Journal of

Fisheries and Aquatic Science

ISSN 1816-4927

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Journal of Fisheries and Aquatic Science

ISSN 1816-4927
DOI: 10.3923/jfas.2016.391.401

Research Article

Exploring the Various Physico-chemical Parameters of Surface Water and Sediments of Dal Lake Srinagar, Kashmir

[1]Basharat Mushtaq, [2]Rajni Raina, [3]A.R. Yousuf, [1]Ashwani Wanganeo and [4]Arshid Jehangir

[1]Department of Environmental Sciences and Limnology, Barkatullah University, Bhopal (MP), India
[2]Govt. Science and Commerce College (Benazir), Bhopal (MP), India
[3]National Green Tribunal, New Delhi, India
[4]Department of Environmental Science, University of Kashmir, India

Abstract

Background and Objective: The purpose of this study is to determine the levels of some physico-chemical parameters in water and sediment samples from various sites of Dal lake Srinagar, Kashmir. During the last few years the lake has been fallen victim of human greed in terms encroachments, direct sewage and runoff dumping from its vicinity as well as from its interior areas were directly emptied into the lake. **Methodology:** The samples for physico-chemical characteristics of water and bottom sediment were sampled on monthly basis from 2010-2011 and were analysed as per the standard methods. **Results:** On the basis of results obtained during present investigation, various physico-chemical parameters of both surface water and sediments depicted polluted status of Dal lake. Nitrate concentration in surface water ranges from 45-1250 μg L^{-1} while in sediments nitrate ranges from 0.5-15.4 ppm. Total phosphorus of both water (5-540 μg L^{-1}) and sediment (13-149 ppm) also recorded higher values. Highest levels of nitrogen, phosphate and other constituents in both water and sediment were recorded at those sites which was located near houseboat and floating garden areas. Present study also highlight the significant positive relation ($p>0.5$) between different chemical parameters viz., pH, conductivity, chloride, nitrate-nitrogen and sulphates of both surface water and sediments. **Conclusion:** This study concludes that deterioration of water and sediment quality in the lake system due to anthropogenic activity and urbanization. The results of the study implies that continuous monitoring has to be carried out to ascertain the long-term impact of anthropogenic inputs to take remedial measures so as to ensure the health of aquatic life.

Key words: Physico-chemical parameters, pollution, water, sediment

Received: July 31, 2016 Accepted: September 15, 2016 Published: October 15, 2016

Citation: Basharat Mushtaq, Rajni Raina, A.R. Yousuf, Ashwani Wanganeo and Arshid Jehangir, 2016. Exploring the various physico-chemical parameters of surface water and sediments of Dal lake Srinagar, Kashmir. J. Fish. Aquat. Sci., 11: 391-401.

Corresponding Author: Basharat Mushtaq, Department of Environmental Sciences and Limnology, Barkatullah University, Bhopal (MP), India

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Nutrient enrichment of lakes is one among the major environmental problems in many countries[1]. Though it stimulates the growth of plants (algae as well as higher plants), nutrient enrichment ultimately leads to deterioration of water quality and degradation of the entire ecosystem[2]. The chemistry of lake water and sediment is a cumulative reflection of catchment geology, weathering and erosional processes as well as anthropogenic inputs. Sediment is an essential, integral and dynamic part of aquatic ecosystems. Sediment has ecological value, it forms a variety of habitats and environments. Sediment-dwelling species are supported by soft sediment systems. Exposure to certain substances in sediments is hazard to the health of these organisms. Bottom sediments serve as a sink for such contaminants in the aquatic environment[3]. These ecosystems act as vessels for storing nutrients and sediments from flooding waters as well as surface runoff, thereby reducing the risk of eutrophication or over enrichment of other natural waters like streams and rivers. Sources of potable water, both surface and sub-surface, are increasingly polluted. Rivers and lakes are important sources of drinking water, the latter being ponded and smaller in size are generally intensely polluted. The weathering of catchment rocks, the disintegration and decay of their constituent minerals liberate elemental ions and act as a natural source of pollution. Human actions often cause pollution of much greater magnitude than natural contributors in lake systems. The sediment reservoir of a lake plays an important role in elucidating the various processes occurring within the total lake system, including the surrounding surface water drainage basin and a rock water interaction. The sediments of any water body contain a historical record of the natural and anthropogenic fluxes of heavy metals received into the lake basin[4].

