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RESEARCH

A Study on Comparative Assessment of Water Quality of Dal and Nigeen Lakes of Jammu and Kashmir, India

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Abstract

The lakes of the Kashmir valley, India are under continuous pressure due to increasing anthropogenic activities. In the present study, an attempt has been made to monitor the quality of two important lakes (Dal and Nigeen) of Jammu and Kashmir (J&K), India. These lakes hold significant ecological, cultural, and economic value, attracting many tourists and serving as vital sources of fresh water for local communities. Five sampling sites were selected in the study area, out of which three are in Dal Lake and two in Nigeen Lake. A comparison of the water quality of both lakes was made in the present investigation based on selected physicochemical parameters like water pH, conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chloride (Cl^-), sulfate (SO_4^{2-}), nitrate (NO_3^-) and phosphate (PO_4^{3-}). The results revealed that the value of most of the parameters was higher in Dal Lake (BOD, EC, COD, and PO_4^{3-}) while some parameters were found higher in Nigeen Lake (NO_3^-, DO, Cl^- and SO_4^{2-}). The student t-test showed significant differences ($p < 0.05$) between the means of most of the studied parameters of both the lake except EC and NO_3^-. Although all the parameters were within the limits if the trend of pollution continues, then the water quality of both lakes will become unfit for aquatic plants, animals, and tourist activities also. This study highlights the urgent need for effective water management strategies and conservation efforts to preserve the water quality of Dal and Nigeen Lakes.

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Statement of Sustainability: Dal and Nigeen lakes are tourist attractions and therefore directly connected with the living of residents of the state. Pollution will affect the aesthetic beauty of these lakes along with aquatic flora and fauna and therefore pose indirect impacts on the living of the people. Therefore, continuous monitoring should be an essential part of the sustainability of freshwater body and their conservation strategies.

1. Introduction

Approximately 2/3 of the planet Earth is covered by water. Water is an essential component of the human body (70% of body weight) as well as of the plant body (97% of body weight) and is therefore essential for the survival of living organisms (Wani et al., 2016; Bhutiani et al., 2019). However, only a small fraction of this water is available as freshwater (Khan et al., 2014). Freshwater ecosystems such as lakes, rivers, and wetlands provide a variety of ecological, social, and economic services, as well as habitat for some plant, animal, and microbial life forms, and are therefore considered the most important natural resources (Dudgeon et al., 2006; Nelson et al., 2015; Walsh and Milon, 2016). Lakes are more vulnerable to pollution due to their comparatively lower self-regulating capacity than lotic systems.

The continuous increase in population leads to urbanization and industrialization, which results in a large amount of groundwater extraction and the generation of a large amount of wastewater (Miller et al., 2010; Bhutiani and Ahamad, 2018; Habib et al., 2020). A small amount of this wastewater is treated while a large amount is discharged into the freshwater bodies either in treated or untreated form (Bhutiani et al., 2021). The sedimentation rate increases due to accelerated nutrient cycling and faster transport of soil constituents, resulting in nutrient enrichment of surface water bodies followed by changes in the composition of aquatic habitats (Smith, 2003; Odada et al., 2004). The large amount of wastes and discards of the society reach the lakes which disturbs the ecology and hydrology of the lakes (Khan et al., 2014; Dar et al., 2020). Similarly, the physical, chemical, biological, and geological characteristics of Dal and Nigeen lakes were disturbed due to the dumping of solid and liquid wastes. The quality of water bodies near residential areas generally reflects the range of human activities in their catchment areas.

