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Current status of nutrient load in Dal Lake of Kashmir Himalaya

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Abstract
Lake water receives substantial concentration of nutrients (Nitrogen and Phosphorus) due to growing anthropogenic pressure. Current status and trend of nutrients in Dal Lake were investigated in this study. The results showed that highest concentration of N-NO_3 (1.128 mg/L) at Shalimar Ghat in summer and lowest (0.078mg/L) was at Dugg Park in autumn. The overall season wise N-NO_3 concentration during the entire investigation was determined 0.558 mg/L in summer and 0.180 mg/L in autumn respectively. The highest 0.075 mg/L phosphates (PO_4^{-3}) were found at Shalimar Ghat in summer and lowest 0.011 mg/L at Dugg Park in autumn. The overall season wise PO_4^{-3} was found maximum (0.047 mg/L) in summer and minimum (0.030 mg/L) in autumn. The concentration of N-NO_3 and PO_4^{-3} with respect to sites and seasons were observed statistically significant at ($p \leq 0.05$) confidence limit. In general, the nutrient concentration was found highest at Shalimar Ghat followed by Ashai Bagh Bridge and least at Dugg Park. Currently lake is in mesotrophic condition; however the growing concentration of these nutrients into the lake due to anthropogenic activities could favour eutrophic condition.

Keywords: Nitrate-Nitrogen, Phosphates, Eutrophic, Dal Lake, Anthropogenic pressure, Sewage

1. Introduction
The production of wastewater from human settlements as sewage amounts roughly 80% of the total domestic water consumption. Owing to uncontrolled discharge into human environment, the huge quantities of municipal wastewater eventually have a tendency of causing substantial disposal problem (Shafiq-ur-Rehman, 2010) [26]. There are many problems associated with uncontrolled urban population growth such as, atmospheric pollution, soil pollution, water pollution, and depletion of natural resources, increase of natural and manmade risks and other negative environmental effects (Arku, 2009) [4]. Besides these, floods can alter the normal physico-chemical properties of soils and water. The relationship between population growth and environmental pollution is inevitable. The more people that live in a given area the more water, resources and energy they need and the more pollutants, garbage, and solid wastes they pump out (McNeil, 2001) [18].

A healthy environment is essential for any organism, since life depends upon the persistence of an appropriate exchange of vital substances and energy connecting the organisms and its environs. Water has a unique place on planet as it supports life on earth. Quality of water is important for drinking, irrigation, fish production, recreation and other purposes. The physico-chemical characteristics help in understanding the structure and function of a particular water body in relation to its habitants. The proper balance of physical, chemical and biological properties of water, for example in lake is an essential factor for successful production of aquatic resources (Hutchison, 1957) [13]. The assessment of physico-chemical properties of water gives a proper indication of the quality status, productivity and sustainability of a water body (Djukie *et al.,* 1994; Masood *et al.,* 2015) [8, 17]. The physico-chemical characteristics like nitrate and phosphate, are pivotal for the sustainability of lakes that support number of ecological activities and functions (Oluyemi *et al.,* 2010) [23]. Nutrient status of water are of extreme significance in the distribution of aquatic life and also in the breeding of aquatic life and control chemical, biological and physical processes taking place in the environment. However, increased human population, industrialization, use of fertilizers in the agriculture and anthropogenic activity enormously uploads different harmful contaminants that alter the normal physicochemical characteristics of lake ecosystems. Industrial development resulted in the generation of waste effluents into the water system causing pollution (Fakayode, 2005) [11]. High levels of pollutants mainly organic matter in lake water cause an increase in biological oxygen demand (Kulkarni 1997) [16], chemical oxygen demand, total dissolved solids, total suspended solids, alkalinity, hardness, and other physicochemical parameters which degrades stable lake ecosystem and damages to all aquatic life especially fish, zooplankton and zoo benthos by way of deceasing dissolved oxygen and increase other harmful substances.

