the lake flows through Shalabugh wetland into the Jhelum River.

2.2 Methods for Chemical and Physical Analyses

Water samples from 15 sites of three lakes were collected at 0.5m (a depth representative of the mixed water columns) on the basis of monthly intervals between March 2012 and Febuary 2013. The samples were kept in 2 L polyethylene plastic bottles which had been previously cleaned with metal free soap, rinsed repeatedly with distilled water, soaked in 10% nitric acid for 24 h, and finally rinsed with ultrapure water. All water samples were maintained at 4°C first during transportation to the laboratory, and then later for processing and analysis. As shown in Table 1, the measurements of water quality parameters are summarized on the basis of standard methods established for surface water monitoring in India [APHA, 1988]. The temperature and pH of each water sample were measured in situ by field instruments including a mercury thermometer and digital pH respectively. All water samples were analyzed for different physico-chemical parameters within 48 h of collection. Total hardness was measured by EDTA complexometry titration. Total alkalinity was determined by acid titration using methyl-orange as endpoint, and chloride by silver nitrate ($AgNO_3$) titration using potassium chromate (K_2CrO_4) solution as an indicator. NH4-N was measured with Phenate method (APHA, 1998). NO_3-N and NO_2-N were analyzed by Salicyalate method and N-(1-naphthyl)-ethylenediamine colorimetry, respectively. T. Phos were analyzed by absorption spectrophotometry after decomposition with sulphuric acid-nitric acid digestion (Stannous chloride method).

Table 1: Water quality parameters, abbreviations, units and analytical methods as measured during 2012–2014 for three lakes.

S.No	Parameter	Abbreviation	Unit	Analytical methods
1	Air Temperature	AT	^0C	Mercury Thermometer
2	Water temperature	WT	^0C	Mercury Thermometer
3	Depth	Depth	m	Graduated String
4	Transparency	Trans	m	Secchi Disc
5	Electrical conductivity	EC	µS/cm	Electrometric
6	pH	pH	pH unit	pH-meter
7	Dissolved oxygen	DO	mg/l	Winklers Azide method
8	Free Co_2	F CO_2	mg/l	Titrimetric
9	Total Alkalinity	T. Alkal	mg/l	Titrimetric
10	Total Hardness	T- Hard	mg/l	EDTA Titrimetric
11	Chloride	Cl_2	mg/l	Titrimetric
12	Ammonical Nitrogen	NH_4-N	µg/l	Spectrophotometric
13	Nitrite Nitrogen	NO_2-N	µg/l	Spectrophotometric
14	Nitrate Nitrogen	NO_3-N	µg/l	Spectrophotometric
15	Total Phosphorus	TP	µg/l	Spectrophotometric