The lakes of the Kashmir Valley are under continuous pressure due to increasing anthropogenic activities. The major factors responsible for the water quality degradation of these lakes include changes in the catchment scale land system (Rather et al., 2016), untreated sewage discharge (Parvez and Bhat, 2014), climate change (Smol et al., 2005; Havens et al., 2019), urbanization (Amin et al., 2014; Rashid et al., 2017; Ducey et al., 2018; Wang et al, 2019), nutrient enrichment due to reduced self-regulatory capacity (Romshoo and Muslim, 2011; Badar et al., 2013), hydrological changes (Li et al., 2016; Markovic et al., 2017), acidification (Moldan et al, 2013; Leach et al., 2019) and sediment loading (Rashid and Aneaus, 2019), which not only affect their water quality (Najar and Khan, 2012; Bhat and Pandit, 2014) but also aquatic biodiversity (Khan et al., 2004; Bhat et al., 2012).

Both Dal and Nigeen lakes receive domestic wastewater in treated, partially treated, and raw forms. Therefore, the hypothesis is that the water quality of both lakes will be polluted. The objective of the present study is to analyze the water quality of two important freshwater lakes (Dal and Nigeen) in terms of selected physicochemical parameters. A comparison of the water quality of both lakes was also performed.

2. Materials and Methods

2.1. Study Area

All the sampling sites are shown in Table 1 and Figure 1. Dal Lake, also known as the "Jewel of Kashmir", is located on the right bank of the Jhelum River at an altitude of 1583 meters above sea level at 34°09'N latitude and 78°08'E longitude. The water quality of Dal Lake receives highly polluted domestic effluents from agricultural lands (containing residues of fertilizers, insecticides, and pesticides) and industrial wastes. The government of Jammu and Kashmir has set up sewage treatment plants to treat this huge amount of sewage, but they are unable to solve this problem. Nigeen Lake is located 9 km northeast of Srinagar at an altitude of 1584 meters above sea level at 34°07'13''N latitude and 74°49'40''E longitude, covering an area of about 4.5 square kilometers (Nissa and Bhatt, 2016). Nigeen Lake receives water from Dal Lake in the northeast and Khushalsar Lake through Nallah Amir Khan in the northwest. Nigeen Lake also receives water from some springs and atmospheric precipitation. It is important to mention that Nigeen Lake provides 2 million gallons of water per day (MGD) which meets the needs of about 30,000 inhabitants living in the vicinity of the lake. This task is carried out by the Public Health Engineering (PHE) department (Abubakr et al., 2018).

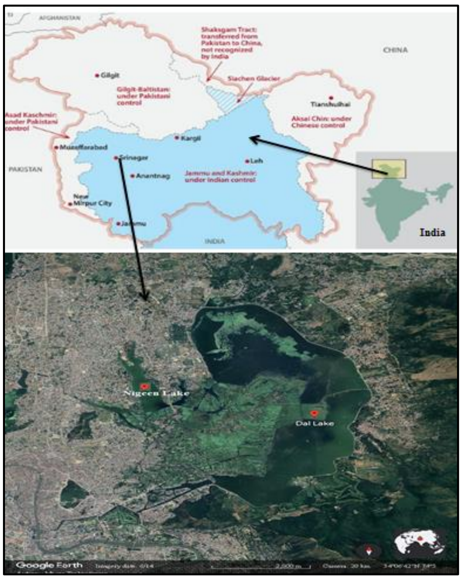

Figure 1. Study sites showing locations of Dal and Nigeen Lakes in Jammu and Kashmir, India.

Table 1. List of sampling sites and their geographical coordinates of Dal and Nigeen Lakes in Jammu and Kashmir, India.

Site Name	**Geographical Co-ordinates**
Dal Lake Site 1	34°03'53.5"N 74°51'34.6"E
Dal Lake Site 2	34°05'16.2"N 74°51'00.8"E
Dal Lake Site 3	34°05'35.5"N 74°50'22.1"E
Nigeen Lake Site 1	34°06'08.8"N 74°48'53.2"E
Nigeen Lake Site 2	34°08'46.1"N 74°50'58.5"E

2.2. Sample Collection and Analysis

Water samples from all five sampling sites were collected in the morning (between 7 am and 10 am) for five months (from December 2021 to May 2022). The samples were collected in pre-washed plastic containers of 2 liters throughout the study period. All the selected parameters were analyzed according to the standard methods prescribed by APHA (2012) and Khanna and Bhutiani (2008).

