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The Hydrochemistry of a Himalayan Lake Nigeen

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ABSTRACT

The Nigeen lake is the deepest and most attractive basin of Dal lake which has attracted foreign tourists because of its placid waters and calm environment. The lake water besides recreation is also being used for cultivation of vegetable and potable purposes. In the recent years huge settlements have come up around the Nigeen lake on all sides reaching to a population of more than twelve thousand souls in the immediate catchment, which excludes the boat population and floating population who live in about fifty house boats within the lake. Raw sewage entering the lake has enriched the freshwater of Nigeen to a large extent. Statistically, ANOVA test showed significant variation in transparency, pH, dissolved oxygen, calcium, nitrogen and phosphorus indicating clear variation between littoral and pelagic zones. The present paper is an attempt to assess its present water quality status and to record the chemical enrichment of the lake water over a period of time.

INTRODUCTION

Aquatic systems are considered as suitable sites for disposal of sewage and are subjected to pollution pressures associated with urbanization and population growth. Moreover, the increasing pollutant load and overexploitation of aquatic resources for potable supplies, irrigation etc. to meet the requirements of the ever-increasing population, significantly reduces its assimilative capacity.

The Nigeen basin is regarded as paradise for aquatic sports and skiing. It is the deepest of all basins of Dal lake with maximum depth of 6.2 meters. The basin is well connected with Dal Lake through Ashai bagh bridge. In the recent years huge settlements have come up around the Nigeen lake on all sides reaching to a population of more than twelve thousand souls in the immediate catchment, which excludes the boat population and floating population who live in about fifty house boats within the lake. Raw sewage entering the lake has enriched the freshwater of Nigeen to a large extent. Eventually towards Suderbal side $3/4^{th}$ of the lake surface has turned into marsh and is full of emergent type of vegetation (*Typha angustata*, *Phragmites communis*), although a portion of the marsh has been retrieved recently by J&K Lakes & Waterways Development Authority under Dal & Nigeen Lake Conservation programme. The water quality of the lake is of prime importance as its water is used for potable purposes. The public Health Engineering Department is harvesting about 2 MGD of Nigeen waters for its 30,000 consumers inhabiting immediate catchment of Nigeen lake. Hence, it becomes imperative to record the water quality changes in the lake water particularly the changes in physico-chemical parameters over a period of time to asses the present status of water quality and the impact of the increasing pollution load to the lake.

MORPHOMETRIC FEATURES

The morphometric features of the Nigeen Lake reveal that it is 2.5 km in length and 0.5 km in width. The surface area is about 0.89 km^2 and shoreline is irregular (Fig. 1). The shoreline index is calculated as 1.75 whereas volume development is 0.685 indicating the convexity of the lake basin walls towards the water surface. The ratio of mean and maximum depth being 0.225 indicates the basin to be saucer shaped (Vass & Zutshi 1979). The total volume of water is calculated as $1.22m^3 \times 10^6$ (Kundangar et al. 1995). The objectives of the study are mainly to review the present water quality status of the lake and to provide an overview of the water quality by comparing its present status with the past.

MATERIALS AND METHODS

The sampling was done on monthly basis during forenoon (1000-1200 hrs) from June 2013 to February 2014 at three sites (Site1, near Ashai-bagh bridge (entry site), Site 2, near Nigeen central (central site) and Site 3, near Nallah Amir

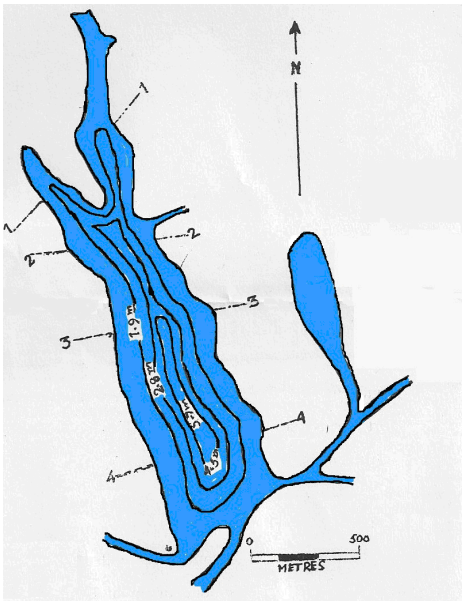

Fig. 1: Morphometery and shoreline of Nigeen lake.

