

Searching for Water Quality Improvement of Dal Lake, Srinagar, Kashmir

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ABSTRACT

The present study was carried out during 2013 to determine the temporal and spatial variations in the water chemistry of Dal Lake, Kashmir and to analyze the variations in the physico-chemical characteristics of lake water with depth. Water samples were collected from five different sites two sites each in Hazratbal and Gagribal basin and one in Nishat basin. Additionally two study sites were analyzed for variations in the physico-chemical characteristics with depth each in Hazratbal SI (D_{3.1m}) and Gagribal basin (SIV (D_{2.2m})). The water chemistry of the lake was found to vary to a smaller extent from one basin to other. The present study revealed that whereas there has been some improvement in the water quality attributable to the installation of sewage treatment facility, however, at some sites the water quality continues to remain deteriorated. The mean concentration of orthophosphorus was found to be about 29 µg/L as compared to 135 µg/L reported earlier in 1996-1997 while as nitrate concentration of about 292 µg/L was observed against the 539 µg/L earlier reported in 2006-07. The main cause of the degraded water quality is the addition of untreated sewage, detergents and run-off from floating gardens. The present findings also highlighted that the lake water can improve provided all the sewage entering the lake is treated, which will in turn depend on how much reduction at various input sources is achieved.

Keywords: Physico-chemical characteristics, water chemistry, sewage treatment, floating gardens.

INTRODUCTION

Nutrient enrichment of lakes is one among the major environmental problems in many countries (Oczkowski and Nixon, 2008). In recent decades, population growth, agricultural practices and sewage run-off from urban areas have increased nutrient inputs many folds than the level of their natural occurrence, resulting in accelerated eutrophication and pollution (Zan et al., 2011).

The lakes form an important and integral

component of fresh water resources of Kashmir valley that over the period of time has revealed signs of ecological deterioration. The Dal lake of Kashmir, situated in the north-east of Srinagar has been a great tourist attraction at international level in the past and still continues to be though only for domestic tourist. However, once beautiful the water body has been the worst victim of the anthropogenic pressures during the second half of the 20th century. Being an urban type lake, municipal and domestic effluents have altered the surface water composition of Dal lake,

leading to increased eutrophication (Hutchinson, 1973). Having a significant ecological and economical role to play for the survivability of the people in Kashmir, the regular monitoring of Dal lake is necessary to restore and sustain it for future. The State Govt. has been handling the sewage problem from last ten years through installation and commissioning of Sewage treatment plants (STPs) by LAWDA (Lakes and Water Ways Development Authority). This has further necessitated having a search for improvement of water quality. It is in this backdrop, the present investigation was carried to search for improvement of water quality on the basis of various physico-chemical characteristics of Dal lake (Fig.1). Also an attempt was made to determine variations in the physico-chemical characteristics with depth.

MATERIAL AND METHODS

The parameters like water temperature, pH and conductivity were measured with digital thermometer, pH metre and conductivity metre respectively while dissolved oxygen (APHA 1998; Wetzel & Likens 2000) was estimated by Winkler's titration method. The parameters like chloride (Argentometric), alkalinity (Titrimetric) and hardness (EDTA titrimetric method) were measured by titrimetry methods while ammonical nitrogen (Phenate method), nitrate (Sodium salicylate), phosphorus (Ascorbic acid), dissolved silica (Molybdate blue), sulphate (Turbidimetric method) and sodium and potassium were analysed by spectrophotometric and flame photometric methods respectively (APHA 1998; Wetzel & Likens 2000).

Study Sites

In order to assess the water chemistry of Dal lake five study sites were selected; two sites in Hazratbal basin, one site in Nishat and two sites in Gagribal basin. For studying the variations in the

physico-chemical characteristics with depth two sites were selected one each in Hazratbal and Gagribal basin.

Site I

This site lies within the Hazratbal basin of Dal lake between geographical coordinates of 34° 08' 00.4" N latitude and 74° 50' 50.9" E longitude. The site is located to the north of the Hazratbal shrine surrounded by human settlements and close to outlet of the Sewage Treatment Plant stationed at Hazratbal. It has proliferous growth of submerged and free floating macrophytes. The free floating macrophytes are especially harvested by some boatmen. At this site water was also collected from the bottom of the lake. The average depth of this site is 3.1±0.2 m. The point at the bottom is here represented as SI (D_{3.1m}).

Site II

This site lies within the Hazratbal basin of Dal lake between geographical coordinates of 34° 07' 31.6" N latitude and 74° 50' 45.8" E longitude. The site is located to the south of the Hazratbal shrine. It is marked by the presence of human settlements on one side. Submerged and free floating macrophytes are abundant.

Site III

This site lies within the Nishat basin of Dal lake between geographical coordinates of 34° 07' 32.6" N latitude and 74° 52' 37.7" E longitude. The site is located close to the aeration pumps installed in the lake just in front of the famous Nishat Garden.

Site IV

This site lies within the Gagribal basin of Dal lake between geographical coordinates of 34° 05' 25.5" N latitude and 74° 51' 05.5" E longitude. It is

located in the centre of the basin. This site is quite open and is visited by tourists in shikaras. At this site also water was collected from bottom of the lake. The average depth of this site is 2.2 ± 0.2 m. The point at the bottom is here represented as SIV ($D_{2.2m}$).

Site V

This site lies within the Gagribal basin of Dal lake between geographical coordinates of $34^{\circ} 05' 55.1''$ N latitude and $74^{\circ} 51' 07.8''$ E longitude. The site is surrounded by a number of house boats and floating gardens. The site also witnesses heavy inflow of tourists.

RESULTS AND DISCUSSION

Physico-chemical parameters of water were analyzed and assessed in order to understand and comprehend the variation of the various parameters amongst the lake basins. The results of various physico-chemical characteristics of the Dal lake water sample are reflected in the Figures (2.1a-z and 2.1.1a-p).