Table 2. Methodologies and instruments used for water quality parameter analysis.

Parameters	**Methodology used / Instruments used**
pH	With the help of a pH meter (Company name: EI, Model no: EI 112)
Conductivity (µS/cm)	With the help of a Microprocessor based conductivity meter (Company name: ESICO, Model no: ESICO 1601)
Dissolved Oxygen (mg/L)	Winkler's Iodometric method
BOD (mg/L)	Winkler's Iodometric method
COD (mg/L)	Reflux method
Chloride (mg/L)	Argentometric method
Sulphate (mg/L)	Spectrophotometric method
Nitrate (mg/L)	Spectrophotometric method
Phosphate (mg/L)	Spectrophotometric method

2.3. Data Analysis

The obtained data were processed using Microsoft Office Excel (Version 2010, Microsoft Corp., USA) for the estimation of range, mean value, standard deviation (SD), and standard error (SE). The unpaired student's t-test was performed to understand significant ($p < 0.05$) differences between water quality parameters using the online version of GraphPad (Boston, USA) software (https://www.graphpad.com/quickcalcs/ttest1/?format=SEM).

3. Results and Discussion

The results of all the selected physicochemical parameters of Dal and Nigeen Lakes analyzed during the study period are presented in Table 3 and Figures 2 and 3.

Table 3. Comparison of physicochemical properties of water samples collected from Dal and Nigeen Lakes (n=6).

Parameters	**Dal Lake**			**Nigeen Lake**			**Student's t-Test**	
	Range	**Average± SD**	**SE**	**Range**	**Average± SD**	**SE**	**t-Statistics**	**p-Value**
pH	7.85-8.03	7.97±0.07	0.06	7.79-7.96	7.90±0.06	0.05	2.8*	0.0084
Conductivity (µS/cm)	249.33-294.67	271.67±19.74	15.43	258.50-263.50	261.10±2.22	1.03	1.8	0.0769
Dissolved Oxygen (mg/L)	3.45-4.13	3.75±0.27	0.17	5.28-5.85	5.54±0.25	0.18	17.4**	0.0001
BOD (mg/L)	8.75-10.33	9.55±0.72	0.24	7.21-8.61	7.86±0.56	0.28	6.9**	0.0001
COD (mg/L)	90.74-109.05	101.39±7.34	2.62	67.80-79.33	74.48±4.58	2.87	11.3**	0.0001
Chloride (mg/L)	33.27-38.47	36.06±1.96	1.06	37.65-40.26	39.07±1.19	0.93	4.8**	0.0001
Sulphate (mg/L)	26.87-28.95	27.75±0.91	0.37	30.46-32.00	31.55±0.66	0.43	12.42**	0.0001
Nitrate (mg/L)	4.40-5.39	4.95±0.38	0.17	4.70-5.58	5.05±0.40	0.15	0.6916	0.4949
Phosphate (mg/L)	5.10-5.77	5.34±0.26	0.15	4.22-4.98	4.52±0.31	0.25	7.8**	0.0001

3.1. pH

pH is an important parameter to maintain the ionic balance in an aquatic body. The pH in Dal Lake ranged from 7.85 to 8.03 with an average value of 7.97±0.07 while in Nigeen Lake ranged from 7.79 to 7.96 with an average value of 7.90±0.06. Student's t-test results indicate a significant difference (p=0.0084, t= 2.8) in the mean values of pH of both lakes. The water of Dal Lake was found more basic in comparison to Nigeen Lake due to the addition of industrial and domestic waste. The water quality of both lakes varied between neutral to slightly alkaline. The slight variations in the value of pH at all the sites and in both the lakes may be due to differences in photosynthetic activity and ionic composition (Hutchinson, 1973).

