"A Case study on Investigation of Physico-chemical Properties of Dal Lake, Kashmir, India"

Abstract

Water quality is a key factor in determining the current condition of the freshwater ecosystem. The current analysis was conducted to assess the water quality status of Dal Lake. The lake was researched for 12 months, from March 2021 to February 2022, and a total of 17 physicochemical parameters were analysed at seven distinct sites at monthly intervals using established methodologies.The measured characteristics included air temperature (6.1°C-37.5°C) and water temperature (1.41°C-28.3°C), depth (1.1-3.1m), Secchi Disc transparency (0.3m-1.9m), specific conductivity (201 µScm-1-364 µScm-1), pH (7-7.9), Dissolved oxygen (4.4-9.2 mg/l), chloride (10-35 mg/l), free carbon dioxide (1.5-18.9 mg/l), total hardness (112-180 mg/l), calcium hardness (27.4-54.9 mg/l), magnesium hardness (17.4-31.8 mg/l), ammonia nitrogen (125-497 µg/l), nitrate-nitrogen (324-782 µg/l), nitrite-nitrogen (10-72 µg/l), orthophosphate (58-194 µg/l), and total phosphorus ranged from 193-568 µg/l. The investigation revealed that almost all of the above parameters indicate that the pollution load is increasing due to anthropogenic pressure, untreated sewage and solid garbage from residential areas, and fertilisers containing nitrates and phosphates, all of which have contributed to the lake's eutrophic condition. As a result, prompt protective measures should be implemented to prevent further depletion.

Keywords:water quality,anthropogenic,P-value,Dal Lake.

INTRODUCTION

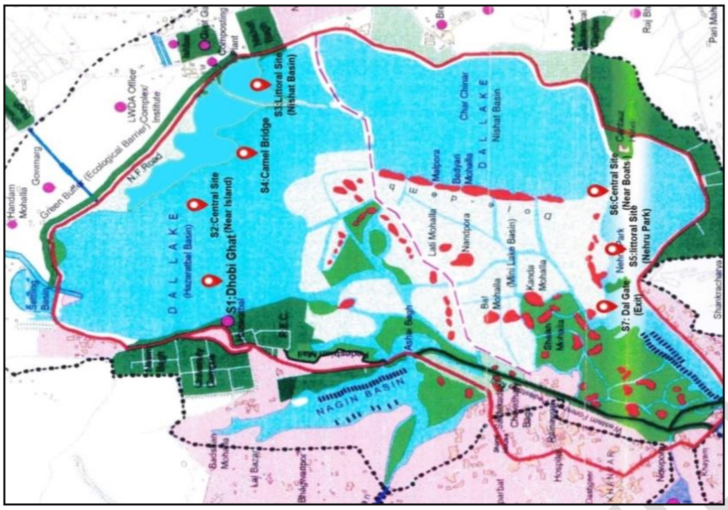
Kashmir Valley is located in the Himalayan Mountains and has a temperate environment with four distinct seasons. The high altitude valley is home to a broad range of freshwater bodies, with lakes serving a critical ecological role. The Kashmir Lakes are located in the flood plain of the Jhelum River, whose huge meanders have cut swampy lowlands out of the Karewas terraces (De-Terra & Paterson, 1939). These lakes are classed as glacial, alpine, or valley lakes based on their origin, altitudinal location, and biota, and they offer a good chance to study the structure and functional processes of an aquatic biological system (Zutshi *et al.,* 1972; Kaul, 1977; Trisal, 1985). These lakes range from oligotrophic to eutrophic, with some currently transitioning to eutrophication (Kaul, 1979). The Kashmir valley's water bodies offer a rich supply of natural products such as fish, fodder, and a range of economically significant plants. The valley has traditionally been regarded as having a high level of floral and faunal diversity. However, unplanned urbanisation, deforestation, soil erosion, and the reckless use of pesticides in horticulture and agriculture have resulted in a significant input of nutrients into these lakes from watershed areas. These anthropogenic influences not only decrease water quality, but also have an impact on aquatic life in lakes, hastening their ageing process. As a result, the majority of lakes in the Kashmir valley are eutrophic (Kaul, 1979).

2. MATERIAL AND METHODS

2.1 STUDY AREA

Dal Lake is referred to as the "liquid heart" of Srinagar, the summer capital of Jammu & Kashmir. The location is between 34º07'N and 74º52'E, at an elevation of approximately 1584m above mean sea level (Kundangar and Abubakr, 2004). It is divided into four basins: Hazratbal, Nishat, Nehru Park, and Nigeen (Kundangar and Abubakr, 2001). Dal Lake's four basins have substantial differences in area, volume, depths, and coastline development indices. The largest basin of Dal Lake is Hazratbal (3.54 km2), while the smallest is Nigeen (0.89 km2) (Zutshi and Vass, 1973). In terms of depth, the Nigeen basin is the deepest (5.7m), whereas Nehru Park is the shallowest (2.5m). Each basin has its own distinct character, with varying morphometry, water quality, and biodiversity (Abubakr and Kundangar, 2005). Dal Lake has a large catchment area; according to AHEC (ALTENATE HYDRO ENERGY CENTRE) (2000) estimates, the lake catchment area is 337.17 sq. kms, with TelbalDachigam accounting for 234.17 sq. kms (69%), followed by Hill side 14 sq. kms, Srinagar city (North and Central) 14.5 sq. kms, and the lake 18.5 square kms. Telbal Nallah is the principal inflow canal for the Dal Lake, which drains mostly through the Harwan, Burzukot, and Mahadev ranges. Furthermore, 10-12 tiny ditches drain water into Dal Lake. The Telbal Nallah supplies 80% of the lake's total inflow, which is around 292×106 m^3. Two permanent outflow channels, one known as Dalgate exit and the other as Nallah Amir Khan, drain water from the lake (Kundangar and Abubakr, 2001). To evaluate the water quality of Dal Lake, seven locations were selected within the lake: Dhobi Ghat (S1), Central Site (Near Island) (S2), Littoral Site (Nishat Basin) (S3), Camel Bridge (S4), Littoral Site (Nehru Park) S5, Central Site (Near Boats) S6, and Dal Gate (Exit) S7 (Fig. 1).

Fig. 1: Map representing overall view of sites within Dal Lake.