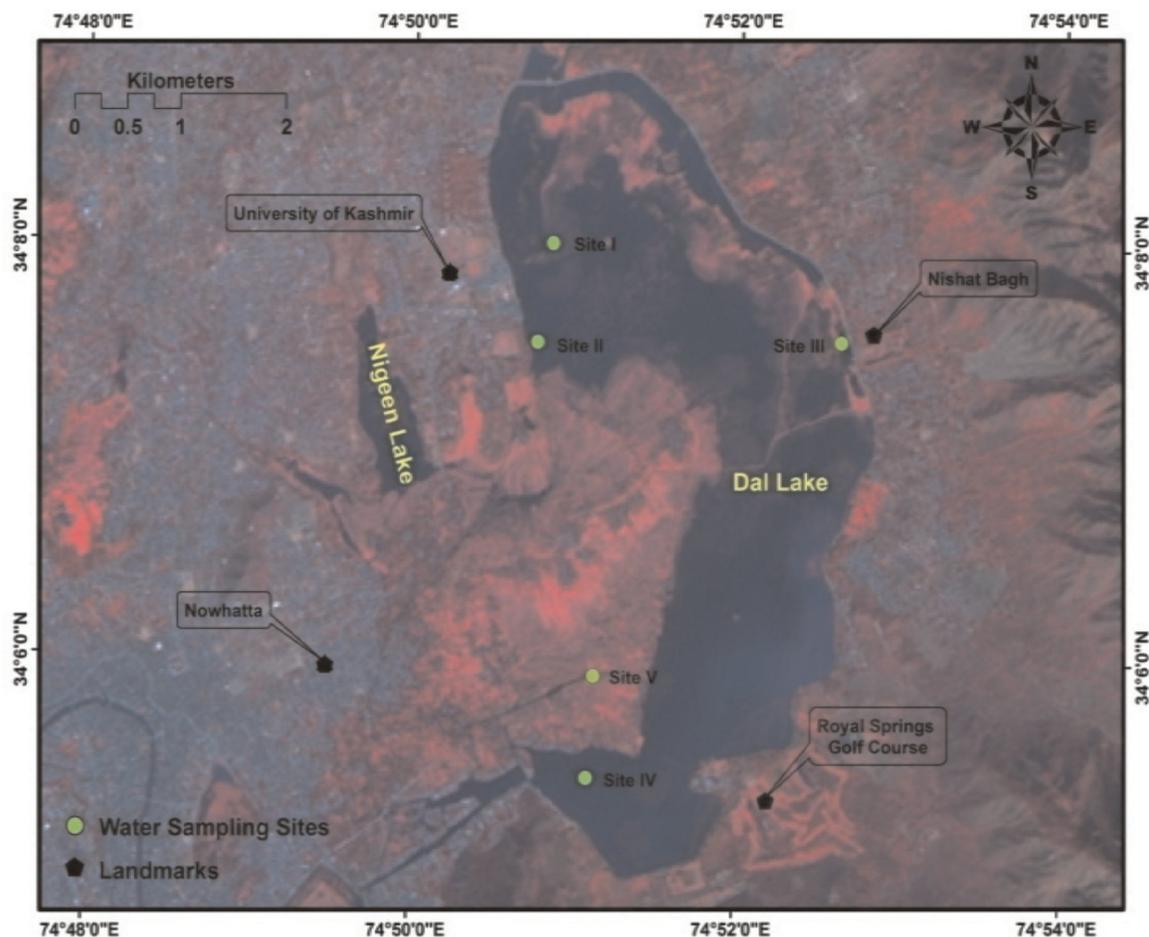
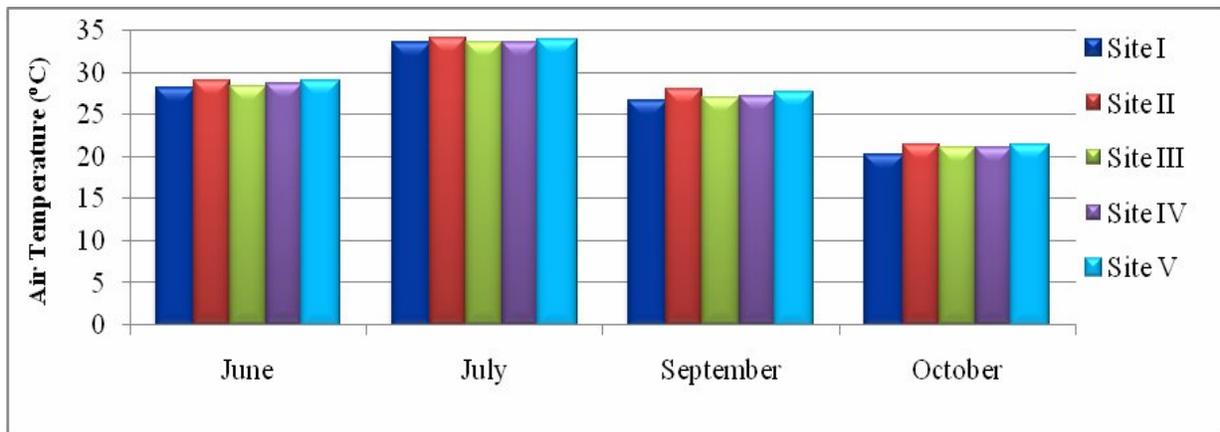
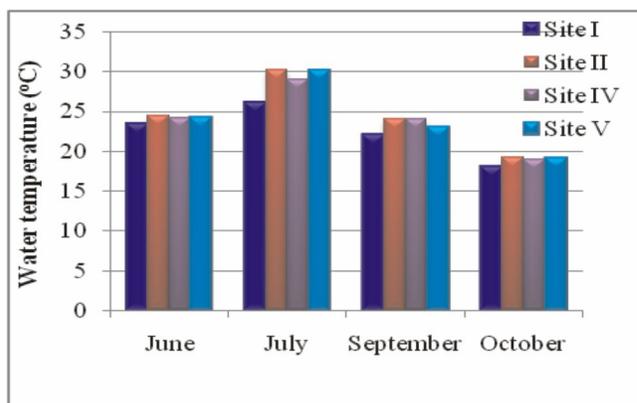


Fig.1. Satellite image of study area and study sites

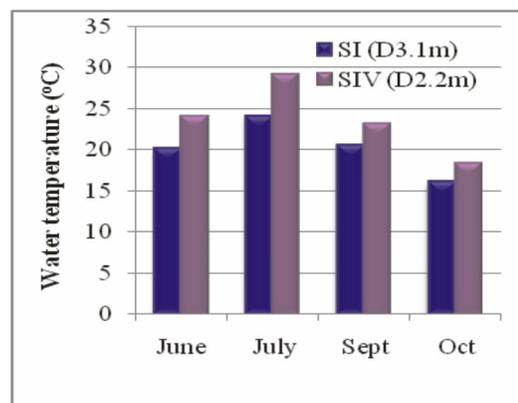
Source: Department of Earth Sciences, University of Kashmir