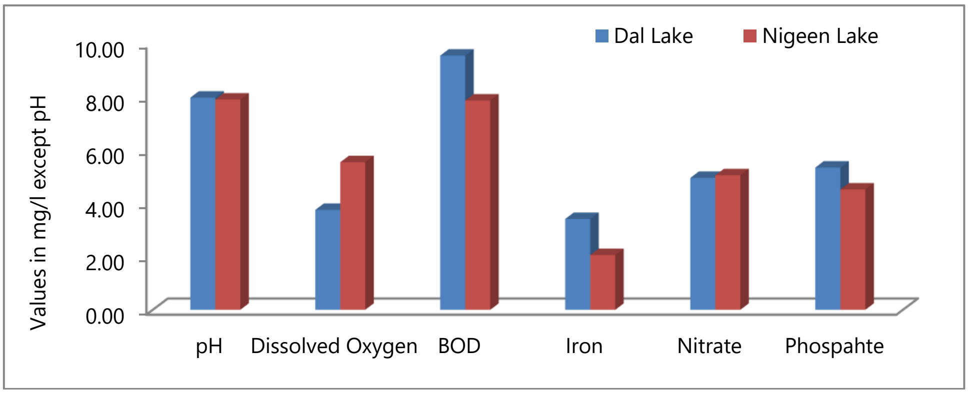

Figure 2. Comparison of different physicochemical parameters of water samples collected from Dal and Nigeen Lakes.

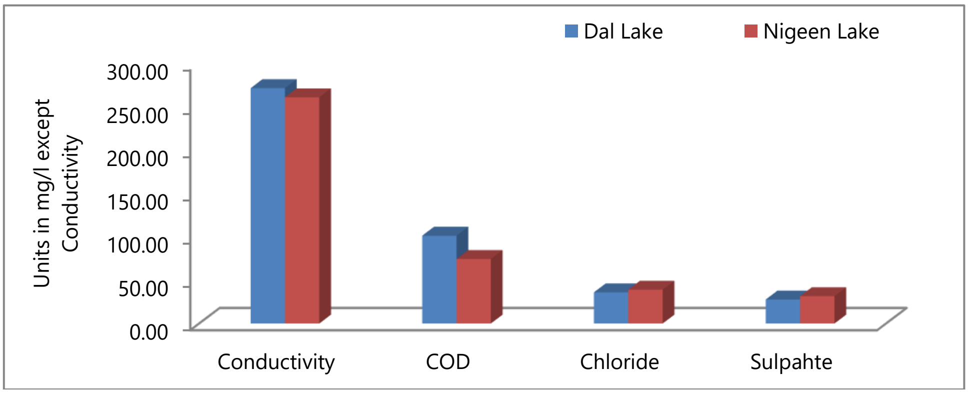

Figure 3. Comparison of different physicochemical parameters of water samples collected from Dal and Nigeen Lakes.

3.2. Electrical Conductivity (EC)

Electrical conductivity (EC) indicates the mineralization status of an environment by the amount of water-soluble products present in the water. The EC was found to be highest during the winter season due to less water inflow and low bacterial degradation. Student's t-test results indicate a non-significant difference ($p=0.0769$, $t= 1.8$) in the mean values of EC of both lakes. During the rainy season, there was a steady decrease in electrical conductivity values, which may be due to rainwater dilution. In summer, nutrient uptake and bacterial degradation slowly decrease. The average conductivity at SS-01, SS-02, and SS-03 of Dal Lake was found to be 312.40±57.31, 235.60±21.54 and 267.00±8.00 µS/cm while 265.40±2.70 and 256.80±2.39 µS/cm at SS-04 and SS-05 of Nigeen lake respectively. The conductivity in Dal Lake ranged from 249.33 to 294.67µS/cm with an average value of 271.67±19.74 µS/cm while in Nigeen Lake ranged from 258.50 to 263.50 µS/cm with an average value of 261.10±2.22 µS/cm. In our study, EC values were found lower than Dar et al. (2020) who reported 329.4±2.22 µS/cm which may be due to the low pH of the water. pH values affect the solubility and availability of different ions in water bodies (Menberu et al., 2021). Ashraf et al. (2022) also reported a similar range of EC (215-275.8 µS/cm) in Anchar Lake, Srinagar, India, and Maansi et al. (2022) reported a similar range of EC (144.9-267.3 µS/cm) in Sukhna Lake, Chandigarh, India.

