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A RECENT STUDY OF WATER QUALITY OF DAL LAKE IN SRINAGAR J&K

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Abstract
The issues of sewage disposal and contamination of surface waters in lakes are rapidly rising due to urbanisation, technological advances, and growing populations. Over the past few decades, the water quality of Dal Lake has experienced significant degradation, rendering it unsuitable for domestic consumption and diminishing its visual appeal. This report aims to provide an overview of the current state of water quality in Dal Lake. Water quality can be evaluated using various physio-chemical and biological indicators such as turbidity, pH, taste, odour, iron, fluoride, total dissolved solids (TDS), conductivity, nitrate, phosphorus, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and coliform bacteria. Water samples were randomly sampled from several locations in Dal Lake, spanning from Dal-gate to Hazratbal. Based on the test findings and data, we observed that majority of the lake's surface is covered by weeds. This is caused by a high concentration of nitrate and phosphorus, which leads to the siltation of the lake water. Bacteriological contamination was found along the entire span of Dal Lake. The primary factor contributing to the diminished water quality of the lake is the introduction of untreated sewage, detergents, and runoff from floating gardens and houseboats. Focus group discussions were held with participants and some awareness programmes were also held to educate the people on the lakes degradation and suggestions for improving the same.

Keywords: Dal Lake, Water quality assessment, Focus group discussions.

1. INTRODUCTION

The Dal Lake in Kashmir, is known as the "*Liquid heart*" of Srinagar, the capital city of the Union Territory of Jammu and Kashmir. The lake is plagued by numerous ailments primarily caused by human encroachments both around its edges and within its waters. The lake is currently experiencing significant environmental issues, such as the large influx of untreated residential sewage, continual accumulation of sediment, leading to unpleasant algal blooms and excessive weed growth, deterioration of water quality, and decline in biodiversity. Dal is a body of water located in Srinagar, which serves as the summer capital of Jammu and Kashmir. The urban lake, known as the "*Jewel in the crown of Kashmir*" or "Srinagar's Jewel," plays a crucial role in tourism and relaxation in the region of Kashmir. The lake serves as a vital resource for economic activities such as fishing and water plant harvesting.

Water testing is essential for monitoring the operations of water supply, assuring the safety of drinking water, detecting disease outbreaks, validating procedures, and implementing preventive measures. To assess the safety of drinking water, it is necessary to employ water quality testing methods either at the point of origin, inside a piped distribution system, or at the final consumer's location. Water quality surveillance and drinking water quality monitoring are distinct yet interrelated endeavours. The Dal Lake, spanning approximately 15.5 kilometres, is surrounded by a boulevard adorned with Mughal era gardens, parks, houseboats, and hotels. It serves as the primary water source for a significant part of Srinagar city.

The shore side Mughal gardens, including Shalimar Bagh and Nishat Bagh, constructed during the rule of Mughal Emperor Jahangir, offer picturesque vistas of the lake. Additionally,

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the lake can be admired from houseboats sailing in vibrant shikaras. In the winter season, the temperature occasionally drops to as low as −10 °C, causing the lake to freeze. The floating gardens, referred to as "Raad" in the Kashmiri language, flourish with lotus blooms in the months of June, July, and August. The wetland is partitioned by causeways into four basins: Gagribal, Lokut Dal, Bod Dal, and Nagin (although Nagin is also regarded as a distinct lake). Lokut-dal and Bod-dal both possess a central island, referred to as Rup Lank (or Char Chinari) and Sona Lank respectively. Dal Lake is intimately linked to houseboats, which serve as lodging options for tourists in Srinagar. The Hanjis, who have inhabited the Dal for millennia, have developed such a comprehensive infrastructure within the lake that they hardly need to venture onto land (Fazal & Amin, 2012) Dal Lake is important due to its strategic location and unique physical characteristics. A number of tourist attractions have been constructed around its border, including as the Mughal gardens, Nishat gardens, Shalimar gardens, Cheshma Shahi, Naseem Bagh, Pari Mahal, Botanical Garden, and several religious temples like Hazratbal and Shankaracharya temple.