Khan (exit site). Usually composite samples were considered for physico-chemical analysis. Air temperature, water temperature, pH and specific conductivity were determined at the sampling spot while for dissolved oxygen only prefixation of the samples was done and samples were immediately transported to the laboratory for detailed analysis. Oxygen concentration was determined by Winkler's modified method and for rest of the parameters, methods given in APHA (1997), and Mackereth (1963) were followed using UV-VIS spectrophotometer (Hitachi, Japan).

RESULTS AND DISCUSSION

Water Temperature: Water temperature records show minimum value (2.7°C) at site 1 during January, while maximum value (25.0°C) in August at site 3. Overall, seasonally minimum water temperature of 3.0°C was recorded during winter and maximum of 23.9°C was recorded during summer. No significant variation in water temperature between various sites was observed. F critical was more than F calculated (4.74 > 0.036), signifying no considerable difference among sites.

Depth: Depth records show minimum value (2.0 m) at site 3 during October and maximum depth (6.2 m) at site 2 during December. Overall, seasonally minimum value of 3.8 m was recorded during summer and maximum value of 4.1m during winter.

The seasonal fluctuation in depth during the study period was on account of dry weather during summer and precipitation (rain/snow) during winter months.

Secchi disc transparency: Transparency recorded minimum values of 0.8m at site 3 in September, while maximum value of 2.7m at site 2 during January. Seasonally, minimum value of 1.4m was recorded in autumn, while maximum value of 1.8m in winter.

Secchi disc transparency is a common method used to assess and compare water clarity. Highest clarity appeared during winter season probably on account of low plankton population while water clarity decreased during summer and autumn on account of higher planktonic population, which can directly be correlated to nutrient enrichment during summer and autumn respectively. A significant variation in transparency among various sites was observed as, F calculated is more than F critical (122.66 > 4.74).

pH: pH showed minimum value (7.5) at site 2 during January, while maximum (8.5) at same site 2 in August. Seasonally, minimum value of 7.7 was recorded in winter, while maximum values of 8.1 during summer.

pH is the measure of hydrogen ion activity and is often used to assess water quality. Lake pH affects chemical and biochemical reactions, regulates toxicity and controls the distribution of many aquatic organisms. Minimum values were recorded during winter, while maximum values during summer. The reason being that during summer the luxuriant growth of aquatic flora is able to bring increase in pH on account of high productivity. A significant variation was observed among the sites, as F calculated was more than F critical (9.1 > 4.7). Nigeen Lake water is well buffered which is in conformity with the findings of Zutshi (1968) and Kundangar & Adnan (2006).

Electrical conductivity: Electrical conductivity (EC) records minimum value (192 µS cm^{-1}) at site 3 during August, while maximum value (382 µS cm^{-1}) at site 2 during February. Overall, seasonally, minimum value of 212.6 µS cm^{-1} was recorded during summer, while maximum value of 330 µS cm^{-1} during winter.