Dal lake (Latitude 340-06'N, 740-45'E, altitdue 1583 m) situated in the heart of Srinagar, the summer capital of Jammu and Kashmir State is under tremendous anthropogenic pressure for the last three decades. Dal lake is the center of civilization and is among the most beautiful and national heritages. It has played a major role in the economy of the state of Jammu and Kashmir through its attraction of tourists as well as its utilization as water and food. During the last few years grave concern have been voiced by many researchers and people of the different walks of life over the deteriorating condition of the Dal lake. There is no denying fact that Dal lake has been fallen victim of human greed. The sewage and runoff from its vicinity as well as from its interior areas were directly emptied into the lake. Moreover, faecal matter from all house boats located in Gagribal and Nigeen basin were disposed into the lake bed. Further farmers also dumping organic wastes from their floating garden into the lake bed. The cumulative impact of these human interferes resulted significant alterations to the entire lake ecosystem. However, this process is accelerated by excess nutrients from human activities and is called "Cultural eutrophication[5]". Both the water and sediment quality problems and concerns for the eutrophication is a major apprehension in urban valley lakes like Dal lake. As a result of accelerating nutrient enrichment to the Dal lake from various sources, there is a dearth of information regarding the water and sediment quality. Plenty work have been carried out on Dal lake by different researchers from time to time viz.,[6-15] whatever work have been carried out so far has been mainly focussed on macrophytic and planktonic dynamics. Structural community of benthic fauna. Therefore, we carried out a study to understand the recent trends in water quality and chemical characterization of bottom sediments samples collected from different Dal lake Srinagar, which is subjected to heavy pollution load and the results of present study will also give a presentation of trophic structure at both bottom sediments and ambient water. It is in this backdrop that the pollution data generated from such regular scientific study will help to implement compatible policies and programmes to gauge the extent of pollution. Therefore, the present study was undertaken to study the chemistry of water and sediment and correlation between the various parameters of both water and sediment of Dal lake.

MATERIALS AND METHODS

Study area: The Dal lake is an urban lake that lies to the east of Srinagar city, at the foot of Zabarwan Hills and is situated at an average elevation of 1,581 m a.s.l. Six sampling sites were chosen for the determination of various physico-chemical parameters of water and sediment within the lake (Fig. 1). Site-1 is located at a latitude 34°08'44.6"N and longitude 74°50'36.0"E near Habak STP where Bok kol enters in the Dal lake. The average depth of this site is 1.4 m. Site-2 is located within the center of Hazratbal basin at latitude 34°07'47.4"N and longitude 74°50'38.0"E, having dense macrophytic growth and average depth of this site is 3.2 m. Site-3 is located in Nigeen basin (at latitude 34°06'53.1"N and longitude 74°50'07.3"E) near houseboats, this site is heavily impacted by direct drainage of sewage from house boats the average depth of this site is 2.4 m. Site-4 is located in dense floating garden area of Kandmohalla with average depth of 2.4 m, situated in Gagribal basin of lake at latitude 34°05'58.6"N and

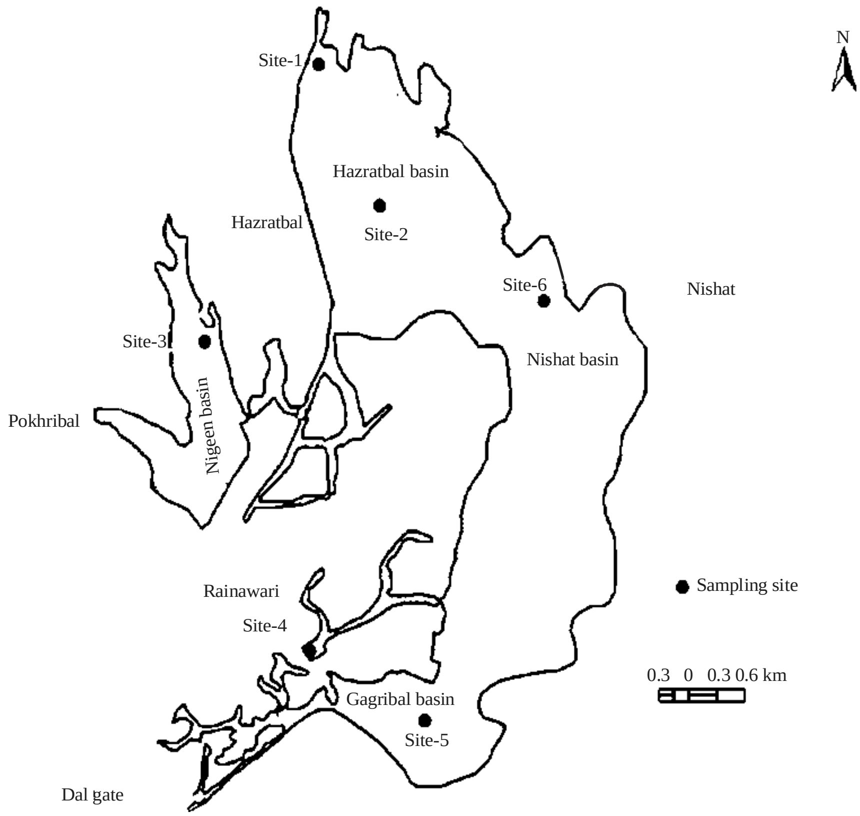

Fig. 1: Location map of sampling sites

longitude 74°50'47.4"E). Site-5 is located with the center of Gagribal basin at latitude 34°04'54.8"N and longitude 74°49'52.0"E, having dense macrophytic growth and average depth of this site is 4.0 m. The last site-6 is situated in Nishat Basin near fore show road at latitude 34°07'41.4"N and longitude 74°52'34.8"E, this site is regularly disturbed in summer months by manual deweeding processes. The average depth of this site is 3.0 m.