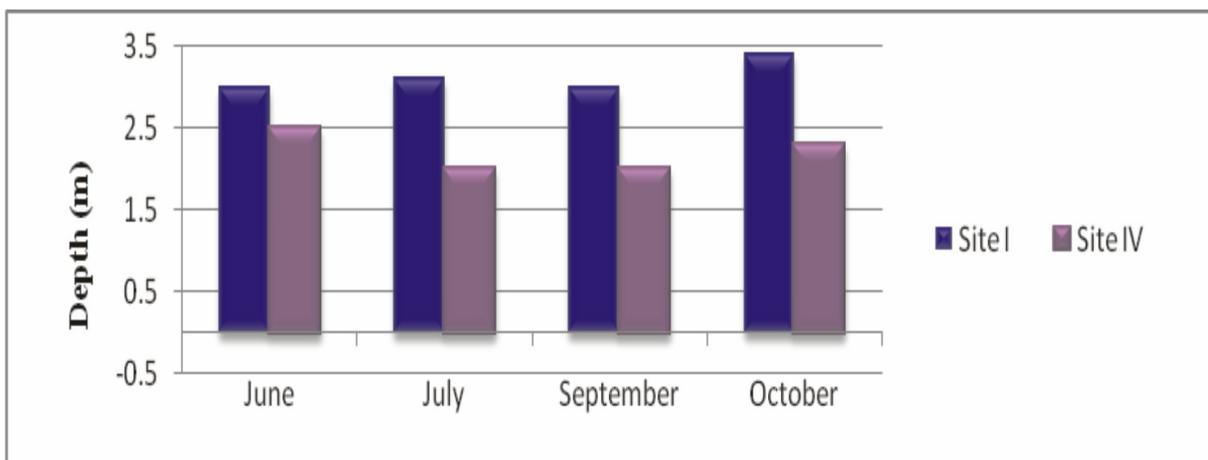
(Fig.2.1a Monthly variations in air temperature (°C) at different study sites during June 2013 - October 2013)



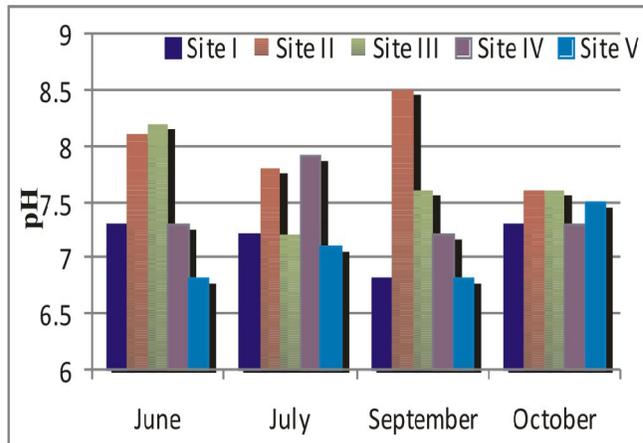
(Fig.2.1b. Monthly variations in water temperature (°C) at different study sites during June 2013-October 2013)



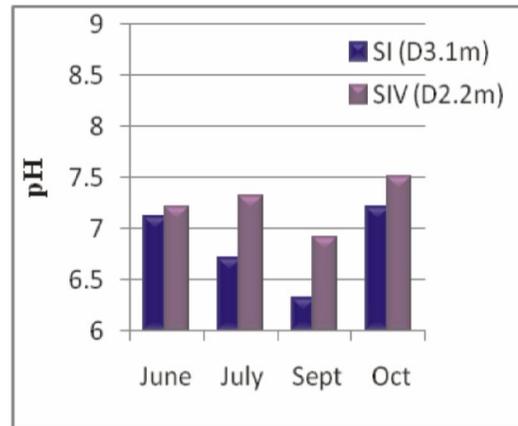
(Fig.2.1c. Monthly variations in water temperature (°C) at different depths during June 2013-October 2013)



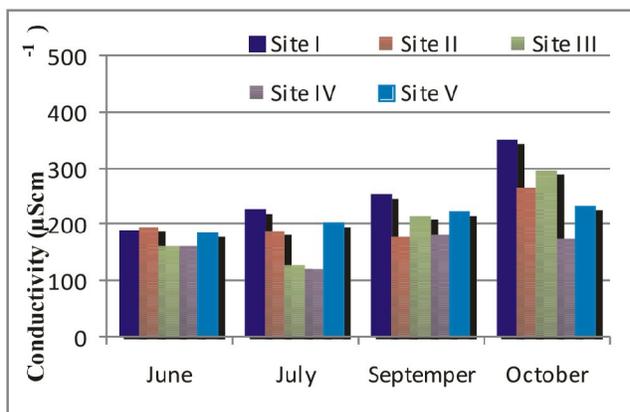
(Fig.2.1d. Monthly variation in depth (m) at study sites I and IV during June 2013 - October 2013)



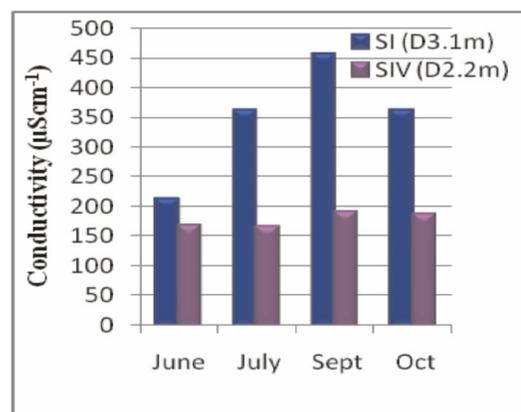
(Fig.2.1e.Monthly variations in pH at different study sites during June 2013- October 2013)



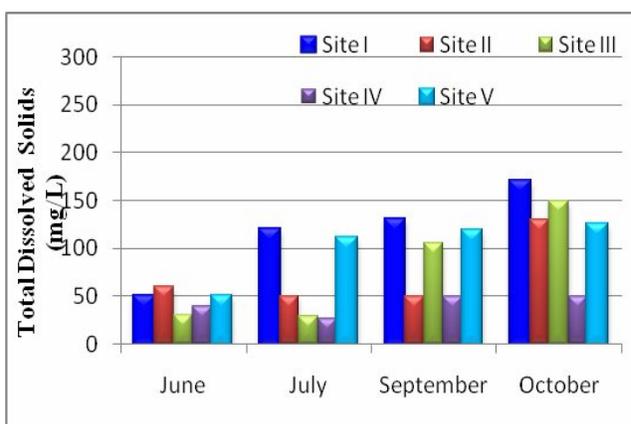
(Fig.2.1f.Monthly variations in pH at different depths during June 2013- October 2013)