Dal Lake, being a lake located in an urban area, has experienced changes in its surface water content due to the discharge of waste from municipalities and households. This has resulted in an increase in eutrophication of the reservoir (Hutchinson, 1999). In addition, high rates of the formation of sediments caused by widespread soil erosion resulting from degradation and intrusion by the neighbouring populace, have significantly decreased the volume of the lake (Chakrapani, 2002). The lake functions as a vital source of potable water and for griculture, fishing, recreational activities, and ecotourism. The biodiversity of lakeshore ecosystems is presently endangered by several human disturbances, with the most significant ones being elevated nutrient load, contamination, pH imbalances, and the introduction of non-native species (Bronmark and Hansson, 2002). The ecological strain on the ecosystem is evidenced by the decline in water quality and the heightened levels of biological productivity. Urbanisation generates significant amounts of pollutants and diminishes the ability of water to infiltrate the ground, resulting in increased surface runoff. Pollutants originating from urban land uses are more susceptible to being carried by runoff from the surface compared to pollution from other types of land applications. In their study, Kanakiya et al. (2014) examined the Water Quality Index of Dal Lake for all four basins during summer, winter, and monsoon seasons. They concluded that the water was unsuitable for consumption. Ahamad et al. (2023) performed a comparative evaluation of the water quality in Dal and Nigeen Lakes in Jammu and Kashmir, India. Their study emphasises the need for efficient water management techniques and conservation initiatives to safeguard the water quality of these lakes.

The Dal Lake is contaminated by sewage systems originating from nearby hotels, houseboats, and various small- and large-scale operations due to its passage through multiple locations within the city. This study was conducted on the Dal Lake, and five sampling locations were selected randomly, starting from Dal Gate and extending up to Dargah Hazratbal. An awareness program was also conducted for the residents living around Dal Lake and houseboat owners, focusing on the importance of cleaning and maintaining the water quality of Dal Lake. The program aimed to educate and involve the local community in preserving the lake's ecosystem, which is vital for both the environment and the livelihood of those dependent on the lake.

2. OBJECTIVES

The objectives of the present study were to:

- analyze the water quality at various points of Dal Lake, Srinagar.
- identify the reasons for the difference in the analyzed parameters.
- understand the public opinion through focus group discussions.

Based on the study results recommendations for improvement in the water quality can be suggested.

Study Area and Sampling

The Dal lake's shoreline, spans approximately 15.5 kilometres.

Water Sampling Spots from Dal Gate to Dargah Hazratbal

Water sampling along the stretch from Dal Gate to Dargah Hazratbal is critical for monitoring the quality and health of Dal Lake. This route covers diverse areas of the lake, each with distinct characteristics and varying degrees of human impact.

- **Dal Gate:** This is one of the primary outlets of Dal Lake, where water is regulated and flows out towards the Jhelum River. Due to its proximity to urban areas, Dal Gate often experiences higher levels of pollution from sewage and waste discharge. Regular sampling here is essential to assess the impact of urban runoff on the lake's water quality.
- **Nehru Park:** A popular tourist spot, Nehru Park is surrounded by houseboats and shikaras (traditional wooden boats). Water sampling in this area helps in evaluating the impact of tourism and houseboat activities on the lake's ecosystem.
- **Char Chinar:** This small island, with its iconic Chinar trees, is located towards the center of Dal Lake. Sampling here provides insights into the central part of the lake, where water quality may be influenced by a mix of natural processes and human activities from surrounding areas.
- **Nigeen Lake:** Connected to Dal Lake, Nigeen Lake is often considered a separate water body due to its relatively cleaner water (Mukhtar et al. 2014). Sampling in this area is important for comparing the water quality between the two interconnected lakes and understanding how activities in Dal Lake might affect Nigeen.

- **Hazratbal:** Near the northern end of Dal Lake, Hazratbal is a significant religious and cultural site. The area sees a mix of pilgrimage-related activities and local residential influence. Water sampling near Dargah Hazratbal is crucial for assessing the combined impact of religious activities and local habitation on the lake's water quality.

Mineralogy and Rock Types in the Area

The Dal Lake area, including the region extending from Dal Gate to Dargah Hazratbal, is geologically part of the Kashmir Valley, which is characterized by a complex assemblage of rock types and mineral deposits. The surrounding hills and mountains are primarily composed of:

- **Limestone:** The dominant rock type in the area is limestone, particularly in the Zabarwan Range that overlooks Dal Lake. This sedimentary rock is rich in calcium carbonate and contributes to the slightly alkaline nature of the lake's water. The weathering of limestone influences the mineral content of the water, particularly in terms of calcium and magnesium ions.
- **Shale:** Shale layers are also present in the region, particularly in the valley surrounding the lake. These fine-grained sedimentary rocks are rich in clay minerals and can contribute to the sediment load in the lake, especially during the rainy season when runoff increases.
- **Sandstone:** Sandstone deposits are found in some parts of the Kashmir Valley, including areas near Dal Lake. The sandstone here is generally composed of quartz and feldspar minerals, which are resistant to weathering and contribute to the coarser sediment fraction in the lake's deposits.
- **Glacial Deposits:** The Kashmir Valley has been shaped by glacial activity, leaving behind moraines and glacial till. These deposits, composed of a mix of rock types, contribute to the varied mineralogy of the sediments found in Dal Lake.