3.3. Dissolved Oxygen (DO)

Dissolved oxygen is of paramount importance to all living things and is also an indicator of the health of a water body (Kumar et al., 2019). Water temperature, water disturbance, types and amounts of aquatic plants, light penetration, and amounts of dissolved oxygen or suspended solids such as organic matter affect DO levels (Das Kangabam et al., 2020; Maansi et al., 2022). Student's t-test results indicate a significant difference ($p=0.0001$, $t= 17.4$) in the mean values of DO of both the lake. The DO in Dal Lake ranged from 3.45 to 4.13mg/L with a mean value of 3.75±0.27 mg/L, while in Nigeen Lake it ranged from 5.28 to 5.85 mg/L with a mean value of 5.54±0.25 mg/L. A decrease in the DO value of

Dal was also reported by Kumar et al. (2022). The lower DO values in both lakes may be due to the discharge of untreated and partially treated wastes. Despite the discharge of wastewater, the DO values touching 5.85 mg/L may be due to the photosynthetic activity of algal biomass (Suplee et al., 2019; Dar et al., 2020). DO levels below 2 mg/L are harmful, while levels between 5 and 6 mg/L are suitable for aquatic life (Geol et al., 1980; Dodds, 2006; Singh et al., 2008; Choi et al., 2017; Kumar et al., 2019).

3.4. Biochemical Oxygen Demand (BOD)

BOD is an important parameter for the determination of organic matter pollution in surface and groundwater (Sudarshan et al., 2019). Student's t-test results indicate a significant difference ($p=0.0001$, $t= 6.9$) in the mean values of BOD of both lakes. The BOD in Dal Lake ranged from 8.75 to 10.33 mg/L with a mean value of 9.55±0.72 mg/L, while in Nigeen Lake it ranged from 7.21 to 8.61 mg/L with a mean value of 7.86±0.56 mg/L. Rather and Dar (2020) reported the increase in a built-up area in the catchment area of Dal and Nigeen lakes, which increases the introduction of fertilizers and phosphates into Dal Lake, resulting in the increased values of BOD in Dal and Nigeen lakes (Pandey and Kumar, 2015; Adimalla and Taloor, 2020; Deep et al., 2020). High values of BOD in aquatic bodies lead to the suffocation of organisms and eventually death (Dhinamala et al., 2015). pH affects the values of BOD by affecting the availability of phosphorus to plants (Menberu et al., 2021).

3.5. Chemical oxygen demand (COD)

The COD and BOD values provide information about the organic matter present in the water. Student's t-test results indicate a significant difference ($p=0.0001$, $t= 11.3$) in the mean values of COD of both lakes. The COD and BOD values are proportional to each other (Roy and Majumder, 2019; Rizk et al., 2020). The COD in Dal Lake ranged from 90.74 to 109.05 mg/L with a mean value of 101.39±7.34 mg/L, while in Nigeen Lake it ranged from 67.80 to 79.33 mg/L with a mean value of 74.48±4.58 mg/L. The higher COD values in Dal Lake as compared to Nigeen Lake may be due to the higher quantity of dumping of solid and liquid wastes in the city in it (Rather and Dar, 2020).