Materials and Methods

Study Area Description

The Dal Lake is an urban lake that is integral to Kashmir tourism and recreation, though it sustains commercial benefits from fisheries, water plant harvesting and vegetable production in floating gardens. It has been an epitome of the Kashmiri Civilization from times immemorial. Human interference by way of settlement in the lake to facilitate pedestrian traffic and establishment of lake tourism by providing floating residences (house-boats) got accelerated. The Dal lake, located in Srinagar at latitude 34^{O} 07′ N; longitude 74^{O} 52′ E; elevation1583 m above mean sea level, the summer capital of Jammu and Kashmir. The length of the lake is 7.44 kilometres (4.62 miles) with a width of 3.5 kilometres (2.2 miles). The average elevation of the lake is 1,583 metres (5,190 ft). The depth of water varies from 6 metres (20 ft) at its deepest in Nagin Lake to 2.5 metres (8.2 ft), the shallowest at Gagribal.

The lake is in the foothill formations of the catchment of the Zabarwan mountain valley, a subsidiary of the Himalayan range, which surrounds it on three sides. It lies to the east and north of Srinagar city and is integral to the city. It receives an average annual rainfall of 655 millimetres (25.8 inches) in the catchment that occurs during summer and also in the winter season. The lake experiences temperatures in the range of 11–1 °C (52–34 °F) during winter and 12–30 °C (54–86 °F) during the summer season (Sharad *et al.,* 2007) [27]. The lake freezes when temperatures drop to about −11 °C (12.2 °F) during severe winter. Based on its thermal behavior, the lake has been typified as warm monomictic under the sub-tropical lake category. Spring sources are also mentioned as contributors to the flow, though no specific data is available to quantify their contribution. Further, the silt load has been estimated at 80,000 tonnes per year with 70% contribution from the Telbal Nallah, out of which the amount that settles in the lake is assessed to be 36,300 tonnes (ENEX, 1987) [10]. The study area and study sites area shown in Fig. 1. For the study, the entire lake was divided into three different sampling sites (Shalimar Ghat, Ashai Bagh Bridge and Dugg Park) falling in three different locations. The sampling sites were selected on the basis of inlet source of water, social geography, settlements, agricultural inputs, population pressure, and outlet system of water in the lake ecosystem. The sampling sites have been divided into three experimental sites:

Sampling Stations

Shalimar Ghat (Inlet location)

Geographically this site is located at 34°08′42.27″ N latitude and 74°51′06.45″ E longitude with an average elevation of 1583 meters above mean sea level. This location is the main inlet water source of Dal Lake and has many residential structures, floating vegetable gardens, agricultural paddy fields in and around it. Dachigam-Telbal Nallah with perennial flow is the main stream which feds the lake with water resources. There are other small streams namely Pishpuw and Meerakshah which flows mostly through paddy fields and residential areas and finally opens into lake. The water qualities in these streams are deteriorating with direct discharge of untreated sewage, agriculture runoff, commercial huts and carries solid wastes, vehicle washing and with commercial activities. The Habbak residential area has a sewage treatment plant that discharges its effluents into the lake.

Ashai Bagh bridge (Outlet location)

This site is located at 34° 06′ 50.56″ N latitude and 74° 50′12.72″E longitude with an average altitude of 1,586 meters above sea level. This site is the outlet of west side of the Dal Lake through which the water flows out to the adjacent Nigin Lake. The site is surrounded with residential houses, hotels, small commercial units, National Institute of Technology (NIT) and *Salix* sp. (Willow) and poplar trees. There are number of Houseboats resting in this location. Floating vegetable gardens are also located in this region. This region is also disturbed with sewage water pollution and anthropogenic activities.

Dugg Park (Control site)

Dugg Park is located at the northeast part of the Dal Lake, geographically at 34° 08′ 51.80″ N latitude and 74° 50 ′50.69″ E longitude with an average altitude of 1,584 meters above sea level. This region receives water from Telbal Nallah and acts as sediment basin to reduce suspended particles load prior to enter into the main lake. This location is least disturbed as for as anthropogenic pressures are concerned.

Sample collection

Water samples from three different selected sites *viz.,* Shalimar Ghat (inlet), Ashai Bagh Bridge (outlet) and at Dugg Park (control site) of Dal Lake and in different seasons (spring, summer and autumn in 2015-2016) were collected in 2000 ml Poly Ethylene (PET) cans, which were carefully pre acid washed, cleaned and rinsed three to four times with distilled water (APHA, 2005) [3]. All the samples were collected just 30 cm below the surface of lake water by dipping the open end of each cleaned can before turning it upright to fill. During collection of samples, extreme care was exercised to avoid contamination of the parts of bottle and water samples were collected in replicates (15) from each selected site during the morning between 8.30 a.m. to 10.30 a.m. on sunny days. All samples were labeled with respect to site, date and season. For physico-chemical analysis, water samples were brought to the laboratory and were immediately analyzed. The location of sampling sites and study area (Dal Lake) are depicted in Fig.1.