The interaction between these geological formations and the water of Dal Lake plays a significant role in determining the mineral content and overall chemistry of the lake's water. This, in turn, affects the aquatic life and the health of the lake's ecosystem.

The present study was carried out for the water quality assessment of Dal Lake. The study is based on primary and secondary sources of data. The primary information was collected from random sampling and testing in the laboratory. The present study is an attempt to examine the water quality in Dal Lake. The present research work is based on intensive fieldwork. The data and information were gathered from various sources. Inferences were drawn based on personal field survey and other field works and observations. Based on the random sampling method, the locations were classified based on the quality of water i.e., from every corner of the lake area, including the central part (Figure 1). The primary data thus gathered was processed, classified and quantified using MS-excel graphs. . Regarding water quality of the Dal Lake from different sources, the recent data was collected from the department of Jal Shakti Kashmir, Department of Lakes and water ways development authority (LAWDA), Srinagar municipal corporation (SMC), Srinagar development authority (SDA). Also data was obtained through discussions with the awareness among locals living around Dal Lake and among hanjis regarding degradation of the lake.

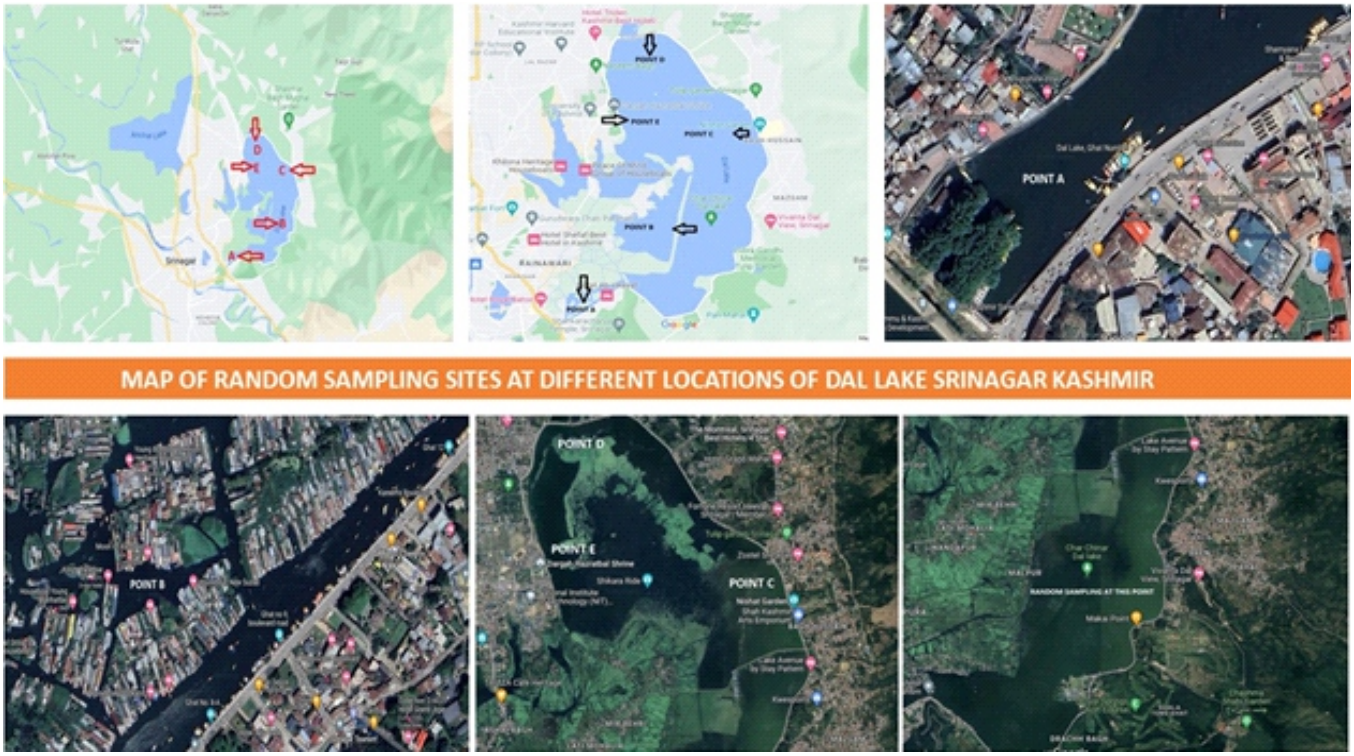

Figure 1: Map of sampling sites at different locations of Dal Lake, Srinagar, Kashmir