Physico-chemical features of water: The samples for physico-chemical characteristics of water were sampled on monthly basin from 2010-2011 and were analysed as per the methods described by the Council for Scientific and Industrial Research[16] and American Public Health Association[17]. Water temperature was recorded on the spot with Celsius mercury thermometer calibrated up to 0.1°C, whereas, samples fixed at the sampling site in accordance with the azide modification of Winkler method[17] for the estimation of dissolved oxygen. Total hardness, total alkalinity, chloride, ammonical nitrogen and total phosphorus was analysed as per methods given in nitrate-nitrogen by salicylate method[16] and sulphate was determined with barium chloride method[18].

Sediment characteristics: Sediment sampling was done with the help of a Ekman's dredge ($15\times15\times15$ cm^3), on monthly basis. At each site the samples were taken in triplicates. The samples were packed in air tight polyethene bags and transported to the laboratory for further analysis. Different chemical parameters were analyzed on air dried samples. Standard methods as given by Jackson[19] and Thomas[20] were followed to assess the chemical parameters of the sediments. pH and conductivity were carried out on dry basis in 1:2 sediment water extract with digital pH and conductivity meters. Chloride (1:4 sediment water extract) by argentometric method, organic matter by Walkley and Black[21] rapid titration, total nitrogen by Kheldahl's method[22], nitrate by phenol-disulfonic acid method[20], total phosphorus[23] method and sulphate in sediment samples was determined by turbidity method.

RESULTS AND DISCUSSION

The concentration of various physico-chemical characteristics of the Dal lake surface water sample are presented in the (Fig. 2a-m). Water temperature of different