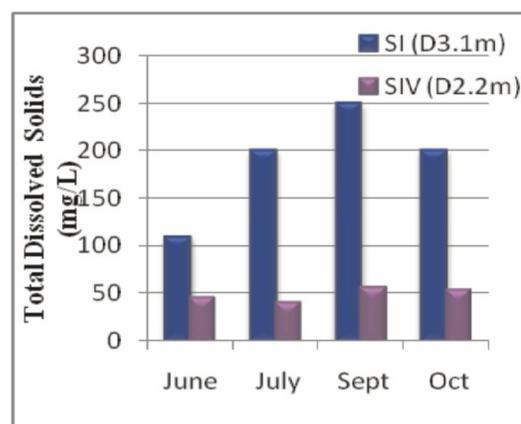
(Fig.2.1g. Monthly variations in conductivity (µScm⁻¹) at different study sites during June 2013- October 2013)



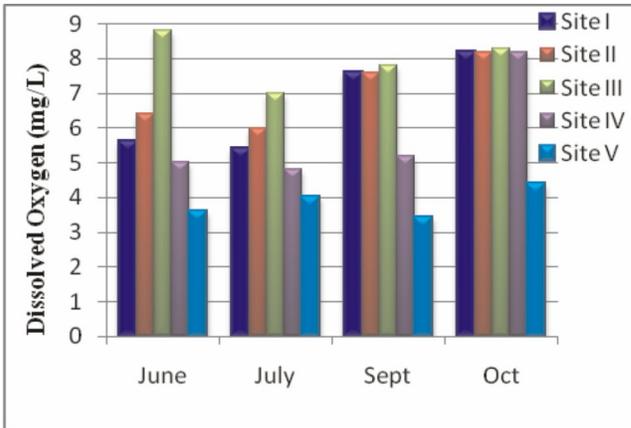
(Fig.2.1h.Monthly variations in conductivity (µScm⁻¹) at different depths during June 2013- October 2013)



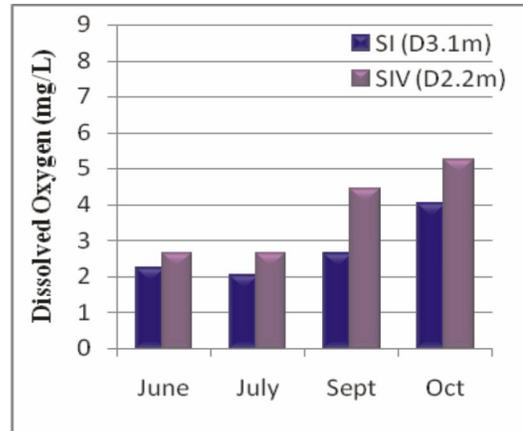
(Fig.2.1i.Monthly variations in total dissolved solids (mg/L) at different study sites during June 2013 - October 2013)



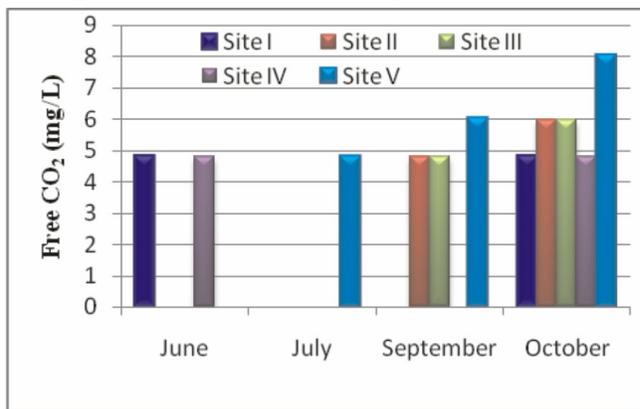
(Fig.2.1j.Monthly variations in total dissolved solids (mg/L) at different depths during June 2013 - October 2013)



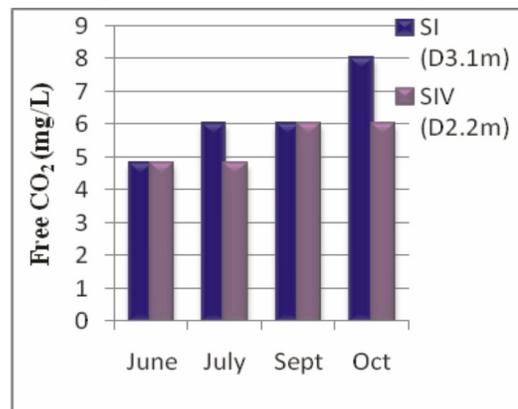
(Fig.2.1k.Monthly variations in dissolved oxygen (mg/L) at different study sites during June 2013- October 2013)



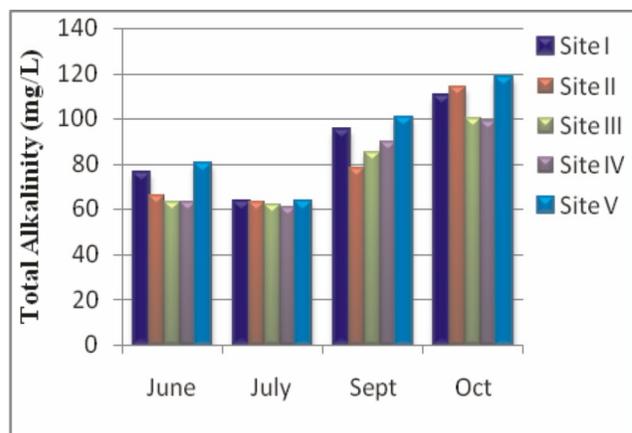
(Fig.2.1l.Monthly variations in dissolved oxygen (mg/L) at different depths during June 2013- October 2013)