3. Methodology

3.1 Sample collection

Water samples were taken from Dal Lake at various locations detailed in Table 1. We chose these points for sampling because some points have occupied large areas with several houseboats resulting in more pollution where some areas are less affected, few other sites are heavily populated and have a greater impact on the water quality. Some points have become contaminated because of increased drainage systems that flow directly or indirectly into the dal lake. Field test kits were used to analyze samples on the spot from all the sites. The samples were collected using the grab sampling method. All samples were collected in 1.5 litre sterile bottles, transported to the lab, and processed within 1- 2 days.

Table 1: Location of sampling sites.

S. No	Name of Location and sampling points	Location Code	Latitude	Longitude
1.	Dalgate	A	34.0985	74.8761
2	Nehrupark	B	34.1251	74.8782
3	Charchinar	C	34.1032	74.8667
4	Nigeen	D	34.1182	74.8317
5	Hazratbal	E	34.1289	74.8425

3.2 Physicochemical and Biological analysis

The samples were collected from April 2024 to July 2024. Standard methods were used to investigate the physicochemical and biological parameters. pH (Digital pH meter Eutech), Turbidity, Total dissolved solid (TDS) was determined by (Digital meter Eutech), Electrical conductivity (EC) (Digital EC meter Eutech). Fluoride, Iron, Nitrate, Sulphate, Chloride, photo spectrometer E. coli by H_2S Vials. Total Alkalinity (TA) as HCO^{3-} , Calcium (Ca^{2+}), Magnesium (Mg^{2+}) Total hardness (TH), chloride (Cl), was estimated by standard titrimetry. Sulphate (SO_4^{2-}) by turbidometry, Nitrate (NO_3^{2-}) by UV-VIS spectrophotometer. Standard methods such as APHA (2017) and BIS were used in the analysis (2012). Field Test Kits were utilized for on-the-spot examination, and additional methods included photo spectrometric methods, turbidity and pH were measured using electrometric methods. As a result, the results were obtained using either digital meters or the colour comparison approach. Figure 2, 3 and Table 2 shows the sample collection, various water quality parameters analysed and the methods employed.

Figure 2: Instruments used, and methods employed.

Table 2: Water quality parameters analysed and methods employed.

Parameters	Methods Adopted	Equipment used
pH	Electrometric method	pH meter
Turbidity	Nephelometric method	Turbidity meter
Odour	Threshold water test	Burette
Taste	Flavour Rating Assessment	Beaker
TDS	Electrometric method	TDS/Conductivity meter
Electrical Conductivity	Electrometric method	TDS/Conductivity meter
Fluoride (as F)	(SPADNS) method	UV-Visible Spectrophotometer
Nitrate (as NO_3)	Chromotropic acid method	UV-Visible Spectrophotometer
Iron (As Fe)	UV-Visible Spectrophotometer	UV-Visible Spectrophotometer
Chloride (as Cl)	Argentometric method	Burette
Sulphate (as SO_4)	Turbidimetric method	UV-Visible Spectrophotometer
E. coli	H_2S vial test	Bacteriological Incubator

Figure 3: Sample collection at various points.

3.3 Focused Group Discussion (FGD)

This aimed to gather insights, opinions, and suggestions from various stakeholders involved in or affected by the condition of Dal Lake. The discussion focussed on understanding the current state of the lake, identifying challenges, and exploring effective measures for cleaning and maintaining water quality. A questionnaire was framed for the discussion and participants were asked about the general perception and other specific questions regarding the deterioration of the lake. The questionnaire is given below.

Questionnaire:

1. **General Perception:**
   - o What is your overall perception of the current state of Dal Lake?
   - o How do you believe Dal Lake has changed over the past few years?
2. **Personal and Community Involvement:**
   - o What steps are you personally taking to help clean and maintain the quality of Dal Lake water?
   - o How is your community or organization involved in preserving Dal Lake?
   - o What motivates you or your community to participate in these efforts?
3. **Awareness and Education:**
   - o How informed do you feel about the environmental issues affecting Dal Lake?
   - o What educational resources or programs have you participated in regarding Dal

Lake conservation?
- How do you think awareness can be increased among the general public?