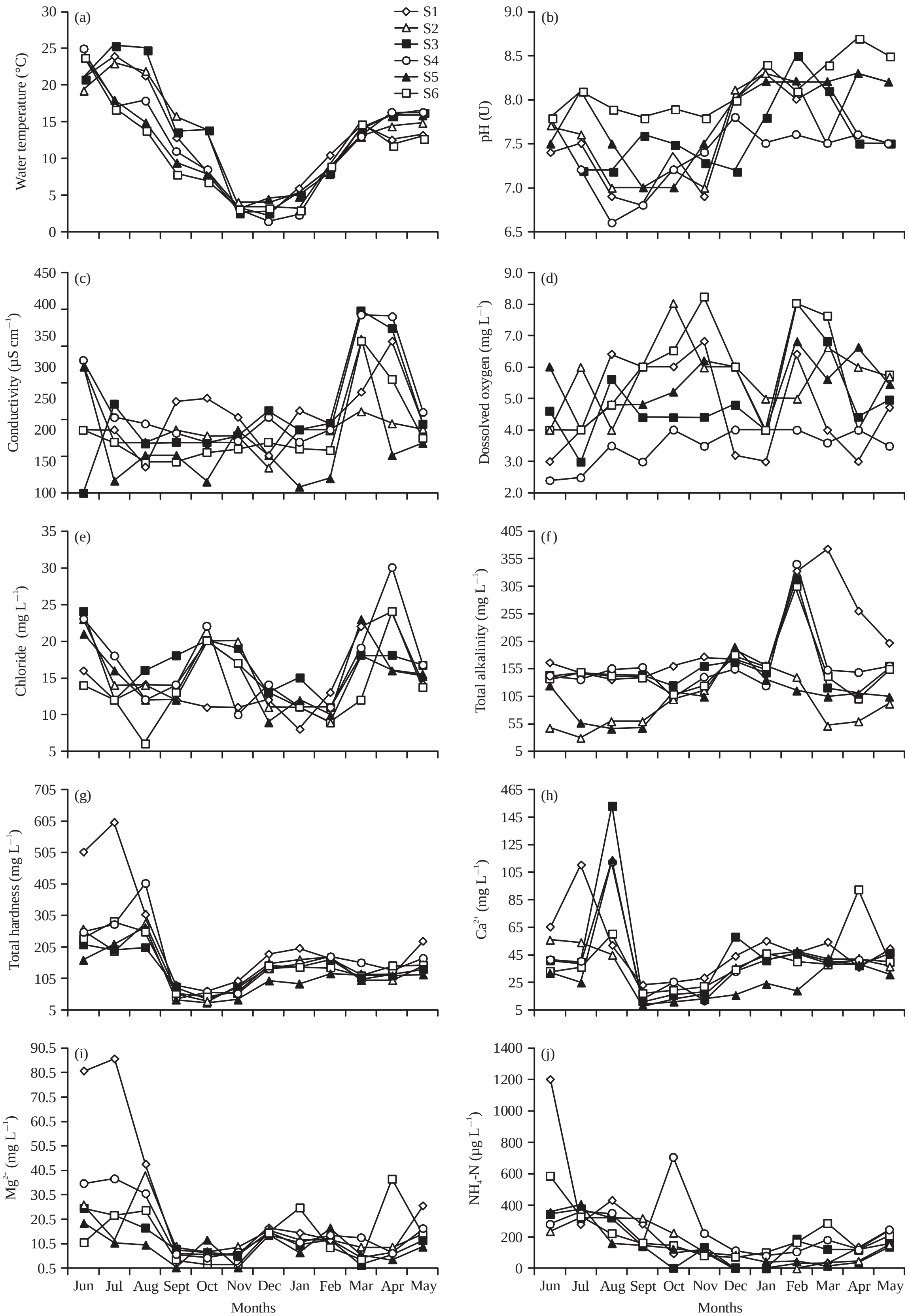

Fig. 2(a-m): Continue

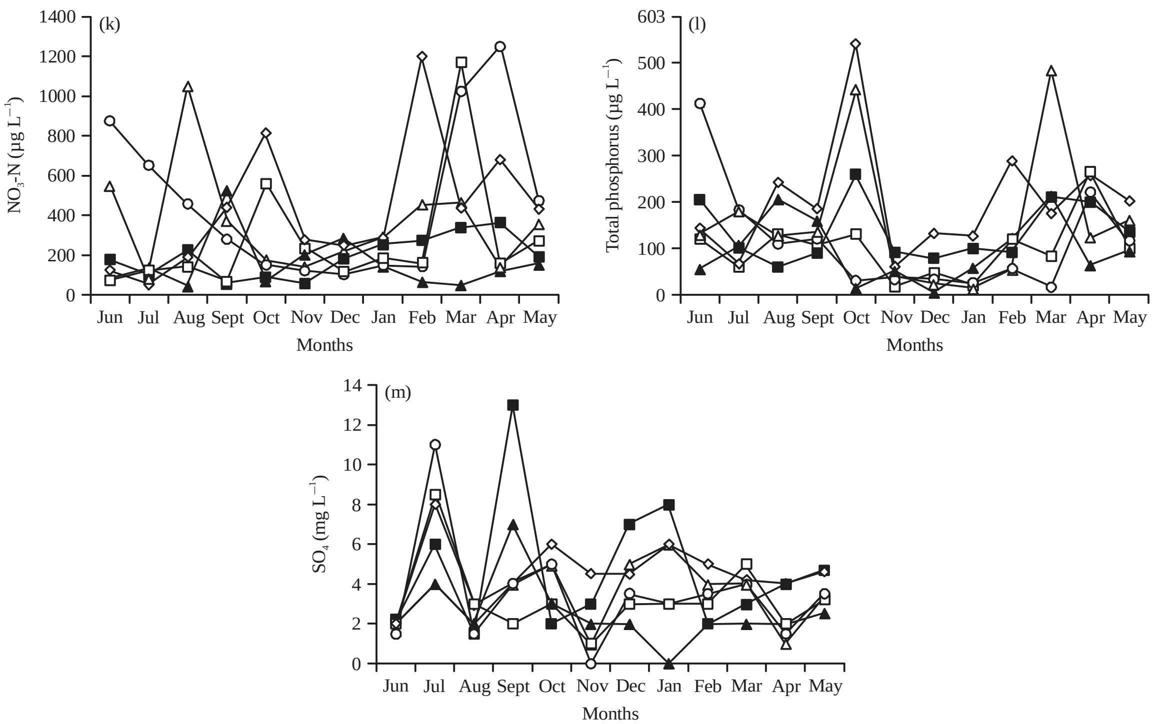

Fig. 2(a-m): Monthly variation in different physico-chemical parameters of water at various sites of Dal lake during 2010-2011

sites in four basins of Dal lake showed almost uniform trend the values fluctuated from a minimum value of 1.5°C at site-4 in December, 2010 to 25.5°C at site-3 during July, 2010. It is well known that water temperature influences organism's physiological parameters directly. Indirectly, the organisms are effected through change in the physico-chemical properties of water. The surface water temperature is one of the most significant parameters which control inborn physical qualities of water. Water temperature was not recorded any significant variation in the present study. The temperature variation recording during the study period was optimal for normal growth and survival of aquatic organisms. The lake is characterized by highly alkaline pH during summer as well as in the winter season. The pH recorded during the present study (6.6-8.7 U) was indicative of the alkaline (mean value 7.7). The pH shows great variations during the study period. The higher values of pH (8.7 U) was recorded at site-6 during April, 2011 while lower values of 6.6 U was recorded at site-4 in August, 2010. The higher values of pH (8.7 U) was recorded at site-6 during April, 2011 while lower values of 6.6 U was recorded at site-4 in August, 2010. The pH recorded in the present study was in alkaline range suggesting that the lakes were well buffered throughout the study period. The pH range between 6.0-8.5 indicates productive nature of water body[24]. Conductivity is a measure of capacity of substance or solution to conduct electric current. The electrical conductivity varies from 100 µS cm^{-1} at site-3 during June, 2010 to 388 µS cm^{-1} in March, 2011 at same site. Electric conductivity depends upon the quantity of dissolved salts present in water[25] and among the six sites the highest conductivity at site-3 may be due to high influence of wastewater which is drained from nearby houseboats.

Dissolved oxygen concentration showed a gradual decrease with time at various sites. While, site-4 depicted almost low concentrations (2.4-4.0 mg L^{-1}) of dissolved oxygen throughout the study period. The higher values with maximum concentration of 8.2 mg L^{-1} recorded in the month of November 2010 at site-6. The dissolved oxygen in surface water comes from air or is produced by photosynthetic organisms like algae and plants in a water body. Depletion of dissolved oxygen in water probably is the most frequent result of certain forms of water pollution[26]. The lower values of dissolved oxygen observed at site-4 could be due cumulative effect of human activities like dumping of organic wastes from floating gardens where oxygen is used in decomposing these organic wastes. Oxygen level is depleted in water bodies due to decomposition of organic wastes[27]. In contrast high dissolved oxygen at site-6 could be due to more photosynthesis as there was presence of excessive growth of macrophytes this site was located in open area of the lake. Further comparatively high dissolved oxygen content at this site may be due the aeration of water by mechanical aerators.