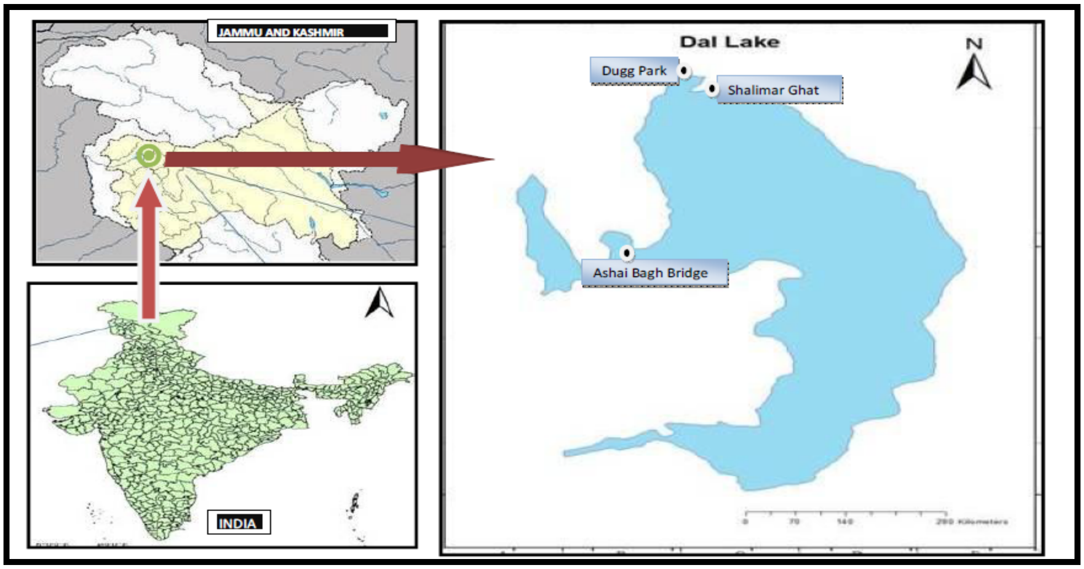

Fig 1: Map of study area (Dal Lake) and study sites

Statistical analysis

Statistical analysis was carried out by using Microsoft excel 2007 and IBM-SPSS-Statistic software package (version 20). Analysis of variance (ANOVA) technique was used to compare the variation in between seasons and sites in water. Results were demonstrated in terms of mean±SE (Standard Error).

Results

The maximum mean nitrate-nitrogen ($N\text{-}NO_3$) 0.595±.04 mg/L was found at Shalimar Ghat followed by 0.185±0.01 mg/L at Ashai Bagh Bridge and minimum (0.094±0.01 mg/L) was recorded at Dugg Park in spring (Table 1). The highest $N\text{-}NO_3$ was observed at Shalimar Ghat (1.128±0.03 mg/L) followed by 0.374±0.04 mg/L at Ashai Bagh Bridge and lowest (0.171±0.02 mg/L) was recorded at Dugg Park in summer. The highest $N\text{-}NO_3$ 0.329±0.03 mg/L was observed at Shalimar Ghat followed by Ashai Bagh Bridge (0.133±0.01 mg/L) and lowest value of 0.078±0.003 mg/L was detected at Dugg Park in autumn. The overall season wise mean $N\text{-}NO_3$ at all sites was determined maximum (0.558 mg/L) in summer followed by 0.292 mg/L in spring and minimum (0.180 mg/L) was detected in autumn. The season wise mean $N\text{-}NO_3$ was statistically significant at ($p\leq 0.05$) confidence limit. The overall site wise mean $N\text{-}NO_3$ was determined maximum at Shalimar Ghat (0.684 mg/L) followed by Ashai Bagh Bridge (0.237 mg/L), while as lowest (0.115 mg/L) was recorded at Dugg Park. The sitewise mean $N\text{-}NO_3$ was also observed statistically significant at ($p\leq 0.05$) confidence limit. The mean $N\text{-}NO_3$ at different sites in particular season was statistically determined significant at ($p\leq 0.05$) confidence limit. The maximum mean phosphates (PO_4^{-3}) of 0.069±0.01 mg/L were found at Shalimar Ghat followed by 0.036±0.02 mg/L at Ashai Bagh Bridge and minimum (0.015±0.001 mg/L) was recorded at Dugg Park in spring (Table 2). The highest PO_4^{-3} was observed at Shalimar Ghat (0.075±0.01 mg/L) followed by 0.046±0.005 mg/L at Ashai Bagh Bridge and lowest (0.021±0.001 mg/L) was recorded at Dugg Park in summer. The highest PO_4^{-3} 0.053±0.004 mg/L was observed at Shalimar Ghat followed by Ashai Bagh Bridge (0.026±0.001 mg/L) and lowest value of 0.011±0.001 mg/L was detected at Dugg Park in autumn. The overall seasonwise mean PO_4^{-3} at all sites was determined maximum (0.047 mg/L) in summer followed by 0.040 mg/L in spring and minimum (0.030 mg/L) was detected in autumn. The seasonwise mean PO_4^{-3} was statistically significant at ($p\leq 0.05$) confidence limit. The overall sitewise mean PO_4^{-3} was determined maximum at Shalimar Ghat (0.066 mg/L) followed by Ashai Bagh Bridge (0.036 mg/L), while as lowest (0.016 mg/L) was recorded at Dugg Park. The sitewise mean PO_4^{-3} was also observed statistically significant at ($p\leq 0.05$) confidence limit. The mean PO_4^{-3} at different sites in particular season was statistically determined non-significant at ($p\leq 0.05$) confidence limit.