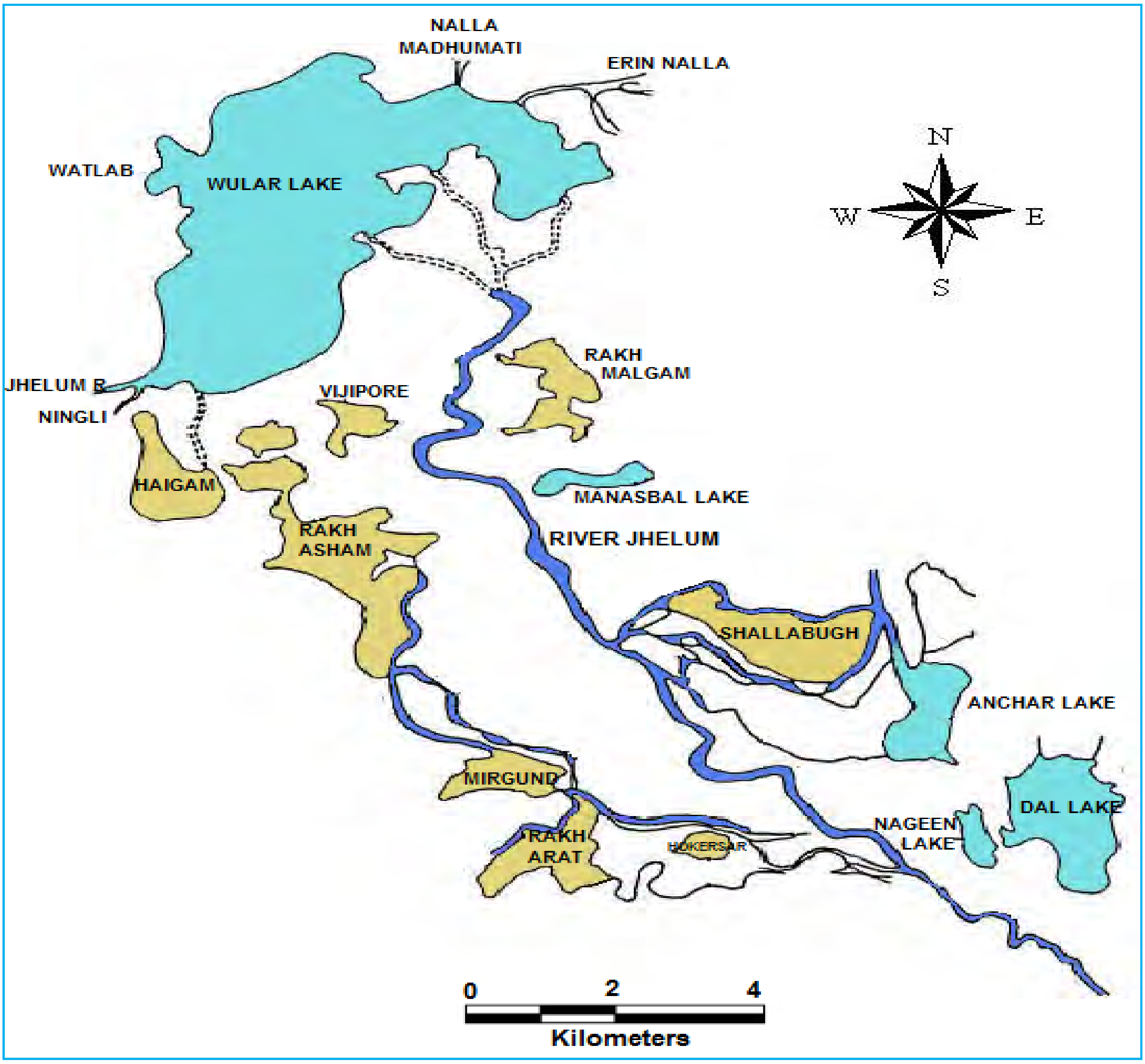

Fig 1: Location map of flood plain lakes (Wular, Manasbal and Anchar) of river Jhelum, Kashmir

3. Results and Discussion

Water temperature is one of the most important limnological parameter that plays a prominent role in regulating nearly all other physico-chemical characteristics of the water as well as biological productivity (Wetzel, 1983) and also in controlling the nutrient input and turnover. Insignificant variation ($p>0.05$) in water temperature were observed across the three lakes, and the values are presented in Table. 2. Temperature showed a mean value of 16.50 ± 8.98 ^{0}C in Anchar Lake, 15.75± 8.68 ^{0}C in Manasbal Lake and 14.67 ±8.76 ^{0}C in Wular Lake. Water temperature influences the chemical and biological activity besides growth of aquatic organisms (Pawar, 2010).

Depth of an aquatic body plays an important role in concentrating ions in water mass, besides being an important determinant for the growth and development of various life forms of vegetation (Kaul and Handoo, 1980). Persistence and level of water column is determined by hydrological factors like the amount of water brought in and sent out, precipitation, melting of snow. During the present study significantly higher ($p<0.05$) values of depth were recorded in Manasbal lake (3.75 ± 4.27 m), followed by Wular (2.61 ±1.07 m) and lowest in Anchar lake (1.19 ± 0.33 m). All the three lakes depicted a distinctive rise of water level in spring and summer and the difference in water level were found statistically significant between the lakes. Increase in the water depth during spring-summer in all the three water bodies is attributed to melting of ice and introduction of run-off waters.

Table 2: Mean of Physico-chemical Parameters in the surface waters of Wular, Manasbal and Anchar Lakes, Mar 2012-Feb 2014