The concentration of chloride during the present study showed great variations from a lower value of 6 mg L^{-1} recoded at site-6 during the month of August, 2010 in comparison to it, the higher concentration of chloride 30 mg L^{-1} was observed at site-4 in the month of April, 2011. The wide fluctuation in chloride content of surface water in present study may be due to different habitat of various sites. High chloride content at site-4 may be attributed to presence of more eutrophic condition as compared to other sites. Site-4 was located between dense floated gardens were human activities regularly disturbs the whole ecological aspect by way of farming activities such as, runoff laden by fertilizers, pesticides and herbicides from floating gardens and also preparing of organic manure etc. Excessive contamination to surface waters by way of runoff and sewage disposal resulted in increased concentration of chloride contents[28,29]. It was observed during the present study that the monthly values of total alkalinity depict an increasing trend in winter months. Although, the higher values of total alkalinity (372 mg L^{-1}) was found in the month March, 2011 at site-1 and lower value (30 mg L^{-1}) was recorded at site-2 during July 2010. Alkalinity is the buffering capacity of a water body. It measures the ability of water bodies to neutralize acids and bases thereby maintaining a fairly stable pH. As far as total alkalinity is concerned it varied greatly between the sampling sites, lesser values were observed in open water areas sites. However, the site located near houseboat and floating garden area. Similar findings were also reported by Siraj *et al.*[30], who also recorded high concentration of total alkalinity in floating gardens areas of Dal lake.

Total hardness showed a different variation in different months during summer months hardness showed increased concentrations almost at each site. The highest value 600 mg L^{-1} was observes at site-1during July, 2010, while lower value (27 mg L^{-1}) was found at site-5 in October, 2010. Calcium and magnesium depicted similar trends in concentration as in case of total hardness. The Ca^{2+} and Mg^{2+}ions showed gradual reduction in their concentration from September-November and start again increasing from December. However, the highest concentrations were observed in summer months. Hardness of water is due to major cations present in the water body. Calcium and magnesium are principle cations that impart the hardness to water. Bicarbonates and carbonates of calcium and magnesium cause hardness in water because of hydrolysis they naturally change into cations. A natural hardness of water depends on geological nature of drainage basin. The values for total hardness during the present study period prevails greater variation in different months at different sites. The values of total hardness are much fluctuating from that of summer months to autumn months while as, in winter months the values also show similar trend as in summers. The hardness was maximum at site-1, it may be due to the outflow of sewage treatment plant at this particular site. Among the various cations, Ca^{2+} and Mg^{2+} were found almost abundant at all sites during the present study. Due to appreciable calcium and magnesium hardness Dal lake can be classified as calcium rich[31]. The Ca^{2+} and Mg^{2+} concentration of freshwater bodies of Kashmir Valley has been associated with thick population of plankton, especially Cyanophyceae[32].

A wide fluctuation was observed in ammonical nitrogen concentrations during the present study. The lowest concentration was recorded below detection level to the highest concentration of 1200 µg L^{-1} was found during June at site-1. Ammonical nitrogen of surface waters in present study depicted wide fluctuation in its values on monthly basis. The highest values at site-4 is attributed organically polluted waters and may be due to presentence of excessive organic matter. Organically polluted waters with high levels of NH_4-N, which is readily available as a nutrient for plant uptake may contribute to increased biological productivity[33]. Ammonical nitrogen showed gradually decrease in the months of December and January. 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 into the lake as it is visited by many aquatic birds[34]. Nitrate nitrogen depicts different variations in its concentration at different sites in different months. However, the maximum concentration of 1250 µg L^{-1} were observed during April, 2011 at site-4 in comparison minimum concentration (45 µg L^{-1}) was recorded at site-5 August, 2010. It was further observed in present investigation that nitrate nitrogen of surface water were also recorded higher at site-4. The higher concentration of nitrate at site-4 could be use nitrogen fertilizers in nearby floating gardens and also due to organically rich waters. The spatial and temporal variations in the total phosphate were much fluctuated. In general, lower concentrations were maintained in the winter months at all sampling sites. On the other hand, monthly concentration depicted a maximum of 540 µg L^{-1} and a minimum of 5 µg L^{-1} at site-1 and 5 during October and December, 2010, respectively. Higher concentration of total phosphorus at site-1 is attributed to direct drainage of sewage at this site. Phosphate enters the lakes through domestic wastewater, accounting for the accelerated eutrophication[35]. Increased concentration of phosphate and nitrate nitrogen in lakes has resulted in enhanced productivity[36]. 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 values of sulphate depict a great variation during the study period. The concentration of sulphate varies from 1 mg L^{-1} at site-6 during November, 2010 to the highest concentration of 13 mg L^{-1} during September, 2010 at site-3. The concentration of sulphate in Dal lake fluctuated between 1-6 mg L^{-1} throughout the period of survey. The maximum mean sulphate concentration was the high concentration of sulphate may be due drainage of untreated sewage from houseboats and other Dal dwellers the lake. This agrees with Renn[37] observation on the abundance of ions into the freshwaters. The source of the sulphate could probably the mineral rocks that are present around the lake.