Electrical conductivity (EC) is a measure of the capacity of water to carry an electrical current. This capacity is related to the total concentration of ionized substances in the water (Wetzel 2001). Minimum values of EC were recorded during summer and maximum during winter. The reason being during summer prolific growth of macrophytes help to reduce the EC values. According to Adnan (2010), the aquatic macrophytes are able to reduce conductivity and the drop of conductivity is due to the diminution in dissolved ions, which is caused by the precipitation of calcium carbonate and other minerals. Such precipitation is carried out at high pH, which is produced by high productivity. No significant variation was recorded among different sites as F calculated (0.197) < F critical (4.70). Overall,

the EC of Nigeen water is higher than earlier records. Zutshi (1987) observed moderate conductivity value in Dal lake during 1980-1982 while Kundangar et al. (1992-93) and Kundangar & Adnan (2006) reported progressive increase in conductivity values of Nigeen waters. Mathew & Vasudevan (2000) attributed the higher values of conductivity to the mineral inputs, while Agarwal & Kanan (1996) hold the concentration of ions, TDS and conductivity keep rising when water quality keeps deteriorating.

Dissolved oxygen: Dissolved oxygen value recorded minimum value of 5.2 mg/L at site 3 during July, while maximum value of 9.0 mg/L was recorded at site 1 in December. Overall, seasonally, minimum value of 6.0 mg/L was recorded during summer, while maximum value of 7.6 mg/L in winter.

Oxygen is of prime importance in controlling aquatic life. The solubility of oxygen in water is proportional to the partial pressure in the atmosphere and decrease nonlinearly with increasing temperature. Moreover, primary production creates oxygen in water whereas, decomposition of organic matter consumes it. Dissolved oxygen recorded minimum values during summer, probably on account of two main reasons, one being D.O. decreases nonlinearly with increasing temperature and secondly due to increased generation of biomass during summer and its concomitant decomposition resulting in continuous utilization of oxygen. ANOVA results show a marked difference among sites as F calculated (7.25) > F critical (4.7). Kundangar & Adnan (2006) observed the depletion of oxygen content in the bottom waters of Nigeen throughout the year, which according to authors depicted the shift in oxygen regime.

Total alkalinity: Total alkalinity records show minimum value (106 mg/L) at site 3 in August, and maximum value (435 mg/L) at site 2 in January. Overall, seasonally, minimum value of 141.5 mg/L was recorded during summer, while maximum value of 298 mg/L during winter.

The total alkalinity of Nigeen lake was comparatively much higher than the earlier records of Kundangar et al. (1992-93). The alkalinity was of bicarbonate type, which is in conformity with Freiser & Ferriande (1996) who stated that when total alkalinity is higher, the carbonate system persists and pH usually remains alkaline. ANOVA showed F calculated (0.689) < F critical (4.7), signifying no significant difference between sites.

Calcium: Calcium showed minimum values (29.6 mg/L) at site 2 in November, while maximum value (44 mg/L) at site 3 in August. Overall, seasonally, minimum value of 35.7 mg/L was recorded during autumn, and maximum value of 38 mg/L during summer.

Calcium, which is of interest because it is required for the growth of exoskeletons in mussels, zooplankton and other aquatic organisms. Ca levels in lakes are a reflection of Ca in catchment soils (Houle et al. 2006). The calcium content during the study period was recorded between 29.6 and 44 mg/L, which shows that basically the lake is a marl lake and the water is rich in calcium. ANOVA result shows a marked difference between sites as F calculated (24.36) > F critical (4.7). Similar observations were made by Kundangar et al. (1992-93) and Kundangar & Adnan et al. (2006). The values of calcium are much higher than those of Zutshi & Khan (1988). According to Kundangar & Adnan (2006) 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 may adsorb organic substances and thereby limit the plankton growth. The direct relationship between bicarbonates and calcium has been observed by Pearsall (1923) and Zafar (1964), whereas, the inverse relationship between carbonates and bicarbonates has been noted by Ganapati (1940).

Nitrate nitrogen and ammonical nitrogen: Nitrate-nitrogen recorded minimum value (275 µg/L) at site 2 during December, while maximum value (625 µg/L) at site 1 during August. Overall, seasonally, minimum value of 386.6 µg/L was recorded in winter, while maximum value of 487 µg/L in summer.

Ammonical nitrogen value showed minimum value (80 µg/L) at site 1 in February, and maximum value (269 µg/L) at site 3 in January. Overall, seasonally, minimum value of 111.6 µg/L was recorded in summer, while maximum value of 158.6 µg/L during winter.