S. No	P. C Parametres	Wular	Manasbal	Anchar
1	AT(^{0}C)	$18.60^a \pm 9.40$	$19.00^a \pm 9.36$	$19.98^a \pm 9.74$
2	WT(^{0}C)	$14.67^a \pm 8.76$	$15.75^a \pm 8.68$	$16.50^a \pm 8.98$
3	Depth(m)	$2.61^b \pm 1.07$	$3.75^c \pm 4.27$	$1.19^a \pm 0.33$
4	Trans(m)	$1.10^b \pm 0.27$	$1.68^c \pm 1.79$	$0.55^a \pm 0.16$
5	DO(mg/L)	$7.88^b \pm 1.55$	$8.12^b \pm 1.46$	$4.05^a \pm 1.68$
6	F.CO_2(mg/L)	$14.82^b \pm 4.41$	$10.03^a \pm 5.18$	$16.10^b \pm 8.75$
7	pH	$7.94^a \pm 0.40$	$8.07^b \pm 0.48$	$8.22^c \pm 0.32$
8	T. Alk(mg/L)	$122.34^a \pm 41.04$	$170.55^b \pm 42.46$	$264.39^c \pm 67.24$
9	EC (µS/cm)	$283.35^b \pm 60.58$	$249.72^a \pm 53.60$	$407.72^c \pm 61.14$
10	Cl_2 (mg/L)	$20.27^a \pm 4.81$	$24.34^b \pm 4.33$	$28.76^c \pm 8.15$
11	T. Hard(mg/L)	$154.34^a \pm 46.93$	$160.33^a \pm 33.15$	$200.23^b \pm 35.00$
12	NH_4-N (µg/l)	$234.46^b \pm 91.56$	$48.28^a \pm 17.22$	$398.23^c \pm 105.79$
13	NO_2-N (µg/l)	$24.25^b \pm 6.34$	$16.70^a \pm 6.77$	$27.35^c \pm 11.95$
14	NO_3-N (µg/l)	$303.94^b \pm 85.37$	$261.00^a \pm 56.20$	$350.78^c \pm 70.85$
15	T. Phos (µg/l)	$213.07^a \pm 43.73$	$225.18^a \pm 82.26$	$382.05^b \pm 82.95$

Values are Mean ± SD. Values obtained from ANOVA post hoc nonparametric test Significant $P < 0.05$, Non significant, $p > 0.05$.
Mean values with different superscripts are significantly different ($p<0.05$, Tukey's HSD)

Transparency is one of the important physical properties of water indicative of degree to which sunlight can pass through water. Variation in Trans was significant ($p<0.05$) between the three lakes. Significantly higher ($p<0.05$) values of Trans were recorded in Manasbal Lake (1.68 ± 1.79 m) and Wular Lake (1.10 ± 0.27 m) as compared to Anchar Lake (0.55 ± 0.16 m) (Table 2). Relatively lower transparency values in Anchar lake seem to be related to large quantities of swamp material brought from the catchment. 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).

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 level in lakes vary according to the lake trophic levels, and depletion of dissolved in water probably is the most frequent result of water pollution (Srivastava *et al*., 2009). DO has significant variation ($p<0.05$) between the three water bodies with a range from a minimum of 4.05 ± 1.68 mg/l (Anchar Lake) followed by 7.88 ± 1.55 mg/l (Wular Lake) to a maximum of 8.12 ± 1.46 mg/l (Manasbal Lake) as given (Table 2) indicating Anchar Lake with higher levels of contamination. However no significant difference ($P>0.05$) were found between Wular and Manasbal lakes.

The Free carbon dioxide is the indicator of the biological respiration activities of aquatic ecosystem. During the present study significantly ($p<0.05$) higher values of FCO_2 were recorded in Anchar lake (16.10 ± 8.75 mg/l) as compared to Wular (14.82 ± 4.41 mg/l) and Manasbal lakes (10.03 ± 5.18 mg/l). The higher values of F.CO_2 in Anchar lake may be attributed to the presence of high amount of organic matter which on microbial decomposition release large amount of F.CO_2 as a by-product of their metabolic activity.

pH is one of the very significant chemical characters of all waters explaining certain significant biotic and abiotic ecological characteristic of an ecosystem in general (Chandrasekhar *et al*., 2003). pH varying significantly ($p<0.05$) among the lakes had a range of 8.22 ± 0.32 in Anchar Lake, followed by 8.07± 0.48 in Manasbal Lake and 7.94 ± 0.40 in Wular Lake (Table 2). pH recorded being in alkaline range indicates that the lakes were well buffered throughout the study period. pH range between 6.0 and 8.5 indicates productive nature of water body (Garg *et al*., 2010).

Total alkalinity is a measure of buffering capacity of water and is important for aquatic life in a freshwater system (Kaushik and Saxena, 1994). T. Alk exhibited significant variation ($p<0.05$) between the three lakes with higher values in Anchar Lake (264.39 ± 67.24 mg/l) followed by Manasbal Lake (170.55 ± 42.46 mg/l) and lowest in Wular Lake (122.34 ± 41.04) (Table 2). The alkalinity of the present lakes appears to be greatly influenced by the inflow from catchment and also by the decomposition of autochthonous organic matter (Sugunan, 2000).