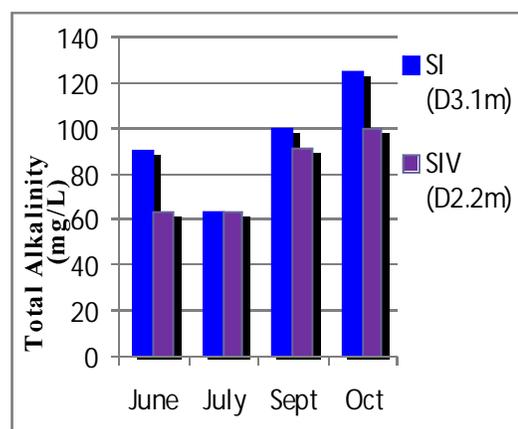
(Fig.2.1m.Monthly variations in free CO2 (mg/L) at different study sites during June 2013- October 2013)



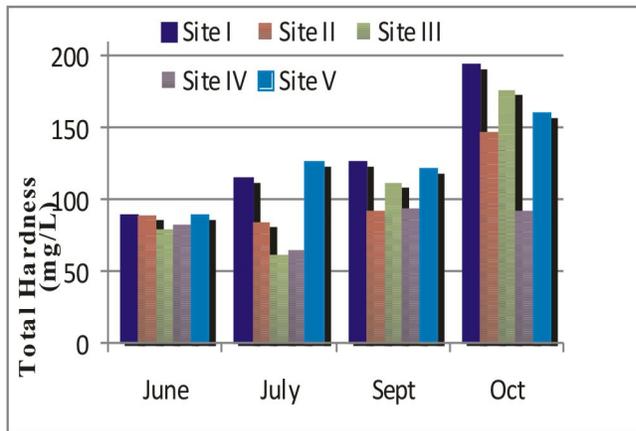
(Fig.2.1n.Monthly variations in free CO2 (mg/L) at different depths during June 2013- October 2013)



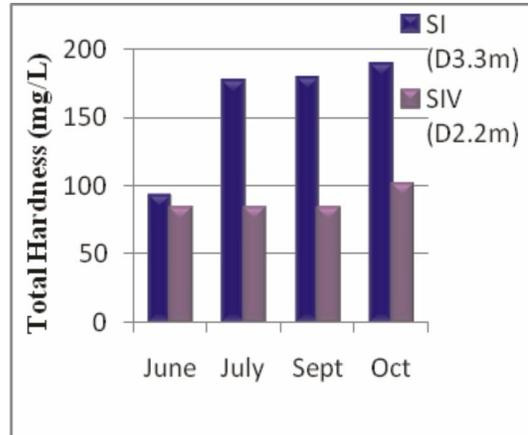
(Fig.2.1o. Monthly variations in total alkalinity (mg/L) at different study sites during June 2013- October 2013)



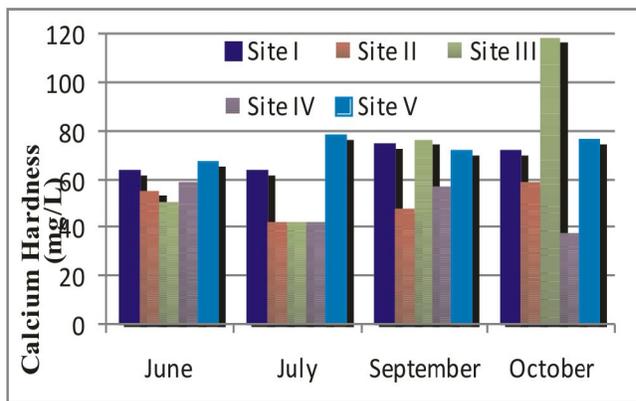
(Fig.2.1p.Monthly variations in total alkalinity (mg/L) at different depths during June 2013-October 2013)



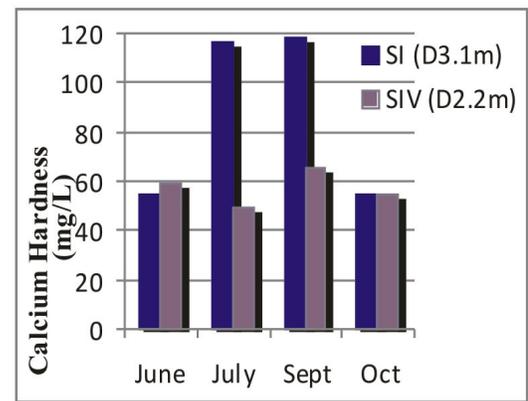
(Fig.2.1q. Monthly variations in total hardness (mg/L) at different study sites during June 2013-October 2013)



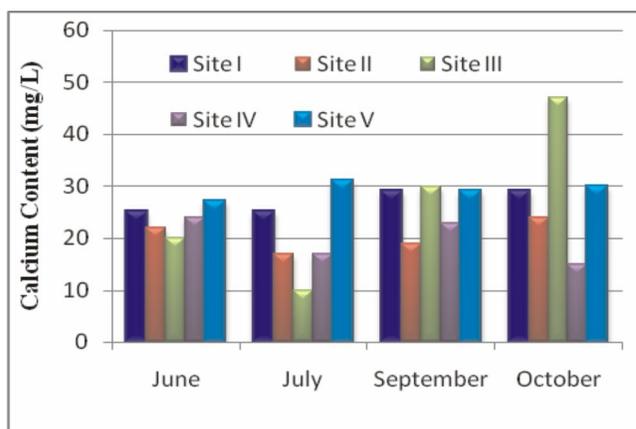
(Fig.2.1r. Monthly variations in total hardness (mg/L) at different depths during June 2013- October 2013)



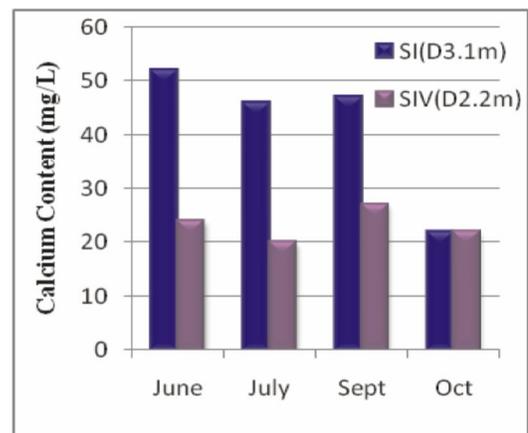
(Fig.2.1s. Monthly variations in calcium hardness (mg/L) at different study sites during June 2013- October 2013)