4. **Challenges and Grievances:**
   - What challenges do you face in your efforts to clean and maintain the lake?
   - Are there any grievances or concerns you have regarding the current conservation efforts?
5. **Government and Organizational Support:**
   - How do you perceive the role of government and NGOs in the conservation of Dal Lake?
   - What support have you received from government agencies or NGOs?
   - What additional support do you believe is necessary from these entities?
6. **Impact of Tourism:**
   - How do you think tourism affects the water quality and overall health of Dal Lake?
   - What measures can be taken to balance tourism with conservation efforts?
7. **Houseboat Owners and Residents:**
   - What practices are houseboat owners and lakeside residents adopting to minimize pollution?
   - How do you manage waste disposal from houseboats and lakeside homes?
   - What support do you need to improve waste management practices?
8. **Suggestions for Improvement:**
   - What new initiatives or strategies would you suggest to further improve the quality of Dal Lake?
   - How can the local community be more effectively involved in the conservation process?
   - What role can schools, religious institutions, and local businesses play in this effort?
9. **Future Outlook:**
   - What do you envision for the future of Dal Lake if current conservation efforts continue?
   - How can we ensure the long-term sustainability of Dal Lake?

Random Questions:
1. How do you feel when you see pollution in Dal Lake?
2. What do you think are the main sources of pollution in Dal Lake?
3. How can we involve more youth in the conservation of Dal Lake?
4. What do you think about the current regulations on waste disposal near the lake?
5. How do seasonal changes affect the lake, and what can be done to mitigate these effects?
6. Do you think the current awareness programs are effective? Why or why not?
7. How do religious practices and rituals impact Dal Lake, and how can we manage this respectfully?
8. What role do you think traditional knowledge and practices play in the conservation of Dal Lake?

General Perception:
1. What is your overall perception of the current state of Dal Lake?
2. How do you believe Dal Lake has changed over the past few years?

Personal and Community Involvement:
1. What steps are you personally taking to help clean and maintain the quality of Dal Lake water?
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Future Outlook:
1. What do you envision for the future of Dal Lake if current conservation efforts continue?
2. How can we ensure the long-term sustainability of Dal Lake?

4. RESULTS AND DISCUSSION

Water is a crucial resource that is necessary for the survival of humans, as well as for the production of goods. The foundation and continuity of social and economic advancement rely on this vital resource (Taiwo et al. 2012). Uninterrupted and convenient availability of clean and high-standard water is an essential entitlement of every individual (Corcoran et al. 2010). The United Nations General

Assembly (UNGA) has identified the provision of clean water and sanitation for all as one of the key objectives to be accomplished by 2030 for sustainable development (UN, 2018). The quality of water is determined by its physical, chemical, biological, and visual characteristics. These factors are used to assess its suitability for various purposes, such as safeguarding people's health and maintaining the health of the aquatic environment. The qualities of water are primarily affected by substances that are either dissolved or suspended in it. Water quality can be altered by both natural processes and human intervention (DWA, 2010; Hubert and Wolkersdorfer, 2015).

The samples for the present study were analysed and were compared to the permissible limit given by the IS: 2296 and the Central Pollution Control Board (CPCB). A wide range of physico-chemical and biological characteristics were studied at these places, along with the comprehensive findings. Significant amounts of rubbish are indiscriminately discarded in various locations by visitors, houseboats, and through drainage systems. This poses a significant issue for the residents living in proximity to these sites and houseboats. The lake is contaminated by different types of waste materials, such as weeds and organic trash originating from nearby locations and marketplaces. These waste materials accumulate and create rubbish mounds at various locations, leading to pollution. Thirteen parameters were checked for Dal Lake in the water testing laboratory as well as on spot. The results obtained are given below in table 3.

Table 3: Water Testing Report of Dal Lake.

Sr. No	Parameter	Unit Site A	Sample Site B	Sample Site C	Sample Site D	Sample Site E	Sample	MEAN
1.	pH	-	7.8	7.7	8.3	8.2	8.5	8.38
2.	Turbidity	NTU	25.95	20.00	27.59	33.62	29.20	32.672
3.	Odour	mg/l	O	O	O	O	O	Objectionable
4.	Taste	mg/l	O	O	O	O	O	
5.	TDS	mg/l	105.4	110.1	119.5	97.4	160.5	118.58
6.	Conductivity	μs/cm	219.3	260.2	199.3	187.4	178.5	208.94
7.	Fluoride (as F)	mg/l	0.00	0.01	0.00	0.01	0.00	0.004
8.	Nitrate (as NO_3)	mg/l	10	05	10	10	05	8.00
9.	Iron (As Fe)	mg/l	0.00	0.01	0.00	0.01	0.00	0.004
10.	Chloride (as Cl)	mg/l	10	05	15	10	20	12.00
11.	Sulphate (as SO_4)	mg/l	0.10	0.50	0.80	0.30	0.10	0.36
12.	Hardness	mg/l	200	180	210	250	160	200
13.	Alkalinity	mg/l	150	110	140	130	120	130
14.	E. coli	MPN	Positive	Positive	Positive	Positive	Positive	-
15.	Residual Chlorine	mg/l	Raw	Raw	Raw	Raw	Raw	-