1.2 WATER SAMPLING:

Surface water samples were collected by hand from the sampling sites using one-litre polypropylene bottles that were clearly marked. At the sampling site, data like air temperature, water temperature, transparency, and depth were recorded. Winkler's modified method was employed to collect dissolved oxygen samples in separate D.O. bottles, and the samples were fixed on-site. Further analysis (pH, specific conductivity, D.O, Free CO_2, chloride, Total Hardness, Calcium Hardness, Magnesium Hardness, Orthophosphate, Total phosphorous, Ammonical-nitrogen, Nitrate-nitrogen, and Nitrite-nitrogen) of samples was carried out in the laboratory using the methods outlined in APHA (2012).

1.3 STATISTICAL ANALYSIS

The results obtained were analyzed with the help of the appropriate statistical methods using Microsoft Excel (Table. 1).

Table 1: Overall Mean ± S.E values of Physico-chemical parameters at seven sites of Dal Lake.

Parameters	Sum of Squares	Df	Mean Square	F	Significance	Overall Mean ± S.E
A.T (°C)	62.13	18	3.45	0.13	P>0.05	19.66±0.24
W.T (°C)	32.65	18	1.81	0.07	P>0.05	16.85±0.14
Depth(m)	0.68	18	0.03	2.29	P<0.01	1.89±0.19
SDT (m)	3.19	18	0.17	2.97	P<0.01	0.82±0.07
SC (μScm^{-1})	43293.07	18	2405.17	3.11	P<0.01	263.72±7.56
pH	1.32	18	0.07	1.23	P>0.05	7.48±0.02
D.O(mg/L)	24.94	18	1.38	1.72	P>0.05	6.14±0.15
Cl$^-$ (mg/L)	335.73	18	18.65	0.69	P>0.05	18.75± 0.45

Free CO_2 (mg/L)	255.57	18	14.19	2.35	P<0.01	8.18± 0.64
TH (mg/L)	6776.59	18	376.47	5.11	P<0.01	136.5±2.87
Cal H (mg/L)	1035.92	18	57.55	3.15	P<0.01	39.85± 0.69
Mg H (mg/L)	304.35	18	16.90	2.47	P<0.01	23.40± 0.61
NH_4-N (μg/L)	57236.04	18	3179.78	2.75	P<0.01	349.5±31.32
NO_3-N (μg/L)	309234.50	18	17179.69	1.81	P<0.05	557.6±23.15
NO_2^-(μg/L)	1771.00	18	98.38	0.84	P>0.05	136.5±2.87
PO_4-P(μg/L)	20117.21	18	1117.62	1.71	P>0.05	97.32±6.61
T.P (μg/L)	99090.85	18	5505.04	1.62	P>0.05	216.77±17.87

2. RESULTS AND DISCUSSION

3.1 AIR TEMPERATURE

In the present investigation, air temperature showed an increasing trend from winter to summer at all sites of the lake. A highly significant variation ($p<0.01$) was obtained in air temperature during different seasons however, a non significant variation ($p>0.05$) was recorded between the sites of Dal Lake (Table 1). Air temperature ranged between 6.1°C in the month of December to 37.5°C in August (Fig. 2). The lowest air temperature in winter season was due to short photoperiod, cold atmosphere while the highest during summer season was due to clear atmosphere and higher solar radiation.Similar trends were observed by various researchers while working on different lakes in Kashmir such as Manasbal lake (Dar *et al.,* 2013, Gul *et al.,* 2021), Dal Lake (Lori *et al.,* 2014; Malik, 2015; Chashoo *et al.,* 2020 and Ruhela *et al*., 2020), Ahansar lake (Javeed *et al.,* 2019).

3.2 WATER TEMPERATURE

In the present investigation, water temperature ranged between 1.41°C in the month of February to 28.3°C in August (Fig. 3). Seasonally, a highly significant variation ($p<0.01$) was obtained in the lake (Table 1). Solar radiation is the most significant source of heat for lakes, and the majority of it is absorbed directly by water (Wetzel, 2000). Similarly, a steady decrease in solar radiation may explain the drop in temperature from October to January, after which it begins to rise again from March onwards. This type of observation is in conformity with the earlier findings of Zuthsi*et al.,* 1980 while studyingcomparative limnology of nine lakes of Jammu and Kashmir; Ali *et al.,* 2014 in Dal, Wular, Anchar and Manasbal Lake.

3.3 Depth

In the present study, depth recorded in Dal Lake varied from 1.1m (in March) to 3.m (in August) (Fig. 4). A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1). Kundangar and Abubakr (2006), noticed fluctuations in water depth in Nigeen Lake and linked this to the opening and closing of Nigeen lake's exit gate, as the water level of the lake is regulated by the lock gate. The depth variations in Dal Lake can also be linked to the opening and closing of gates at Dal Gate and to the water level fluctuations from winter to summer on account of precipitation received in the form of rain and snow (Yousuf *et al.,* 2006, Zutshi *et al.,* 1980 and Bhat *et al.,* 2013).

3.4 Secchi disc transparency

Transparency is an important criterion for defining the optical qualities of a body of water (Lorenzen, 1980). In the present investigation, Secchi disc transparency was recorded to vary from 0.3m (March) to 1.9m (August) (Fig. 5). A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1). Lowest transparency was recorded at Dal gate exit which might be partly due to higher inflow of tourists, inflow of waste waters including night soil from house boats and hotels which are in abundance might have caused reduced water transparency. Abubakr *et al.* (2018) also related lower transparency values with sewage contamination in Anchar Lake. Chashoo *et al.* (2020) also reported that the transparency in Dal Lake was lower at polluted sites which may be ascribed mainly to disposal of partially treated liquid sewage from STPs directly into the lake as they contain colloidal particles, suspended particles and dissolved particles which cause reduction in water transparency. However, at central site, the values of transparency were relatively higher which may be because of no direct impact of wastewater discharge as this site was relatively away from STPs and these sites are pelagic in nature with no direct anthropogenic pressures and less photosynthetic activity and sedimentation of suspended soil particles in winter season.

3.5 Specific conductivity

Specific conductivity ranged from 201μScm^{-1} in the month of September and October to 364μScm^{-1} in July (Fig. 6). A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1). The lowest Specific conductivity values was found at central site which may be because of no direct influence of the effluents discharged from the STPs and presence of aquatic macrophytes along with higher concentration of D.O. at this sites also play a significant role in lowering EC values as observed by Abubakr (2010) who reported that submersed macrophytes cause diminution of dissolved ions, thus signifying that high productivity with elevated levels of dissolved oxygen are responsible for reducing of conductivity. Higher specific conductivity values at Dhobi Ghat site which might be due to continuous discharge of domestic sewage from houses and fertilizer run-off in this area. Neves *et al.* (2003) related conductivity with the higher concentration of organic residue originated with domestic sewage in river Cuiaba. Higher conductivity values can also be related to lower volume of water at littoral sites. Similar observation was made by Handoo (1987) and Kebede & Belay (1994) who reported that conductivity values increase as the volume of water decreases in the lake.