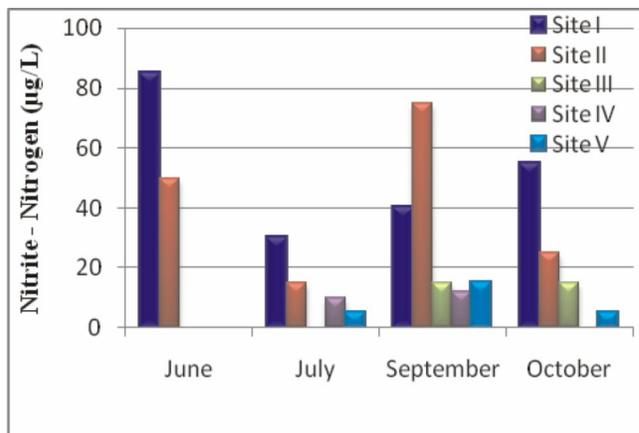
(Fig.2.1t. Monthly variations in calcium hardness (mg/L) at different depths during June 2013- October 2013)



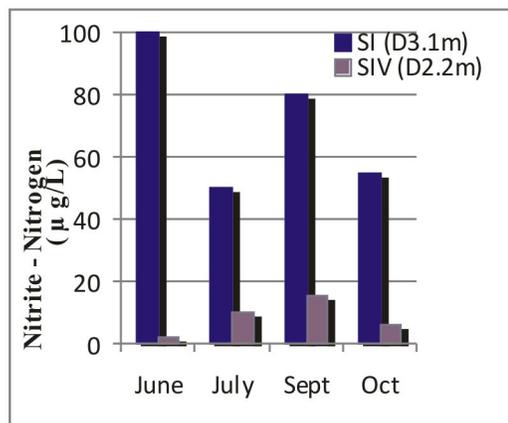
(Fig.2.1u. Monthly variations in calcium content (mg/L) at different study sites during June 2013- October 2013)



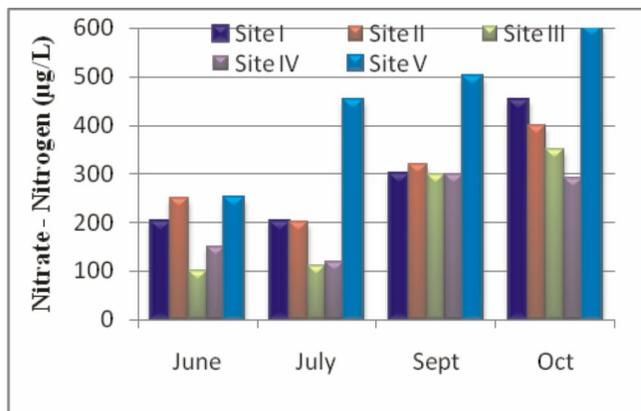
(Fig.2.1v. Monthly variations in calcium content (mg/L) at different depths during June 2013-October 2013)



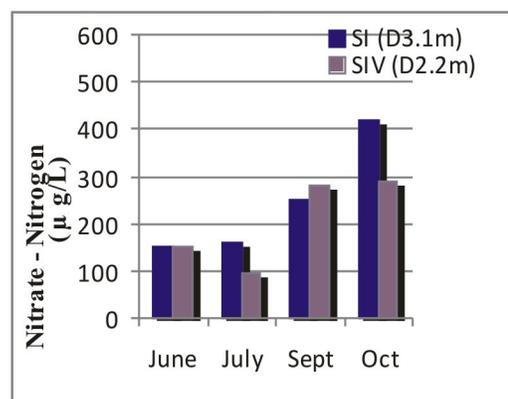
(Fig.2.1.1i. Monthly variations in nitrite-nitrogen (µg/L) at different study sites during June 2013- October 2013)



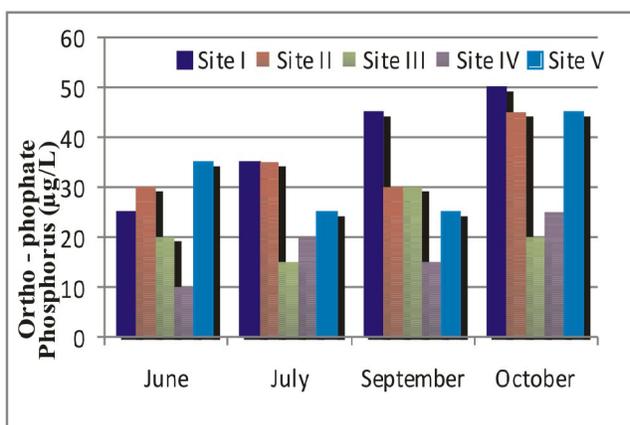
(Fig.2.1.1j. Monthly variations in nitrite-nitrogen (µg/L) at different depths during June 2013-October 2013)



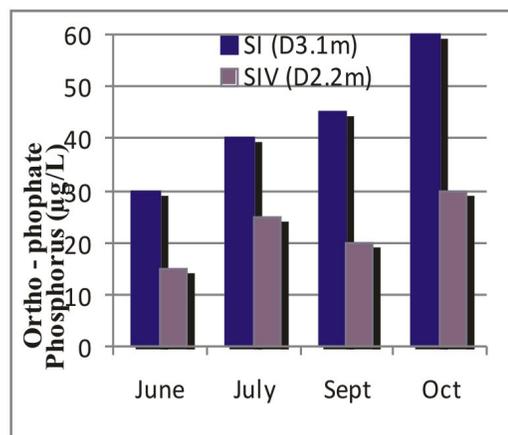
(Fig.2.1.1k. Monthly variations in nitrate-nitrogen (µg/L) at different study sites during June 2013- October 2013)



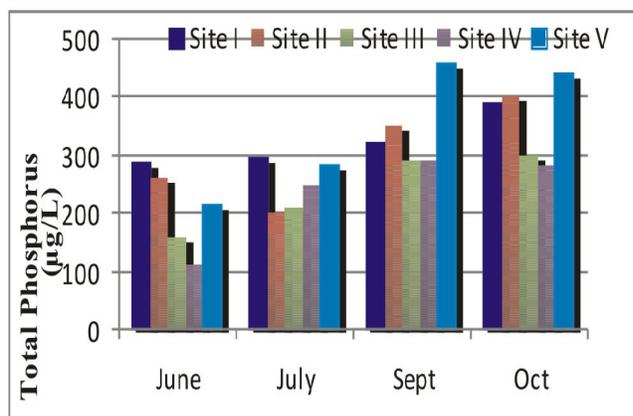
(Fig.2.1.1l. Monthly variations in nitrate-nitrogen (µg/L) at different depths during June 2013- October 2013)