Table 1: Effect of seasons on nitrate-nitrogen ($NO_3\text{-}N$) mg/L at different sites in Dal Lake water

Site / Season	Dugg park (Control)	Shalimar Ghat	Ashai Bagh Bridge	Overall Mean
Spring	0.094±0.01	0.595±0.04	0.185±0.01	0.292
Summer	0.171±0.02	1.128±0.03	0.374±0.04	0.558
Autumn	0.078±0.003	0.329±0.03	0.133±0.01	0.180
Overall Mean	0.115	0.684	0.237	

The data are given in Mean ± Standard Error of 15 replicates.

C.D ($p \leq 0.05$)

Seasons (S) : 0.044
Sites (ST) : 0.044
S × ST : 0.072

Table 2: Effect of seasons on phosphate (PO_4^{-3}) mg/L at different sites in Dal Lake water.

Site / Season	Dugg park (Control)	Shalimar Ghat	Ashai Bagh Bridge	Overall Mean
Spring	0.015±0.001	0.069±0.01	0.036±0.002	0.040
Summer	0.021±0.001	0.075±0.01	0.046±0.005	0.047
Autumn	0.011±0.001	0.053±0.004	0.026±0.001	0.030
Overall Mean	0.016	0.066	0.036	

The data are given in Mean ± Standard Error of 15 replicates.

C.D ($p \leq 0.05$)

Seasons (S)	:	0.007
Sites (ST)	:	0.007
S × ST	:	NS

Discussion

Several forms of nitrogen are present in wastewater, for example as ammonium (NH_4^+) and nitrate (NO^-_3). The concentration of Nitrates is indication of level of micronutrients and pollution load in water bodies and has ability to support plant growth. Higher concentrations of Nitrate favored growth of phytoplankton (Mlitan *et al.,* 2015) [20]. In fresh aquatic ecosystems, nitrogen content is naturally produced from mineralization of organic matter (detritus), nitrification and denitrification processes. Nitrate nitrogen pollution of surface waters is mainly due to discharge of industrial and municipal/domestic wastewaters and agricultural runoff including animal feedlots. Nitrogen pollution by high nitrate can cause eutrophication in surface waters (Fried, 1991; Mlitan *et al.,* 2015) [12, 20]. Very high levels of NO_2^- in waters indicate unsatisfactory microbial activity (Das and Acharya, 2003) [7]. It is known for its toxicity effects on aquatic plants, biota as well as on human beings. Nitrate-nitrogen (NO_3-N) in Dal Lake was varied between 0.180 to 0.558 mg/L in all the seasons. The findings are conformity with the findings of (Wang and Evans, 1970; Edmondson 1970; Zimba *et al.,* 2011; Parveen *et al.,* 2013; Singh and Choudhary, 2013) [32, 9, 35, 24, 29]. Furthermore, highest concentration of NO_3-N was detected in summer followed by spring and least was in autumn. High volumes agricultural, domestic run-off and organic load in summer and spring could be the main reasons of high concentration of NO_3-N. Similar findings have been reported (Mir, 1977; Yousuf, 1979; Abdar, 2013) [19, 34, 1]. The minimum concentration of NO_3-N in autumn might be due to lower concentration of organic load and low rate of decomposition of organic matter, and least agricultural activities. The findings are in accordance with the findings reported by Shilpa *et al.* (2011) [28]. The highest NO_3-N was recorded in the Dal lake water at Shalimar Ghar followed by Ashai Bagh Bridge compared to Dugg Park. This might be due to high discharges of urban sewage, agricultural run-off and high which drastically triggers the NO_3-N concentration at these location. Similar results was also reported by (Jaji *et al.,* 2007; Zimba *et al.,* 2011; Umerfaruq and Solanki 2015) [14, 35, 30].