4.1. pH

According to water quality standards, the pH limits should be 6.5 - 8.5. The pH values for all the samples were above 7.0 at all points (Figure 4). The pH of all the samples was found to be within the BIS range of 6.5 to 8.5. Samples were mostly neutral. The pH from A to E points were normal. The pH limit for drinking water is 6.5 to 8.5. Majority of the samples most of the time showed more than a pH of 8 (Table 1). Similar results were reported by other researchers on the dal lake. Therefore, the pH fluctuated from 7.8 to 8.5. In lakes the occurrence and abundance of components of carbonate system and the pH are determined primarily by current and chemical nature of the substrate. The pH greatly affects the biogeochemistry in aquatic ecosystems, such as growth of fishes and aquatic plants. Because most of their metabolic activities are pH dependant, pH has an impact on aquatic species.

Figure 4: pH of the samples analysed.

4.2. Turbidity

The samples were tested for their turbidity, and it was observed to be high and exceeds the permissible limits at almost all points (Figure 5). At point A it was 25.95 NTU and it was above 25 NTU at points C, D, and E but remains above 20 NTU at all points up to point E. At point A the turbidity was noted as (25.95), B (20.0), C (27.59), D (33.62), E (29.20) NTU. Hence, turbidity was above permissible limit at all points (Table 2). The normal range of turbidity as per BIS is that it should not exceed 5NTU.The higher turbidity values indicate pollution and contamination of the waters.

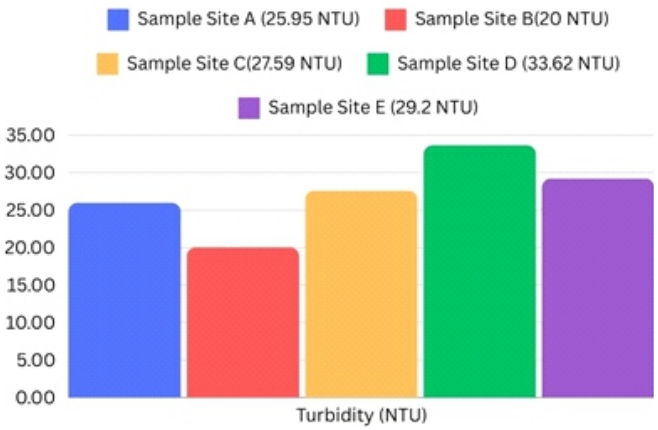

Figure 5: Turbidity of the samples analysed.

4.3 TDS:

High concentrations of total dissolved solids (TDS) was observed at site E with 160.5 mg/L. This may be due to saprophytic substances due to the decomposition of aquatic plants and animals. The lowest value of TDS was 97.4 mg/L at site D (Figure 6). The rainwaters may have a role in this decrease of TDS concentration during monsoon.

Figure 6: TDS of the samples analysed.

4.4 Conductivity:

This served to assess the purity of water and the conductivity was not more than 260 and not less than 170 thus, average conductivity was around 208.9 us/cm (Figure 7). A high level of conductivity may indicates the pollution status of the lake as well as trophic levels.

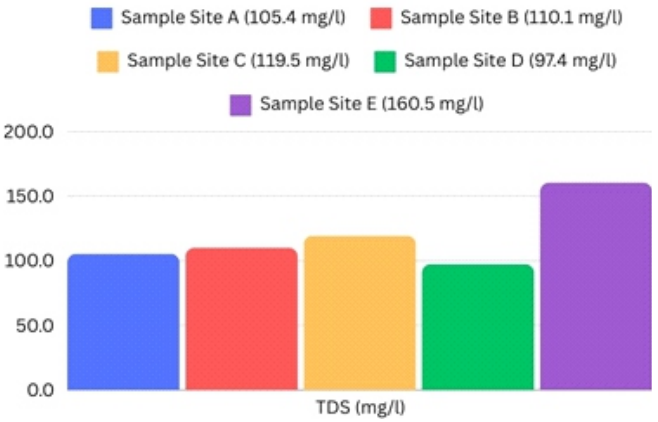

Figure 7: Conductivity of the samples analysed.