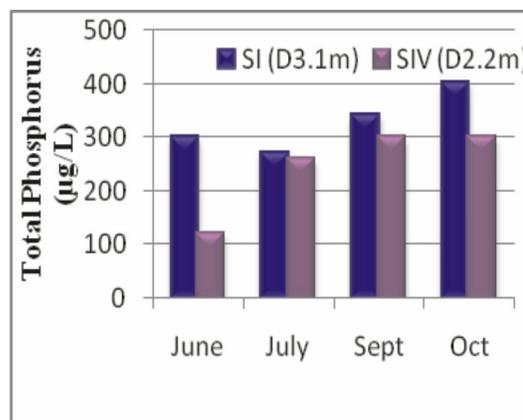
(Fig.2.1.1m. Monthly variations in ortho-phosphate phosphorus (µg/L) at different study sites during June 2013- October 2013)



(Fig.2.1.1n. Monthly variations in ortho-phosphate phosphorus (µg/L) at different depths during June 2013 - October 2013)



(Fig.2.1.1o. Monthly variations in total phosphorus (µg/L) at different study sites during June 2013-October 2013)



(Fig.2.1.1p. Monthly variations in total phosphorus (µg/L) at different depths during June 2013- October 2013)

The minor variations in air and water temperature was found to be a result of day time differences in recording temperature, depth apart from seasonal effect. The pH recorded during the present study (6.8-8.5) indicates the alkaline nature of the lake (mean value 7-8). The monthly pH values did not show significant variations as the waters stand well buffered due to presence of calcium rich rocks (lacustrine deposits) in the catchment areas. The pH at bottom was lower than surface at sites I and IV mainly due to decomposition of organic matter at bottom leading to liberation of acids as byproducts of decomposition (Kaul and Handoo, 1980). Conductivity was found to fluctuate from a minimum of $122\mu\text{Scm}^{-1}$ at Site IV in July to a maximum of $348\mu\text{Scm}^{-1}$ at Site I in October 2013. The relatively lower values of conductivity during summer could be related to the uptake of ions by autotrophs during their peak growth in summer and also the dilution factor in peak flow (Pandit and Rather, 2006) while higher values in autumn can be attributed to low discharge in lean flow and decomposition of organic matter. Relatively lower conductivity values were observed in the surface waters as compared to bottom samples at sites I and IV, which seems to be due to assimilation of ions by photosynthetic organisms

and the mineralization of organic matter under the influence of reducing conditions prevailing at the bottom of lake (Motimer, 1941).

TDS values during the study period ranged between 27 mg L^{-1} recorded at Site IV in July 2013 and 170 mg L^{-1} being recorded at Site V in October 2013. The values of TDS were reported lower in summer which seems to be attributed to the consumption of ions by aquatic plants and the rate of evaporation. Site I and V was recorded to have highest TDS concentration that can be attributed to the domestic sewage and floating gardens. Higher TDS values at bottom than in surface layers at study sites I and IV could be attributed to higher concentrations of HCO_3^- which are largely balanced by equivalent increases in Ca^{2+} , Mg^{2+} , and Fe^{2+} concentrations (Crowe et al., 2008).

Dissolved oxygen was found to be higher during autumn as compared to summer due to lower water temperature in autumn. The low values of DO in summer are due to low dissolution at high temperature and is also due to use by decomposers in the water body. The lower values of dissolved oxygen observed at Site V could be due to cumulative effect of human activities like dumping of organic wastes from floating gardens

where oxygen is used in decomposing these organic wastes. The higher values of dissolved oxygen observed at Site III could be due to the aeration pumps installed very close to the study site. The lower values of dissolved oxygen in the bottom layers as compared to surface layers at sites I and IV can be explained as a result of biological oxidation of organic matter, both in water and especially at sediment-water interface, where bacterial decomposition is predominant. The amount of free CO₂ in water usually shows an inverse relationship with oxygen (Radhika et al., 2004). With the onset of warmer months, the rate of photosynthesis increases and the free CO₂ content gradually decreases. The minimum values were, thus, recorded during July when the macrophytes attained luxuriant growth. The higher values of free CO₂ observed at Site V could be due to the high rate of decomposition of organic wastes dumped from floating gardens where CO₂ is released during decomposition of these organic wastes. The bottom waters were observed to contain higher quantities of free carbon dioxide at sites I and IV as a result of decomposition of organic matter, indicating the productive nature of the lake.

The total alkalinity was found to be highest during October and lowest during July which may be associated with increased growth and multiplication of macrophytes and phytoplankton during summer which converts bicarbonates to carbonates and hence reduces the total alkalinity in the surface layers. The values for alkalinity were greater in bottom as compared to surface layers at sites I and IV. This can be related to the re- entering of carbonates from sediments into the water by conversion into bicarbonates due to the presence of large quantity of free CO₂ concentration in these layers (Ebel and Koski, 1969 and Yousuf, 1979).

The monthly range of hardness concentration

was from a minimum of 62 mg L⁻¹ at Site III in July 2013 to a maximum of 193 mg L⁻¹ at Site I in October 2013. On the basis of their monthly average values of hardness all sites belonged to the medium hard category (Sawyer and McCarty, 1967).

Sodium content of the water samples ranged from 0.5 mg L⁻¹ at Sites IV and V in June to 9.5 mg L⁻¹ at Site III in October. Low sodium values in the present study can be related to the rich limestone lithology of the catchment areas (Awad et al., 1997). The sodium concentration did not show significant variations between surface and bottom samples at sites I and IV. The lower values of potassium can be due to highly stable nature of potassium bearing fixation in clay minerals if formed due to weathering or use in biological systems (Hem, 1985). The exceptionally high value of potassium at Site V in the month of September can be attributed to the use of potash fertilizer in the floating gardens present near the site. This assumption further gains support by the very high chloride concentration recorded at the same site in the same month. The potassium concentration did not show significant variations between surface and bottom samples at sites I and IV.

Chloride content in water is usually regarded as an indication of organic load of animal origin from the catchment area (Kumar et al., 2004). Its increased concentration is considered as an indicator of eutrophication and pollution due to sewage (Chourasia and Adoni, 1985). The concentration of chloride during the present study did not show any significant temporal and spatial variations except at Site V which in the month of September was reported to have very high value of chloride concentration. This can be attributed to the use of potash fertilizer (potash = potassium chloride) in the floating gardens present near the site. This assumption further

gains support by the very high potassium concentration recorded at the same site in the same month. The chloride concentration did not show any significant variations between surface and bottom samples at sites I and IV.