3.6 pH

pH is the negative logarithm of the hydrogen ion concentration of a solution and is the measure of whether the liquid is acidic or alkaline. In the present study, pH values depicted that the lake to be well buffered as the values were greater than 7 indicated that the lake water is alkaline (Fig.7). All the sites remained on alkaline range throughout the study period indicating that good buffering capacity of lake waters without showing much change in pH values. The presence of calcium-rich rocks in catchment areas may contribute to the alkaline nature of Kashmir lakes (Zutshi *et al.,* 1980). The conversion of CO_2 to organic carbon by photosynthesis causes a rise in pH at high water temperatures (Araoye, 2009) and lower pH values were recorded during winter season which could be ascribed to low photosynthetic activity, as well as the dominance of decomposition over photosynthesis which results in CO_2 liberation, and hence causes pH to fall (Otsuki and Wetzel, 1972). Statistically, no significant variation ($p>0.05$) was recorded between these sites (Table 1). Singh & Mahajan (1987), Abubakr *et al.* (2014) also suggested the higher pH may be because of increased photosynthetic activity of phytoplankton or macrophytes and high input of sewage.

3.7 Dissolved oxygen

In aquatic ecosystems, oxygen is present in a dissolved form. Dissolved oxygen (DO) in the water is necessary for respiration, and thus is necessary for aquatic life to exist. During the present study, the dissolved oxygen varied from 4.4mgl^{-1} in the month of April, June and August to 9.2mgl^{-1} in December (Fig. 8). A highly significant variation was recorded seasonally in the lake which was also confirmed statistically ($p<0.01$) (Table 1). High D.O was recorded during winter season because cold water contains more oxygen than warm water since, DO is inversely related to water temperature (Hynes, 1960) and it can be also assigned to low biological activity (Vass *et al.*, 1977; Qadri *et al.,* 1981). Abubakr *et al.* (2018) also related high DO with increased solubility of oxygen at lower temperature. This is known as the law of solubility of gases. Jin *et al.* (2017) related high D.O. to photosynthesis of plants /micro-plants in the water. The low D.O. values recorded at Dal gate (Exit) site, being the centres for water sports and shikara rides, are heavily loaded with hotels, restaurants and street vendors causing continuous inflow of pollutants into the lake and thus reducing its oxygen levels. The lower value of dissolved oxygen can also be attributed to the higher rate of organic matter breakdown which is controlled by temperature (Singh *et al.,* 2002).Yousuf & Shah (1988), Kaur *et al.* (2003), Bhat *et al.* (2013), Bashir *et al.* (2017), Abubakr *et al.* (2018) have also related low D.O state with high organic matter and sewage which consumes oxygen for decomposition in different lakes in Kashmir.

3.8 Chloride

During the present study, chloride content was recorded to vary from 10mgl^{-1} (December) to 35.0 mgl^{-1} (July) (Fig.9) and showed a significant difference ($p<0.05$) during different seasons (Table 1). Higher value of chloride was found at the littoral sites of Nehru Park basin and littoral site of Nishat basin could be due to direct discharge of night soil from the house boats into the lake and from other human settlements in the interiors of the Dal Lake. Discharge of partially treated sewage effluents loaded with high concentration of chloride can also be one of the reasons of its enhancement. Blum, 1957 and Murthuzasab *et al.,* 2010 also suggested that elevated chloride levels in aquatic bodies might be caused by sewage. Abubakr &Kundangar (2008) while working on number of Kashmir Lakes reported higher values of chloride and attribute it to the presence of organic matter while Mathew & Vasudavan (2000) related the elevated chloride to the flow of sewage in river Pamba. Chashoo *et al.,* 2020 also reported that a high concentration of chloride content due to direct discharge of effluent from the STPs in Dal Lake. The lowest chloride concentration was recorded at the central site which can be explained by no direct influence of partially treated sewage effluents from STP and can also be attributed to the dilution effect of rain (Chashoo *et al.,* 2020). Prasannakumari *et al.* (2000) also observed low chloride content in waters devoid of sewage contamination**.**

3.9 Free carbon dioxide

One of the most essential processes in biological systems is the hydration of carbon dioxide. During the present study, free CO_2 was recorded to vary from 1.5mgl^{-1} in the month of June to 18.9mgl^{-1} in February (Fig.10). A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1). The lowest value might be attributed to the rate of photosynthetic activity in these systems. As the weather warms, the rate of photosynthesis rises, and the amount of free CO_2 in the atmosphere drops. The major reason for the loss of CO_2 is usage of carbon dioxide by submersed macrophytes and phytoplankton in summer season (Yousuf, 1979). Higher values of free carbon dioxide during winter could be attributed to the high decomposition of organic matter (Yousuf *et al*., 1986)

3.10 Total hardness

In the present investigation, total hardness valuewas recorded to vary from 110mgl^{-1} in the month of September to 180mgl^{-1} in January (Fig. 11). A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1) which could be possibly due to the sort of minerals in the soil as well as the volume of lake water that comes into contact with these minerals (Tepe *et al.,* 2005). Higher hardness values in Dal Lake might be caused by calcium carbonate precipitation, and photosynthetic activity by primary producers (Ahmad *et al*., 2020). The raised hardness value in Dal Lake is due to the large amount of calciferous runoff coming from the catchment area. Similar results were obtained in Zutshi and Vass (1973) who reported that calcium is the major cation that contributes to overall hardness in Lake Manasbal. Waters with hardness levels ranging from 0-75 mg/L are classified as soft waters, 75-150 mg/L as moderately hard waters, and 151-300 mg/L as hard waters (Sawyer *et al.,* 1967). The total hardness of the lake was quite high indicating their “hard water” nature.