Sediments: The monthly fluctuations of different chemical parameters of sediments at various sites are presented in Fig. 3a-i. The pH values fluctuated from a minimum of 6.2 at site-4 during August, 2010 to the maximum value of 7.8 at site-3 in April, 2011. Bottom sediments are extremely important for nutrient economy of a lake, acting as sink or source of nutrients depending upon the redox condition. In present study low pH of sediments at site-4 could be to the presence of polluted sediments. Conductivity of sediments recorded its lowest value of 112 µS cm^{-1} at site-4 during December, 2010 while highest value of 385 µS cm^{-1} was recorded during April, 2011 at same site. The highest conductivity values in sediments during winter may also be due to large decomposition of organic wastes from floating gardens as compared to spring months. It may also be due to direct drainage of sewage and runoff. As per Clarke and Wharton[38] direct drainage of domestic sewage into water bodies comparatively increases conductivity and other cation concentration in sediment profile. Chloride content of bottom sediments showed wide variation ranged from minimum value 28 mg kg^{-1} each at site-3 (July, 2010) and site-6 (June, 2010) to the maximum value of 300 mg kg^{-1} during February, 2011 at site-5. The organic carbon content during present study showed considerable variations between different sites. It was also point out that during August, 2010 almost all sites depicted higher concentration of organic carbon. The monthly values were fluctuated from lower value of 0.5% at site-1 during December, 2010 to the higher value of 19.0% in August, 2010 at site-4. The chloride content of sediments of Dal lake at site-6 may be attributed to removal of upper sediment layers by mechanical excavation operations it may also be due to low decomposition of organic wastes. While high chloride content at site-5 may be due heavy pollution load in terms of direct dumping of both domestic as well as commercial sewage. According to Cole[39] disposal of sewage and other solid wastes into water bodies may result in high chloride content both in water as well as in sediments. The high concentration of chloride in sediments was directly related to dissolved nutrients and other cations in sediment composition[40]. However, organic matter showed similar trend with organic carbon in its concentrations at various sites. The monthly fluctuation of organic matter recorded its minimum percentage of 0.8% at site-1 in December, 2010 to the maximum of 55.1% at site-2 during August, 2010. The low organic carbon of the lake sediment at site-1 may be due to presence of low decomposition of organic matter and low primary productivity, as there was absence of macrophytes at site-1 and the sediment of composition this site was mostly sand. According to Bianchini *et al*.[41] and Rejmankova and Houdkova[42] the organic carbon of sediments is dependent on supply of organic matter via primary productivity, its subsequent retention in sediments and the rate of microbial decomposition. The high values of organic carbon percentage of sediment samples at site-4 could be attributed to high organic loading from the nearby floating gardens and the process of dumping of organic matter of these floating gardens into the lake bed. Last and Ginn[43] reported high organic carbon content in bottom sediments may be due to increased decomposition of organic wastes the nutrient load on lake bottom were considerably increased.

During the present investigation the total nitrogen of sediments of Dal lake fluctuates from 0.1% at site-1 in different months to the maximum value of 5.3% during February, 2011 at site-2. It was further observed that total nitrogen depicted peak values almost at each site during winter months. High concentration of organic matter and total nitrogen percentage at site-2 could be due to organically polluted sediments. Site-2 was littoral sites having low depth and sediment samples was mostly composed of decomposed organic wastes. In present study nitrate nitrogen depicted wide fluctuation between different sites. The lowest concentration of NO_3-N (0.5 ppm) was recorded at site-6 during June, 2010 while maximum concentration of (15.4 ppm) was recorded at site-4 during December, 2010. It was observed that site-4 depicted higher concentrations of nitrate nitrogen concentration in comparison to other sites during whole study period. Low nitrate in sediments could also be due to presence of low organic matter. As per Eriksson[44] and Wetzel[45] the lowest concentration of NO_3-N could be due to denitrification process and inhibition of nitrification rate by organic matter especially lignin. The high nitrate concentration at site-4 could be due presence of large decomposed organic matter in bottom. The high nitrate content in sediments of site-4 could be due to leaching and surface run off of nitro-phosphate