4.5. Fluoride:

Fluoride was also determined spectrophotometrically. Fluorides in the water samples were present within permissible limits (Figure 8). It did not go above 0.5 at all points (Table 2). The permissible limit for fluoride is 0.5-1.5 mg/l as per BIS and WHO. Very low levels of fluorides can lead to deficiency and health effects such as dental caries and higher levels can lead to bone deformities and mottling of the teeth.

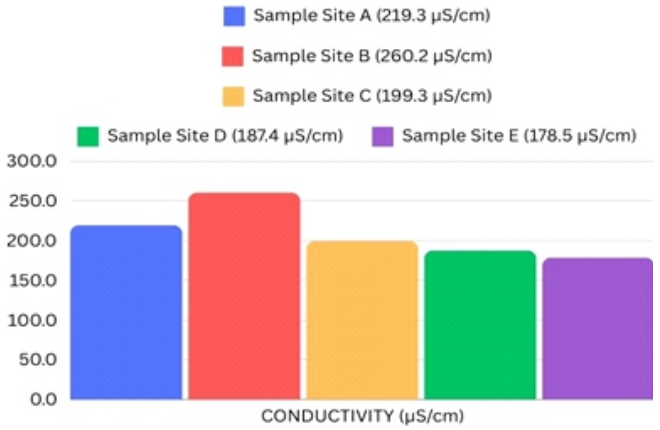

Figure 8: Fluoride content of the samples analysed.

4.6. Nitrate:

Nitrate was estimated using a UV-Visible Spectrophotometer. Nitrogen and phosphorus are important factors in an aquatic ecosystem and play a key role in the productivity of an aquatic habitat. Nitrates were present within the permissible limits at all points throughout the period of study. The maximum permissible limit of Nitrate is 40 mg/l.

Almost all the samples had nitrate levels of nearly 05-10 mg/l (Figure 9).

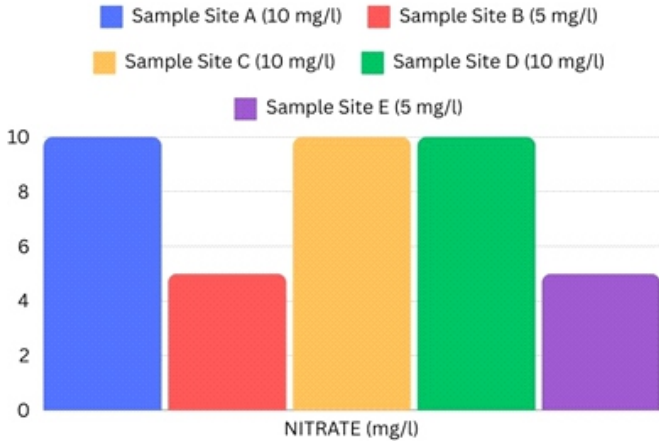

Figure 9: Nitrate content of the samples analysed.

4.7. Iron:

Iron was also determined spectrophotometrically. Iron in the water samples was zero at all points (Table 2). Hence the water was free from iron content at all points of the study area. The permissible limit for iron is up to 1 mg/l as per BIS and WHO.

4.8. Chloride:

Highest concentrations of chloride of 20 mg/L was reported at site E (Figure 10). The high chloride concentrations indicate the presence of organic matter. The lowest value of chloride was 05 mg/L at site B. It may be possible that during the rains dilution of lake can occur. Similar values between 15 -28 mg/L were reported in Dal lake by Samie and Khan, 2022).

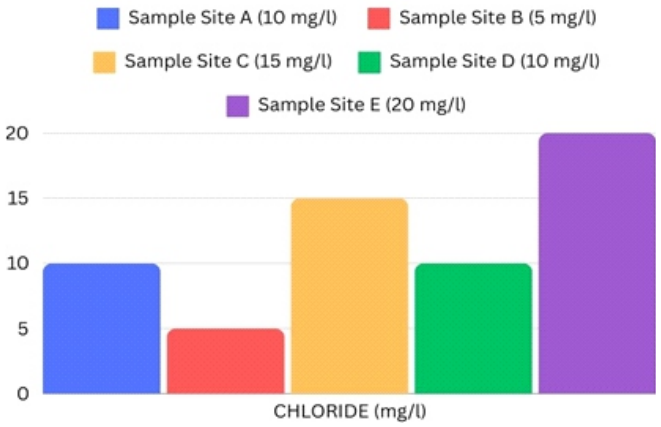

Figure 10: Chloride content of the samples analysed.