3.6. Chloride (Cl^-)

Chloride plays a metabolically active role in photosynthesis and is essential for autotrophic photophosphorylation reactions. The high level of chloride in a water body indicates the degree of contamination, especially due to a large amount of wastewater input (Gopalkrushna, 2011). Student's t-test results indicate a significant difference ($p=0.0001$, $t= 4.8$) in the mean values of chloride of both the lake. It shows that the contamination is higher at the site. The chloride in Dal Lake ranged from 33.27 to 38.47 mg/L with a mean value of 36.06±1.96 mg/L, while in Nigeen Lake ranged from 37.65 to 40.26 mg/L with a mean value of 39.07±1.19 mg/L. Chloride concentration was found lower in both lakes in comparison to Dar et al. (2020) who observed a mean chloride concentration of 26 mg/L. The only source of chloride in the lake water is the dumping of untreated and treated wastewater (Rather et al., 2016; Rubella et al., 2020). Mansi et al. (2022) reported a similar range of chloride in the winter season (22.4-27.4 μS/cm) in Sukhman Lake, Chandigarh, India.

3.7. Sulcate (SO_4^{2-})

Sulphate is detected in almost all surface and groundwater sources (Deep et al., 2020). Student's t-test results indicate a significant difference ($p=0.0001$, $t= 12.42$) in the mean values of sulfate of both lakes. Sulphate in Dal Lake ranged from 26.87 to 28.95 mg/L with a mean value of 27.75±0.91 mg/L, while in Nigeen Lake it ranged from 30.46 to 32.00 mg/L with a mean value of 31.55±0.66 mg/L. Sulfate levels in both lakes are within the standard values of BIS (2012) and WHO (1996).

3.8. Nitrate (NO_3^-)

Most nitrogen in aquatic systems is inorganic (Maansi et al., 2022). Nitrate is responsible for the enhanced growth of macrophytes (Lodh et al., 2014). Student's t-test results indicate a non-significant difference ($p=0.4949$, $t= 0.6916$) in the mean values of Nitrate of both the lake. The nitrate nitrogen in Dal Lake ranged from 4.40 to 5.39 mg/L with a mean value of 4.95±0.38 mg/L, while in Nigeen Lake it ranged from 4.70 to 5.58 mg/L with a mean value of 5.05±0.40 mg/L, respectively.

3.9. Phosphate (PO_4^{3-})

Phosphate is an important nutrient that controls the productivity of an aquatic ecosystem (Hutchinson, 1957; Maansi et al., 2022). Student's t-test results indicate a significant difference ($p=0.0001$, $t= 7.8$) in the mean values of Phosphate of both the lake. The phosphate in Dal Lake ranged from 5.10 to 5.77 mg/L with a mean value of 5.34±0.26 mg/L, while in Nigeen Lake it ranged from 4.22 to 4.98 mg/L with a mean value of 4.52±0.31 mg/L. The phosphate levels in the lake water can be attributed to domestic sewage and detergents entering from the residential areas (Xu et al., 2008). The higher levels of phosphorus may be due to agricultural runoff containing fertilizer and pesticide residues (Purandara et al., 2003; Dumont, 2009; Gopalkrushna, 2011; Abdelrazek, 2019).

4. Conclusion

The water quality of Dal and Nigeen Lakes was analyzed from December 2021 to May 2022 to make a comparison of water quality based on some physicochemical parameters. During the field visits, a lot of anthropogenic activities were observed on both lakes. The main reason for the pollution of both lakes was found to be the dumping of solid and liquid waste from industrial and residential areas without any treatment or in a partially treated form. The concentration of most of the parameters studied was found to be higher in Dal Lake as compared to Nigeen Lake. As both lakes are centers of tourist activities and therefore the main source of livelihood of local people and if the rate of increase of pollution in the lakes will continue for some time, the aesthetic value of both the lakes will reduce which will affect the livelihood of local people. Thus, there is a great need for continuous monitoring of the water quality of both lakes and the treatment of wastewater coming into these lakes.

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