Nitrogen (N) and nitrogen compounds are common in plant and animal material and in decomposition wastes, sewage, fertilizers and industrial discharge. As is evident from Table 1, the nitrate-nitrogen and ammonical nitrogen contents in the Nigeen waters are much higher than the earlier records of Vass (1980), Zutshi & Khan (1988). Thresh et al. (1944) have attributed the nitrogen richness of a freshwater body to the pollution of animal origin. ANOVA results show a marked difference among sites as F calculated (5.48) > F critical (4.7) in nitrogen concentrations. The difference among the sites is probably because of the reason that the central site is less prone to direct impact from human activities and also from point and non-point sources of sewage.

Ortho-phosphate and total phosphorus: Ortho-phosphate shows minimum value (68 µg/L) at site 2 in December, while maximum value (153 µg/L) at site 1 in October. Overall, seasonally, minimum value of 96.0 µg/L was recorded during winter, while maximum value of 118 µg/L in autumn.

Total phosphorus recorded minimum value (240 µg/L)

Table 1: Changes in water quality over a period of time.

Parameters	Units	1992-1993 (Min-Max)[1]	2013-2014 (Min-Max)[2]
pH		8.0-8.8	7.6-8.5
Specific conductivity	µSm@25°C	247-344	192-382
Depth	m	N.A	2.0-6.2
Transparency	m	N.A	0.7-2.7
Dissolved oxygen	mg/L	5.9-13.0	5.5-9.0
Total Alkalinity	mg/L	107.0-159.8	128-435
Calcium	mg/L	38.5-50.8	29.6-44
Nitrate nitrogen	µg/L	58-79	275-625
Ammonical nitrogen	µg/L	9.8-17	85-269
Orthophosphate	µg/L	21.5 - 121	84-153
Total phosporus	µg/L	49.6-101	240-396

(1) - After Kundangar et al. (1995); (2) - Present study

at site 1 in the month of February, while maximum value (396 µg/L) at site 3 in the month of October. Overall, seasonally, minimum value of 313 µg/L was recorded in autumn, while maximum value of 347 µg/L during autumn.

Phosphorus is often the nutrient in least supply, meaning that biological productivity is often limited by the amount of available phosphorus. Increase in phosphorus concentrations can lead to more frequent and dense algal blooms, which are a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by species that can produce toxins. The orthophosphate and total phosphorus values are much higher than those of earlier records. The higher phosphorus content in the lake water can be attributed to the influx of raw sewage entering the lake through surface drains. Hutchinson (1957) also reported the increase of phosphorus as a result of sewage contamination. Schindler et al. (1971) singled out phosphorus for attention because it is believed to be nutrient frequently controlling eutrophication. Lund (1965) and Einsele (1936) support the view that phosphorus plays a major role in eutrophication as well as in production. Wetzel (1975) holds the view that number of bacteria increases with increasing productivity and concentration of organic and inorganic compounds in lakes.

A visible deterioration in water quality of Nigeen lake has been observed over a period of time. The possible reason being increase of population, rapid expansion in the urban activities and agricultural practices in the immediate catchment that has resulted in generation of high volume of waste material causing gradual degradation of aquatic resources. However, it is also encouraging to find that central sites of lake with lesser human activity still remain in a relatively pristine condition. It is also clear that human activities have resulted in elevated levels of biologically important nutrients, as compared to natural conditions. Inadequate sanitary system, poor land use practices in the immediate catchment, and the discharge of grey water continues to jeopardize the water quality of lake for human use. The increase in the concentration of P and the optimal ratio between P and N shall have important effect on the primary production, structure of plankton community coupled with spontaneous algal blooms and aquatic macrophytes in various parts of the lake and subsequent deterioration of water quality. We can expect water quality to deteriorate further unless authorities are willing to manage the activities to ensure safe water quality of lake.

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