Phosphorous is predominantly present in waters and wastewater as phosphates, and is classified as orthophosphates, condensed phosphates and organic phosphates. These compounds occur either in solution in the body of organisms, particulates or detritus (Rapin *et al.,* 1989) [25]. Phosphorous is an essential requirement for living organisms. However, at high concentrations it is considered as a pollutant, because it causes eutrophication. Though NO_3^- pollution is also responsible for eutrophication, PO_4^{3-} is the major cause in freshwaters (Alam *et al.,* 2007) [2]. Eutrophication not only harms aquatic organisms, such as fishes, but also results in increasing the costs of water clean-up process. Ferric and calcium phosphates in rocks form the greatest reservoir of phosphates. The phosphorous in the soil gets dissolved in water, and in turn flows into the aquatic ecosystems. Another source of phosphorous in surface water is its release from bed sediments. Some specific bacterial actions cause the release phosphate from organic phosphorous compounds, chiefly formed by biological mechanisms, present in the detritus such as plant residues (Neal *et al.,* 1999) [22]. Organic phosphorous may also be drained in natural aquatic systems and during biological wastewater treatment processes. Organic phosphates from household food residues and body wastes end up in sewage (Correll, 1998) [6]. Natural animal manures, including animal excretions, also release phosphates in water resources. Common household detergents have emerged as a modern source of phosphorous to aquatic bodies. The detergents enter wastewater systems and released into surface waters (Neal *et al.,* 1999) [22]. Large scale use of phosphorous containing mineral fertilizers, such as superphosphate (a mixture of calcium dihydrogen phosphate and gypsum) in agriculture also enriches water with phosphates from surface runoff (Alam *et al.,* 2007) [2]. The highest concentration of PO_4^{-3} in lake was observed in summer followed by spring and least concentration in autumn. Washing of clothes, vehicles, agricultural run-off, and untreated domestic sewage could be the enhanced sources of PO_4^{-3} in summer and spring. Besides this, weathering of parent bedrocks along the tributary water channel of Dal Lake, soil erosion in the catchment area could be the possible conformity of high concentration of PO_4^{-3} in summer and spring. PO_4^{-3} enters surface water by ways of anthropogenic activities; wastewaters and land run off, domestic waste, fertilizers, (Kataria *et al.,* 1995; Mushtaq *et al*., 2013; Yaqoob *et al.,* 2008; Vyas *et al.,* 2006) [15, 21, 33, 31]. However, reduced volumes of water volumes, agricultural activities and due to dry conditions may be attributed to low concentration of PO_4^{-3} in autumn. High concentration of PO_4^{-3} by luxuriant growth macrophytes reduced the PO_4^{-3} quantity in lake water (Umerfaruq and Solanki 2015) [30]. The PO_4^{-3} concentration in Dal Lake was highest at Shalimar Ghat, and Ahai Bagh Bridge compared to Dugg Park. This may be due to the high input of domestic waste effluent, agricultural run-off, mineralization due to weathering which enters into the source tributary of Dal Lake, wastes from houseboats and the enhanced influx of untreated municipal wastes and urban runoff considerably added PO_4^{-3} in these particular locations. The results are in accordance with results reported by Arvindkumar (1995) [5].

Conclusion

Anthropogenic factors are responsible for growing substantial concentration of nutrients (N and P) in Dal Lake. Currently lake is in mesotrophic condition but at the rate nutrients are discharged into the lake could be the factor to change the fresh water dynamics of the lake into eutrophic condition.

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