3.11 Calcium hardness

Calcium and magnesium are key elements in aquatic ecosystems that play a vital role in biogeochemical processes. In the present study, Calcium hardness valuewas recorded to vary from 27.4mgl^{-1} in the month of March to 54mgl^{-1} in February (Fig. 12). However, a highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1) which could be due to theabundance of lime rich rocks in the catchment area and also due to increased runoff from the catchment region, which is dominated by calcareous material that might be partially responsible for the higher Ca^{2+} level in Dal lake.The calcium hardness of a lake can vary throughout the year due to various factors, including temperature and water chemistry. High calcium hardness was recorded in winter season as; it's possible for the calcium hardness to be higher in colder winter because cold water can hold more dissolved minerals like calcium. When water temperatures drop, the solubility of minerals generally increases, which can lead to higher calcium levels in the water**.** Also the higher concentrations of both Ca^{2+} and Mg^{2+} in Dal Lake can be attributable to their leaching from agricultural soils. As the farming practises in the Telbal sub-agricultural catchment's zones are adding up the calcium content in the lake (Ishaq and Kaul, 1989). Kundangar and Abubakr (2006) reported the high levels of calcium in water and presence of marl on the leaves and stems of the macrophytes in all the basins of Dal Lake.

3.12 Magnesium hardness

Magnesium is often associated with calcium in all kinds of waters; however, its concentration is lower than calcium (Venkatasubramani and Meenambal, 2007). During the present study, Magnesium hardness valuewas recorded to vary from 17.4mgl^{-1} in the month of September to 32.9mgl^{-1} in February (Fig. 13). A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1).The lower magnesium content could be due to increase precipitation and snowmelt, leading to greater dilution of lakes, thus reduces concentration of magnesium ions while as higher magnesium content might be due to increased agricultural run-off from catchment and through floating gardens. These levels can also be attributed to the release of this cation from decomposing macrophytes which are left unattended/unlifted. Mushatq *et al.,* 2013 also reported higher Mg levels due to the enhanced agricultural run-off from catchment through Telbal and from floating gardens located in Dal Lake. However, low magnesium content is possibly due to plant absorption in the synthesis of chlorophyll-porphyrin metal complexes and enzymatic transformation in Manasbal Lake (Wetzel, 1975). Sewage inflows and minerals resulting from soil erosion are the principal sources of magnesium in the lake.

3.13 Ammonical-nitrogen

In the present study, ammonical-nitrogen valuewas recorded to vary from 125µg/Lin the month of March to 494µg/Lin July (Fig. 14). Minimum values of ammonical nitrogen were recorded at Central site (near island) while maximum value was recorded at Dal gate (exit) site. The raised level of ammonical nitrogen is due to discharge of wastes from the hotels, house boats and also from human settlements in catchment area. These findings are in the conformity with the findings of Zuber (2007) who also reported the fluctuations in the values of ammonical nitrogen could be due to decomposition of organic matter in Dal Lake. The higher values of ammonical nitrogen are indicating significant level of sewage contamination in the lake and it could be due to excessive decomposition of organic matter and runoff from the floating gardens. Bu *et al.* (2014), Ding *et al*. (2016) have observed that an increased human activity leads to a rise in the concentration of ammonium nitrogen in freshwater.Lower values of ammonia-nitrogen may be related to no direct influence of partially treated effluents from STPs and can also be related to presence of proper conditions for natural nitrification process in Dal Lake (Chashoo *et al,* 2020). It can also be related to presence of proper conditions for natural nitrification process. A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1).

3.14 Nitrate- nitrogen

Nitrogen is essential for all living beings and the primary nutrient that limits life on our planet (Kuypers *et al.,* 2018). Nitrate is the most abundant nitrogen form, and its availability is determined by a variety of transformative reactions, including nitrification, denitrification, and biological absorption (Kendall *et al.,* 2007).During the present study, nitrate-nitrogen valuewas recorded to vary from 324µg/Lin the month of

December to 782µg/Lin May (Fig. 15). A significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.05$) (Table 1). The major causes of high nitrate concentrations could be due to partially treated sewage released from STP, agricultural, household run-off, and organic load from the catchment areas.According to Sylvester (1961) the domestic sewage is primarily responsible for higher nitrate concentrations in fresh waters. The findings are conformity with Wang and Evans (1970); Singh and Choudhary (2013) and Yousuf (1979). Abubakr & Kundangar (2004) also ascribed the increased nitrogen values to sewage contamination in Dal Lake. A higher concentration of nitrate was reported in Dal waters (Kundangar and Abubakr, 2006). Chashoo *et al*., 2020 reported higher values of nitrate could be related to release of effluent partially treated from STPs and due to runoff of fertilizers from adjacent areas. However, Gorski *et al.* (2019) stated that the high nitrate levels are observed during autumn and winter when temperature is low and biological activity is limited and there was a significant decrease in the nitrate levels when the improvement of sewage treatment technology in Warta river in Poland. Lower nitrate-nitrogen concentration in Dal Lake may be attributed to dilution factor of water and no direct impact of discharge of effluents from STP. Jaji *et al.* (2007) stated that unpolluted natural waters usually contain only minute amounts of nitrate while studying the water quality of Ogun river.

3.15 Nitrite-nitrogen

In the present investigation, nitrite-nitrogen valuewas recorded to vary from 10µg/Lin the month of December to 72µg/Lin September (Fig. 16). A highly significant variation was recorded seasonally ($p<0.01$) and a significant variation was recorded between the sites in the lake which was also confirmed statistically ($p<0.05$) (Table 1). Nitrite concentrations in surface waters approximately 10 ug/l have been considered an indicator of sewage pollution (Williams and Eddy 1986). The lower level of nitrite in the lake is because the nitrogen exists in the more reduced (ammonia) or more oxidized (nitrate) forms. The low concentration nitrite values in the lake may be owing to short residence time in water (Malhotra and Zanoni, 1970). Chashoo *et al.* (2020) reported lower nitrite-nitrogen values at unpolluted sites can be related to less to no impact of effluent discharge from STP and proper supply of oxygenation in waters for the natural process of nitrification i.e., conversion of relatively instable form of nitrogen (i.e., nitrite) into stable form (i.e., nitrate). The major causes of high nitrate concentrations could be due to partially treated sewage released from STP, agricultural, household run-off, and organic load from the catchment areas. According to Sylvester (1961) the domestic sewage is primarily responsible for higher nitrate concentrations in fresh waters. The findings are conformity with Wang and Evans (1970); Singh and Choudhary (2013) and Yousuf (1979). A higher concentration of nitrate was reported in Dal waters (Kundangar and Abubakr, 2006). Chashoo *et al.* (2020) reported higher nitrite-nitrogen values at polluted sites of Dal Lake could be related to discharge of sewage effluent from STPs, absence of condition for proper nitrification process and leaching of nitrogen rich fertilizers into the lake.