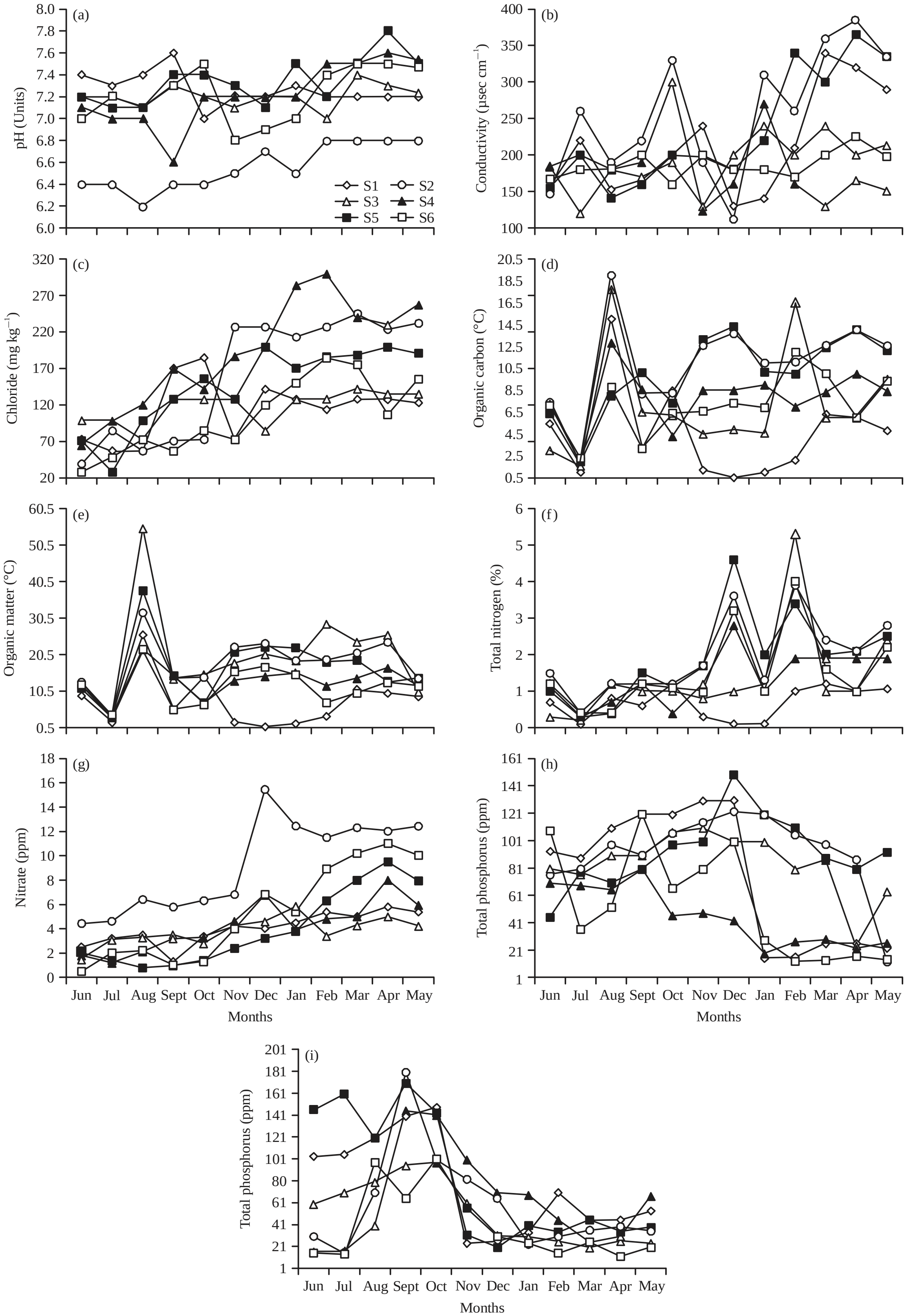

Fig. 3(a-i): Monthly variation in different physico-chemical parameters of water at various sites of Dal lake during 2010-2011