Conductance is a measure of the ability of water to conduct an electric current and has been used for assessing the trophic status of water bodies (Shastree *et al*., 1991). Variation in EC was significant ($p<0.05$) between the three lakes. Significantly higher ($p<0.05$) values of EC were recorded in Anchar Lake (407.72 ± 61.14 mS/cm) and Wular Lake (283.35 ± 60.58 mS/cm) as compared to Manasbal Lake (249.72 ± 53.60 mS/cm) (Table 2) and indicates the quantity of dissolved salts in water (Gupta *et al*., 2008) besides the nutrient loading of the lakes. The relatively higher EC recorded in the present study in Anchar Lake is attributed to the high degree of anthropogenic activities such as waste disposal and agricultural runoff.

Chloride content in water is regarded as an indication of organic load of animal origin from the catchment area (Kumar *et al*., 2004). Concentration of chloride in an aquatic system is an index, not only of eutrophication, but also of pollution caused by sewage and other wastewaters (Munawar, 1970). Variation in Cl_2 was significant ($p<0.05$) between the three lakes. Significantly higher values of chloride were recorded for Anchar lake (28.76 ± 8.15 mg/l) followed by Manasbal lake (24.34 ± 4.33 mg/l) and lowest for Anchar (20.27 ±4.81 mg/l) (Table 2). The relatively higher values of chlorides observed at Anchar were due to the addition of city sewage and domestic waste (Dwvedi and Odi, 2003; Sanap *et al*., 2006).

The total hardness in all the three habitats was very high indicating hard water nature which seems to be related to the source of Ca^{++} and Mg^{++} owing to its origin to the lacustrine deposits in the valley (Wadia, 1961). The mean values of total hardness were found highest for Anchar lake (200.23 ± 35.00

mg/l) followed by Wular (154.34 ± 46.93 mg/l) and lowest for Manasbal lake (160.33 ± 33.15 mg/l). Higher hardness in Anchar lake may be due to presence of large quantities of sewage, detergents and more anthropogenic activities.

Ammonical-nitrogen has been reported to be the preferred nitrogen for phytoplankton uptake (Wetzel, 2001) and is also a product of many organic degradation processes and thus could be expected to show large variations in concentration. NH4-N exhibited significant variation ($p<0.05$) between the three lakes with higher values in Anchar Lake (398.23 ± 105.79 µg/l) followed by Wular Lake (234.46 ± 91.56 µg/l) and lowest in Manasbal Lake (48.28 ± 17.22 µg/l) (Table 2). Organically polluted waters with high levels of NH4-N show increased biological productivity due to readily available nutrients (Sheela *et al*., 2010). Though Anchar Lake has been associated with organic pollution (Bhat *et al*., 2001) the variation between these three lakes is highly significant.

Nitrite-nitrogen concentrations in unmodified waters are generally low in the range of 0-10 µg/l (Wetzel, 2001) while concentration above 10 µg/l are regarded to be indicative of sewage contamination. Bhat and Yousuf (2004) found nitrite-nitrate in some water bodies of kashmir in the range of 1-12 µg/l while in the present investigation, the NO_2-N concentration varied significantly between lakes and had a range of 27.35 ±11.95 µg/l in Anchar, followed by 24.25 ± 6.34 µg/l in Wular and 16.70 ± 6.77 µg/l in Manasbal (Table 2). The higher concentration of nitrite in Anchar lake may be attributed to the greater sewage contamination and use of fertilizers in the catchment area.

NO_3-N and T. Phos showed significant variation ($p<0.05$) among the investigating lakes. The range of NO_3-N was 350.78 ± 70.85 µg/l, 303.94 ± 85.37 µg/l and 261.00 ± 56.20 µg/l in Anchar Lake, Wular Lake and Manasbal Lake, respectively (Table 2) indicating Anchar Lake as having the highest concentration of NO_3-N. Concentration of T. Phos was highest in Anchar Lake (382.05 ± 82.95 µg/l) compared to Manasbal Lake (225.18 ± 82.26 µg/l) and Wular Lake (213.07 ± 43.73 µg/l) (Table. 2). T. Phos enters the lakes through domestic wastewater, accounting for the accelerated eutrophication (Vyas *et al*., 2006) and the augmented concentration of T. Phos and NO_3-N in lakes resulted in enhanced phytoplankton productivity (Pandit and Yousuf, 2002).

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