3.16 Orthophosphate

In the present study, orthophosphate valuewas recorded to vary from 58µg/Lin the month of December and March to 193µg/Lin July (Fig. 17). The lower concentrations of ortho-phosphate at central site (near island) can be related to no direct influence of STP's effluent discharge, decreased anthropogenic activities and the dilution factor of the water (Chashoo *et al.,* 2020). However, higher concentration at Dhobi ghat site and Dal gate (Exit) is possibly due to higher amounts of domestic wastes, detergents and agricultural effluents are being discharged into the lake and are consideredas the major sources of phosphorus. And it may be also related to the use of detergents and dyes in the catchment areas which find their way into the waters.Hutchinson (1967) linked elevated phosphorus levels to sewage pollution.Abubakr *et al.* (2018) also attributed the higher orthophosphate to the influx of sewage, agricultural runoff contaminated with phosphate (applied as fertilizers) in Anchar Lake. Chashoo *et al.* (2020) also reported higher ortho-phosphate values can be attributed to inadequate treatment of sewage which is loaded with soap detergent and fertilizers and is discharged at periphery of the lake from STPs. A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.05$) (Table 1). The highest value of orthophosphate was recorded at Dhobi ghat site which is due to washing clothes along banks of lake with thick foamy detergents was observed on the surface water. Our results are in agreement with Maulood and Saadalla (1992) who attributed high concentrations of ortho-phosphate to the wastewater with high content of soap detergents and fertilizers and the hydrolysis of polyphosphates and revert to the orthophosphate forms in Saklawia irrigation channel in Baghdad. Similar observation was reported by Malik *et al.* (2017).

3.17 Total phosphorous

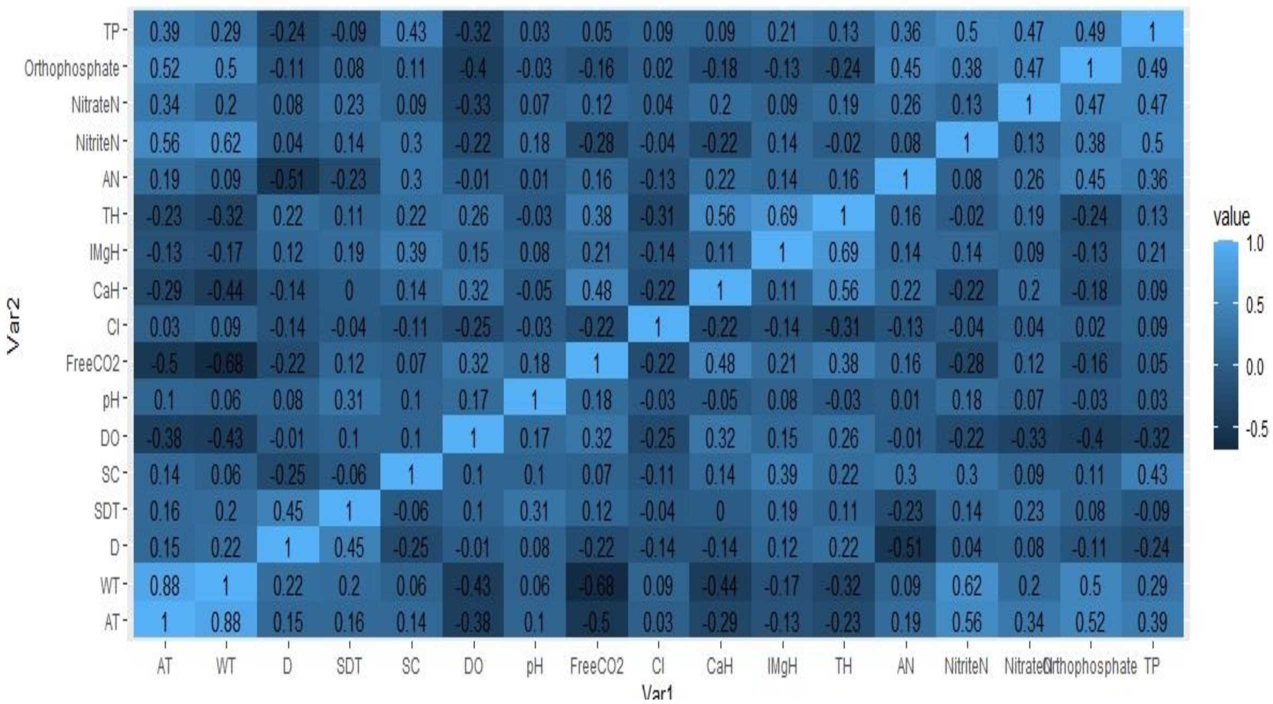
Phosphorus is an essential component of nucleic acids and many intermediary metabolites, such as sugar phosphates and adenosine phosphates, which are an integral part of the metabolism of all life forms. Phosphorus only occurs in the pentavalent form in aquatic systems. During the present study, total phosphorous valuewas recorded to vary from 201µg/Lin the month of March to 579µg/Lin September (Fig. 18). The low phosphorous concentration is possibly due to low discharge of sewage, detergents, fertilizers used in agricultural activities from the catchment areas whereas, the higher values of total phosphorous might be attributed to the widespread use of phosphate fertilisers in agricultural activities and sewage pollution from the catchment areas. High phosphate concentrations in Dal water were attributed by Khan *et al.* (2014) to sewage pollution, disruptions caused by human activity in the catchment region. Solim and Wanganeo (2008) also reported that phosphate fertilizers and organic manure is prevalent in the agricultural areas which result in transport of soil laden with various fractions of total phosphorous in Dal Lake. Solim and Wanganeo (2008) also reported that phosphate fertilizers and organic manure is prevalent in the agricultural areas which result in transport of soil laden with various fractions of total phosphorous in Dal Lake. Sharma (2015a) and Sharma (2015b) also reported higher phosphorus level in Dal Lake is related to the direct discharge of untreated human wastes from houseboats, sewage disposal and illegal settlements adjoining the lake. Thus, the present study strongly suggests that effluent zone of STPs is highly eutrophic and it needs an immediate attention. Chashoo *et al.* (2020) reported higher T.P concentration can be related mainly to the influx of partially treated sewage effluents from STP directly into the Dal Lake. However, in addition to this increased agricultural activities and use of phosphate based fertilizers may be the cause of increased levels of phosphorus at polluted sites. A highly significant variation was recorded seasonally and between the sites in the lake which was also confirmed statistically ($p<0.01$) (Table 1).