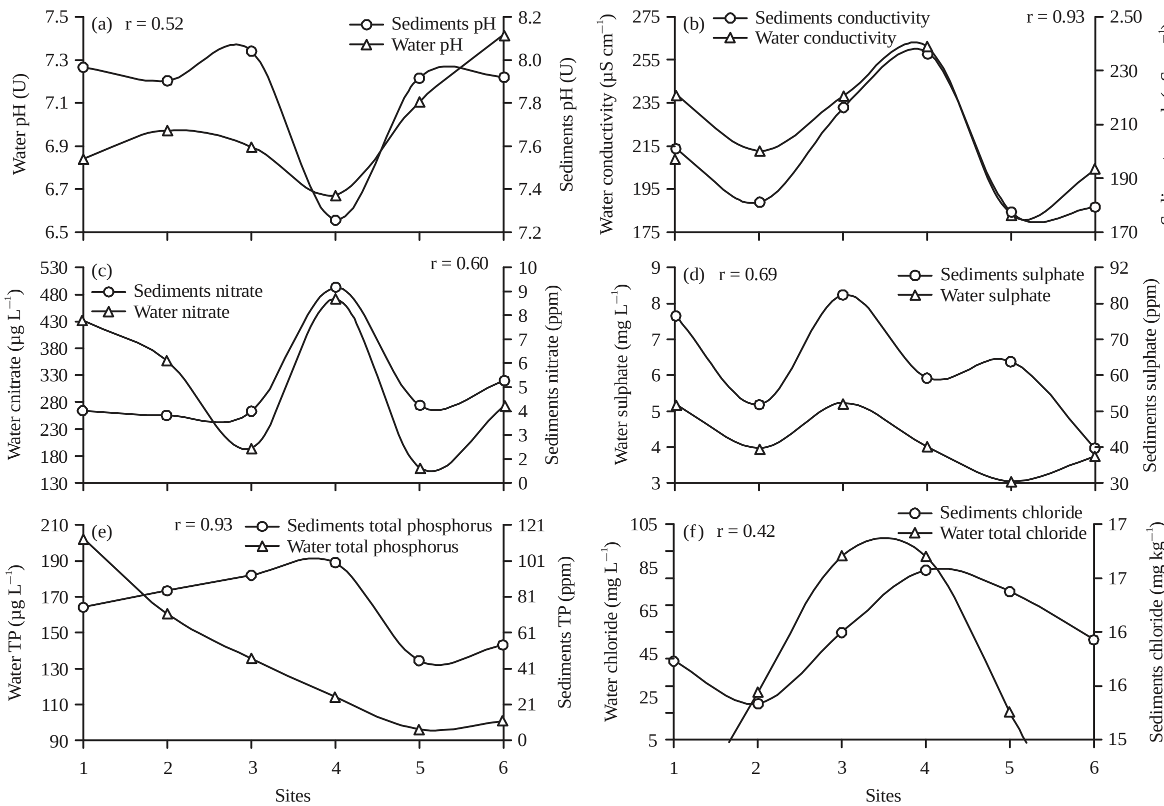

Fig. 4(a-f): (a-d) Significant positive relationship between pH, conductivity, nitrate and sulphate of water and sediment at various sites of Dal lake and (e-f) Insignificant positive relationship between chloride and total phosphorus of water and sediment at various sites of Dal lake

fertilizers from nearby floating gardens into lake as well as from domestic sewage. Jeelani and Shah[46] reported high concentration of NO_3-N in Dal lake and attributed it to input of fertilizers and sewers from catchment areas. Total phosphorus concentration of bottom sediments during the present study depicted wide variations. The monthly value of different sites were fluctuated from a minimum of 13 ppm at site-6 during February, 2011 to the maximum of 149 ppm during December, 2010 at site-3. Sediments are considered as sinks for phosphorous in lakes. Total phosphorus loading resulting from watershed development has long been recognized as an important factor affecting lake trophic status[47-49]. Total phosphorus concentration of bottom sediments during the present study depicted wide variations. The low concentration of total phosphorus at site-6 can be attributed to removal of sediments and decomposed organic material from lake bottom with mechanical excavation operation. In comparison high phosphorus concentrations at site-3 could be due to runoff of nitro phosphate fertilizers and dumping of organic material from nearby floating gardens. Solim and Wanganeo[50] also reported that increased runoff from urban catchments particularly in Srinagar city and increased phosphorus loading from telebal and dachigam catchments were the major factors which were responsible for increase in total phosphorus in Dal lake. Sulphate showed a wide range of variation in its concentration at various sites during the present study period. The monthly values of sulphate of sediment varied from a minimum of 12 ppm at site-6 during April, 2010 to the maximum of 180 ppm during September, 2010 at site-4. High sulphate concentration in sediments of site-4 was mainly attributed to decomposition of organic matter. During whole study period it was observed that farmers dump macrophytes and other weeds into sediments at site-4 for organic manure. The decomposition process of aquatic plants during winter period may result in increase in sulphate concentration in lake sediments.

Relation between surface water and sediment parameters: During the present study various parameters of surface waters and bottom sediments of different sites of Dal lake were correlated. It was observed that various parameters depicted significant positive relation between water and sediment while certain parameters showed intermediate correlation. In present investigation various parameters such as, pH (r = 0.52), conductivity (r = 0.93), nitrate (r = 0.60) and sulphate (r = 0.69) of both surface water and sediments showed significant positive correlation with each other almost at each sites (Fig. 4a-d). It was further observed that chloride (r = 0.42) and total phosphorus (r = 0.40) of surface water and sediments showed intermediate positive relationship with each other (Fig. 4e-f). The positive relation between these parameters almost at each sites during the present study is attributed the polluted status of lake. The positive relationship between major characteristics of surface water and sediments samples from different sites in different basins of Dal lake clearly indicated that both surface water and bottom sediments of the lake were contaminated due to various anthropogenic stresses to the lake system. Direct disposal untreated sewage from inside of the Dal lake such as from houseboats and other human habitation inside the lake as well as from residential areas in vicinity around the lake. Other human activities like dredging, deweeding and regular farming activities by farmers in floating gardens were also responsible for deterioration of both water as well as sediment quality of Dal lake.

CONCLUSION

Based on the results of this study, it was conclude that most of physico-chemical parameters of Dal lake indicated its polluted status. The present experimental data indicate that increasingly high levels of pollution in the water quality and bottom sediments almost at each site along the lake ecosystem due to various human disturbances occurring inner side as well as outside of the lake ecosystem. The mechanical interference in the lake metabolic processes was found to be responsible for bringing about a change in physico-chemical characteristics of both sediment and ambient water. The existing situation of the Dal lake if not controlled properly may cause severe ecological harm and lead it to distrophic status in near future as such, attention is invited to look to the conservation aspects of biological spectrum along with the developmental processes/adopted management strategies.

ACKNOWLEDGMENTS

We are grateful to Director, Center of Research for Development (CORD) and Head P.G. Department of Environmental science, University of Kashmir for facilitating the opportunity to carry out the research study.

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