Ammonical-nitrogen during the present investigation fluctuated from their minimal values in July to maximum in October. The higher values in the month of October may be due to increased decomposition of organic matter in autumn. The lower values in summer may be due to the photosynthetic assimilation by autotrophs during their growth in late spring and early summer (Pandit, 1999). Among different sites, Site I recorded the highest values of ammonical-nitrogen that can be related to the decomposition of organic matter coming from the nearby human settlements. The concentrations of ammonia were higher at bottom than in surface layers at study sites I and IV that can be related to the lower oxygen levels at bottom which prevents ammonium oxidation to nitrate. Nitrite-nitrogen is extremely toxic to aquatic life, however, is usually present only in trace amounts in most natural freshwater systems because it is rapidly oxidized to nitrate. The low concentration of nitrite-nitrogen ($\text{NO}_2\text{-N}$) in the present lake signified the low rate of denitrification. Temporal variations in nitrite-nitrogen concentrations were irregular. The highest nitrite levels at Site I and Site II can be attributed to the domestic sewage flowing into this site from the nearby human settlements. The nitrite concentrations were higher at bottom than in surface layers at sites I and IV which can again be related to lower oxygen concentrations at the bottom.

Monthly nitrate-nitrogen concentration fluctuated between a minimum of $100 \mu\text{g L}^{-1}$ at Site III in June, 2013 and a maximum of $600 \mu\text{g L}^{-1}$ at Site V in October, 2013. Lower nitrate values in summer can be attributed mainly to its sequestration by phytoplankton (Quiros, 2003).

Higher nitrate-nitrogen values at Site V could be due to the surface run off of nitro-phosphate fertilizers from the floating gardens present near this site and also to the domestic sewage coming from nearby house boats. The lower values of nitrate-nitrogen concentration at the bottom of sites I and IV could be related to the lower D.O concentration at the bottom and it is supported by the increase in ammonium-nitrogen, as enough oxygen was not present for the transformation of ammonia to nitrate (Boyd and Tucker, 1998).

In the present study, low values of ortho-phosphate were recorded which can be attributed to the formation of an insoluble calcium-phosphate complex. Such a phenomenon functions as scavenger of some inorganic nutrients and also acts as a removal agent of dissolved organic matter by absorption (Otsuki and Wetzel, 1974). The ortho-phosphate concentrations did not show any significant temporal variation. Its concentration was noticed to be highest ($50 \mu\text{g L}^{-1}$) at Site I that can be attributed to the domestic sewage entering this basin from the nearby human settlements. The higher values of ortho-phosphate concentration at the bottom of sites I and IV may be due to its increased release from sediments.

The minimum value of total phosphorus $110 \mu\text{g L}^{-1}$ was recorded at Site IV in June 2013 against a maximum value of $440 \mu\text{g L}^{-1}$ at Site V in October 2013. According to Cole, (1975) the high concentration of phosphate in water is due to decay and subsequent mineralization or decomposition of dead organic matter and surface run-off. The values for total phosphorous concentration were lower in summer than in autumn. The low concentration of phosphate phosphorus in summer is attributed to its use and uptake by the macrophytes (Kaul et al., 1978; Pandit, 1984, 92). The total phosphorous concentration was highest at Site V that can be

attributed to the domestic sewage and detergents coming from the large number of houseboats present close to this site and also may be due to the use of nitro-phosphate fertilizers in the floating gardens located near this site. Site I also recorded higher values of total phosphorus that can be attributed to the decomposition of organic matter entering the site from the nearby human settlements. Hutchinson (1957) also pointed out that water contaminated with sewage had more phosphate. The total phosphorus concentrations were higher at bottom than in surface layers at sites I and IV that can be due to the remobilization of P from sediments (Bluszcz et al., 2008).

CONCLUSIONS

The comparative assessment of present and past data (Table 1) available on the water chemistry

revealed some improvement in water quality attributable to the installation of sewage treatment facility. However some sites like Sites I, II and V witnessed same quality as reported earlier which can be as a result of failure of arresting the causal factors in the vicinity of these sites.

The effect of domestic sewage, detergents and large inputs of organic matter could be clearly manifested at Site I that was noticed to have highest values for conductivity, total hardness, magnesium hardness, magnesium content, ammonia, nitrite and total dissolved solids. The elevated levels of total alkalinity, calcium hardness, calcium content, chloride, nitrate, total phosphorus and potassium at Site V indicates the effect of run-off from floating gardens and untreated sewage from houseboats.

Table.1: Water quality changes in Dal Lake during last forty years

Year Parameters	1974-1976*	1985*	1996-1997*	2006-2007*	2013 (P.S)					
					Site I	Site II	Site III	Site IV	Site V	Mean
Dissolved oxygen mg/l	10.25	8.7	8.6	6.8	6.7	7.0	7.9	5.8	3.8	6.2
Total alkalinity mg/l	69.5	85.6	104	115	86	80	78	78	90	82
Nitrate nitrogen µg/l	481	483	272	539	288	293	215	215	450	292
Ammonical nitrogen µg/l	23.6	37.0	362	438	92	58	54	31	40	55
Ortho phosphate µg/l	65.5	80.5	135	93	39	35	21	18	33	29
Total phosphorus µg/l	187.8	211.5	768	615	323	303	241	233	348	290
Total dissolved solids mg/l	30.2	32.2	119.8	20	118	73	79	42	101	83

*(c.f. Abubakr and Kundangar, 2009) P.S= Present study

Since the lake is generally shallow and no thermal stratification is yet reported. The low concentration of dissolved oxygen and high values of conductivity, TDS, free CO₂, total alkalinity, total hardness, calcium hardness, magnesium hardness, ammonia, nitrite, nitrate and total phosphorus at the bottom of the Site I is an indication of nutrient enrichment.

The present findings reveal that the lake water can improve provided all the sewage entering the lake is treated, which will in turn depend on how much reduction at various input sources is achieved. The key to the success will be how best the authorities will successfully treat autochthonous sewage added to the lake continuously. The authors further believe that the study is of preliminary nature and there is more scope to use large data sets to reach on the concrete conclusion regarding the improvement of water quality in Dal lake.

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