According to Welch (1952), a water body is eutrophic if the total phosphorus content is between 20-30µg/l. As per this classification, Dal Lake can be put under eutrophic category.The correlation among physic-chemical parameters is given in table 2.

4. CONCLUSION

According to the current research, the effects of various environmental stresses and their consequences can be seen in Dal Lake. These changes are due to anthropogenic forces, natural factors, and a lack of adequate management. However, because Dal Lake is an urban lake, the stress is more noticeable. The possible reason being a more rapid increase in human population being settled in the immediate catchment area of the lake, leading to an increase in developmental activities and thus putting more pressure on the lake in terms of release of higher level biologically important nutrients (N&P) and also due to inefficient/incomplete treatment of wastewaters by STP's, which is directly releasing sewage in this water body, which has resulted in changing the trophic condition of the Dal Lake. Chashoo *et al*. (2020) also reported similar findings. Although, Lake Conservation and Management Authority (LCMA) is managing the lake through a number of interventions. However, there is a need of well planned long term experimental research which requires training in appropriate methodology and development of infrastructure. Such measures shall go long way in managing the quality of water and aquatic biological resources for sustainable development of this water body. Empowerment of LCMA to enforce the rules and regulations with proper legislation to curb the lake encroachments and violations is necessary for the success of Dal Lake restoration programme.

Table 2: Correlation among various physico-chemical parameters of Dal Lake



**Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level

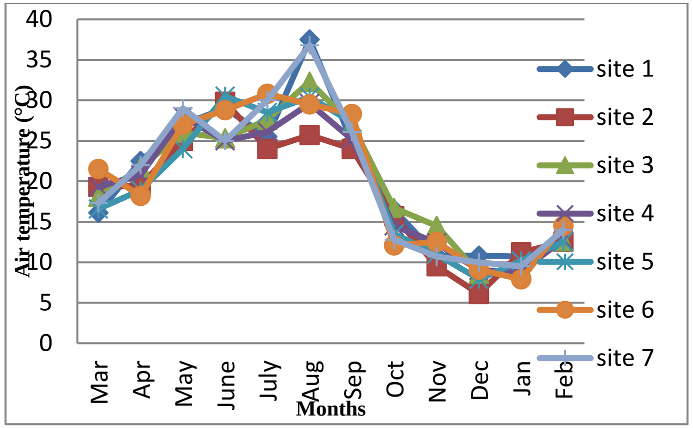


Fig. 2, showing monthly variation in Air temp. (°C) at different sites of Dal Lake

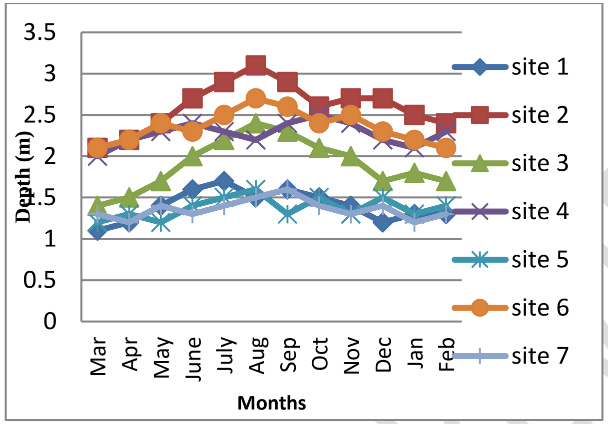


Fig. 4, showing monthly variation in depth (m) at different sites of Dal Lake.

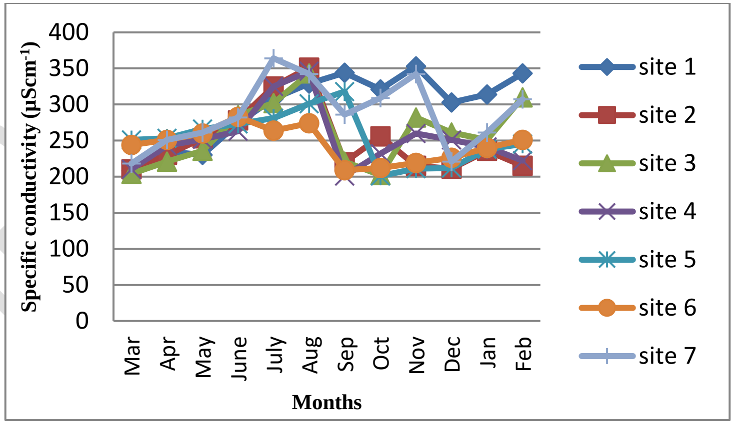


Fig. 6, showing monthly variation in Specific conductivity (µScm^{-1}) at different sites of Dal Lake

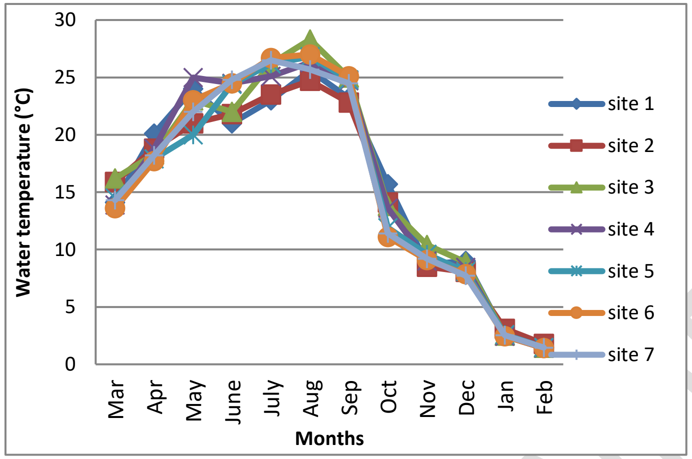


Fig. 3, showing monthly variation in water temperature (°C) at different sites of Dal Lake.

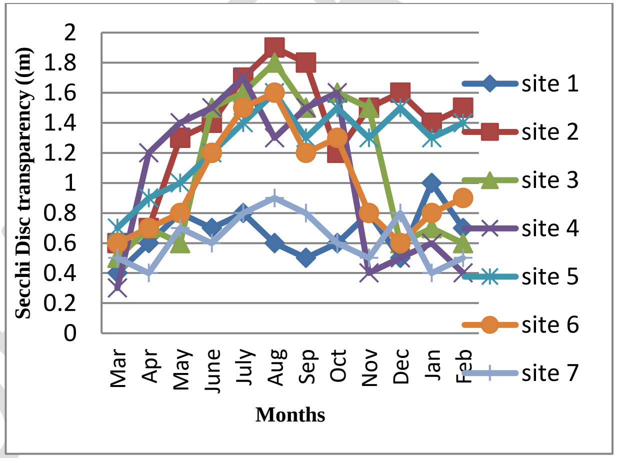


Fig. 5, showing monthly variation in Secchi Disc transparency (m) at different sites of Dal Lake.

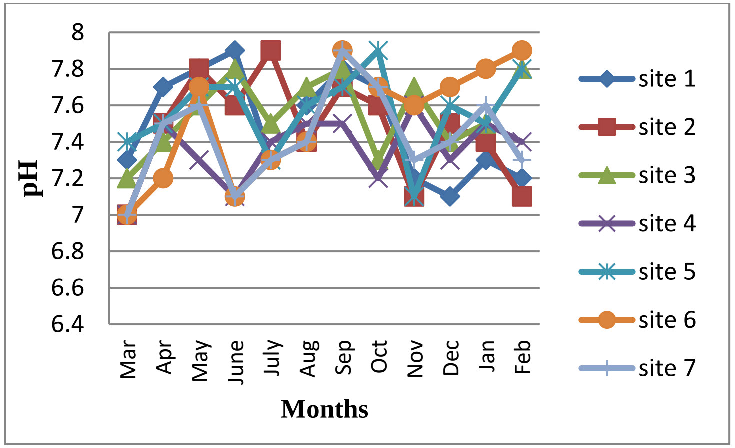


Fig. 7, showing monthly variation in pH at different sites of Dal Lake.

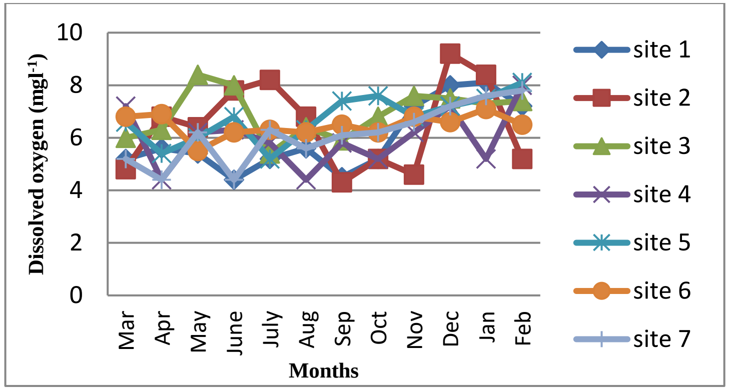


Fig. 8, showing monthly variation in Dissolved oxygen (mgl^{-1}) at different sites of Dal Lake.

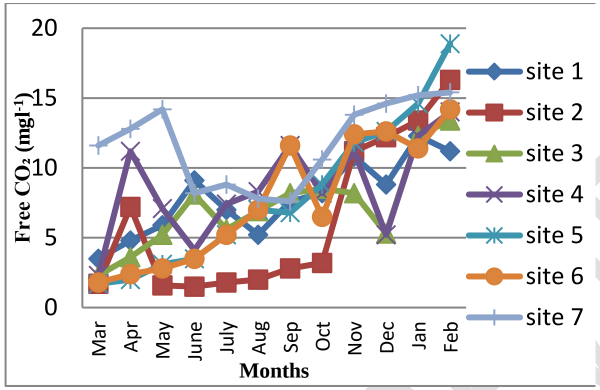


Fig.10, showing monthly variation in Free CO_2 (mgl^{-1}) at different sites of Dal Lake.

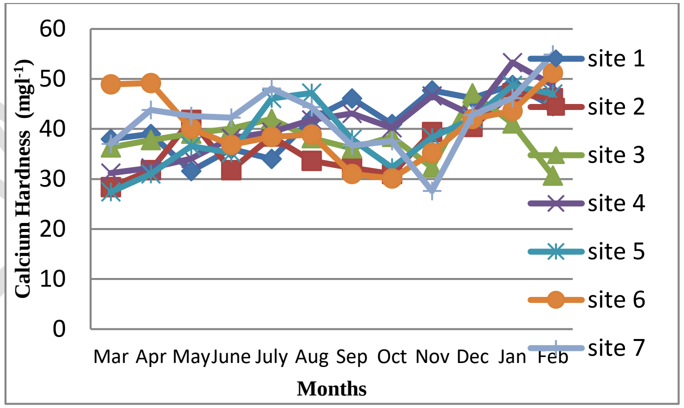


Fig. 12, showing monthly variation in Calcium Hardness (mgl^{-1}) at different sites of Dal Lake.

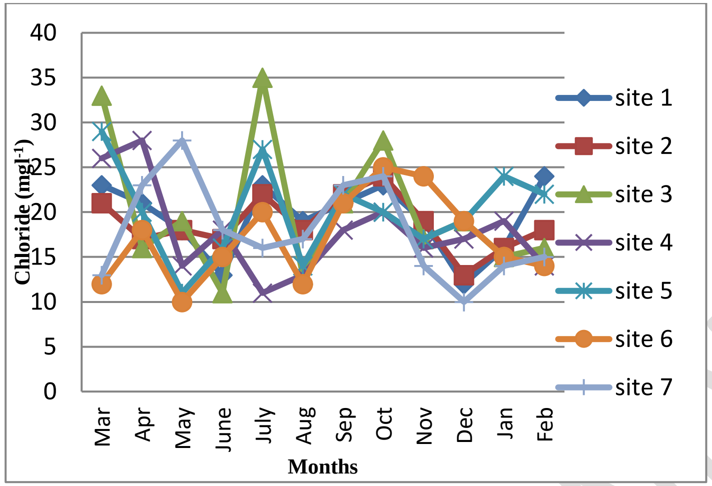


Fig. 9, showing monthly variation in Chloride (mgl^{-1}) at different sites of Dal Lake

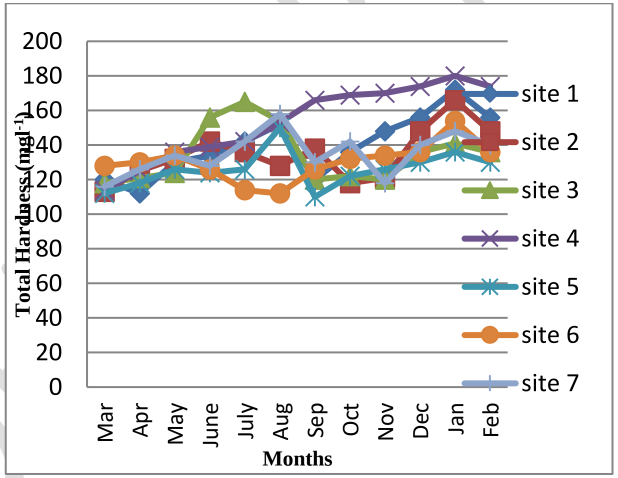


Fig. 11, showing monthly variation in Total Hardness (mgl^{-1}) at different sites of Dal Lake .

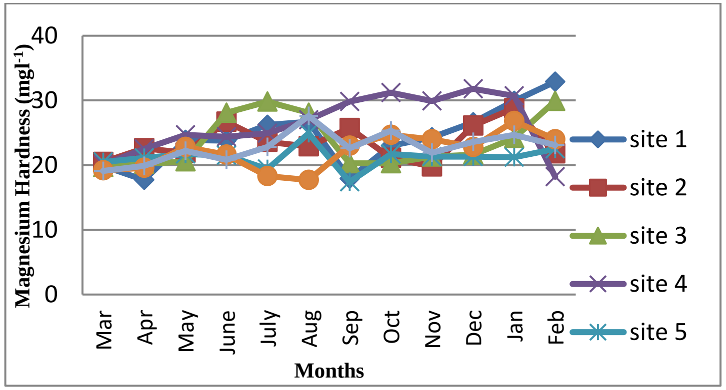


Fig. 13, showing monthly variation in Magnesium Hardness (mgl^{-1}) at different sites of Dal Lake.

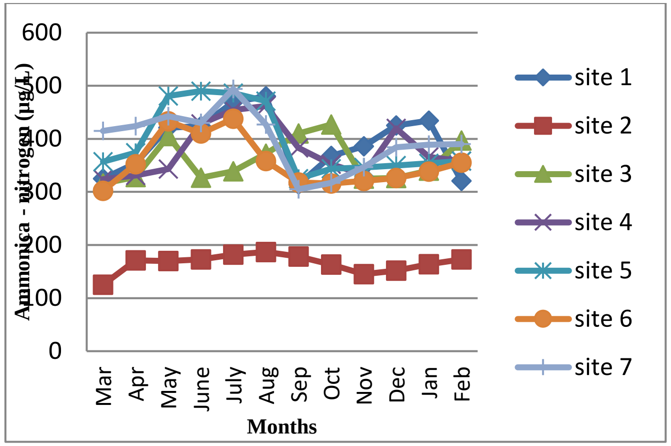


Fig. 14, showing monthly variation in Ammonical-nitrogen (µg/L) at different sites of Dal Lake.

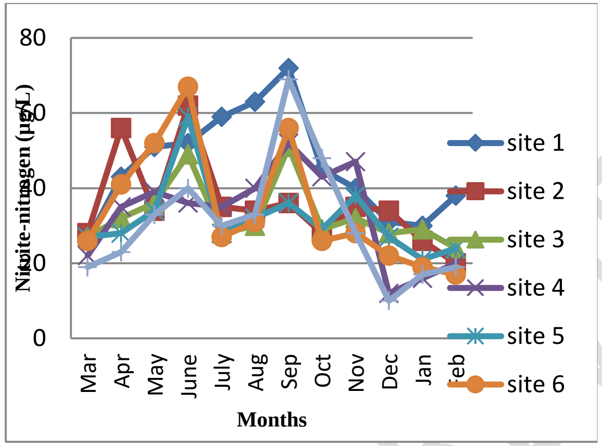


Fig. 16, showing monthly variation in Nitrite-nitrogen (µg/L) at different sites of Dal Lake.

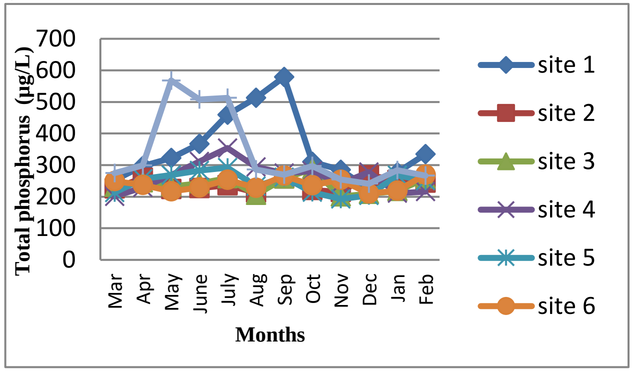


Fig. 18, showingmonthly variation in Total phosphorus (µg/L) at different sites of Dal Lake.

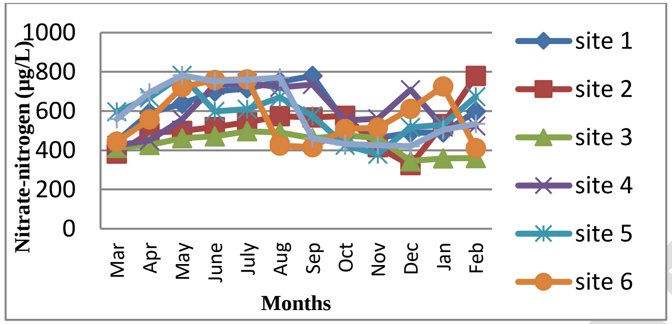


Fig. 15, showingmonthly variation in Nitrate-nitrogen (µg/L) at different sites of Dal Lake.

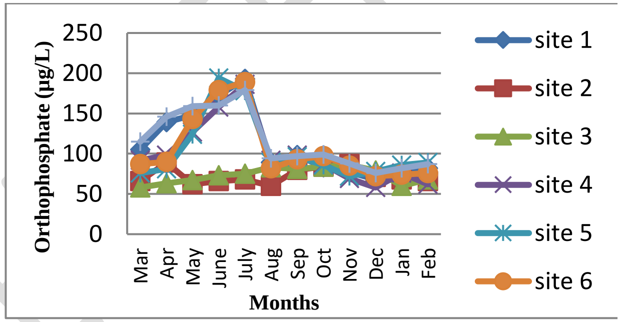


Fig. 17, showingmonthly variation in Orthophosphate (µg/L) at different sites of Dal Lake.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Details of the AI usage are given below:

1.

2.

3.

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