4.11. Alkalinity is the capacity of water to neutralize acid. It is a measure of bicarbonates, carbonates and hydroxides present in water. Alkalinity was found to be within permissible limit. Total alkalinity of all the samples was not found to be higher than permissible

4.9. Sulphate

Sulphate concentration was analysed through spectrophotometer as well as on spot using Field Test Kit Sulphate was found within the permissible limits at all sampling points (Figure 11). At point A, sulphate was observed as 0.10 mg/l. The points at B,C,D and E recorded almost similar values of sulphate concentrations from 0.1 and 0.8 mg/l (Table 2, Figure 4). The higher values may be due to municipal waste effluents and agricultural run-off.

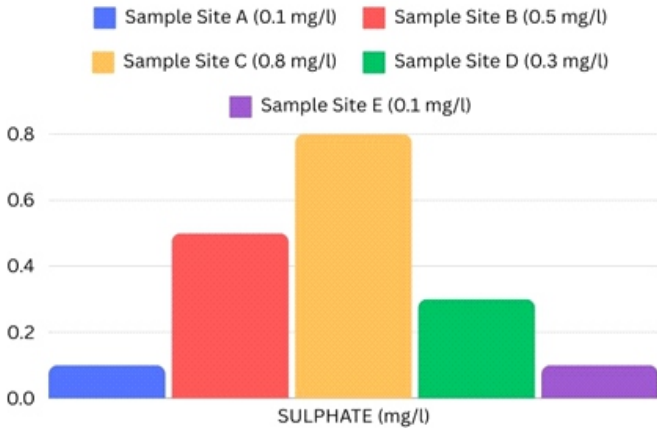

Figure 11: Sulphate content of the samples analysed.

4.10. Hardness.

Total hardness of all the samples was found to be within permissible limit. Average total hardness of most of the samples in the study area was found to be higher than 150mg/l indicating that the water is hardwater. Total hardness in most cases is always higher than 200mg/l which is the permissible limit by BIS as well as WHO standards. At point A Hardness was found (200). B (180), C (210), D (250), E (160) mg/l (Figure 12).

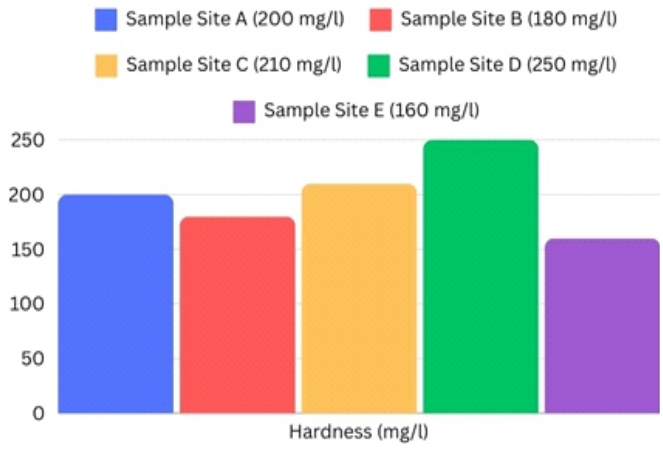

Figure 12: Hardness of the samples analysed.

value (200mg/l & 600mg/l) suggested by BIS as well as WHO. At point A Alkalinity was found (150). B (110), C(140),D(130),E(120) mg/l (Figure 13).

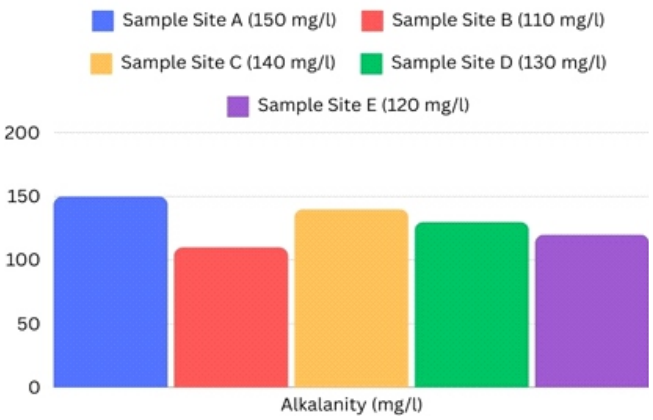

Figure 13: Alkalinity of the samples analysed.

4.12. Residual chlorine the value of residual chlorine at all points was 0mg/l.

4.13. Taste & Odour Taste and Odour was Objectionable at all points.

4.14. Total coliforms

Bacteriological contamination was found at all points (Table 2). The reason for the bacteriological contamination may be that at most of the places all the waste products, animal debris, drainage waste, were thrown to the Dal Lake which has resulted in the biological contamination of all samples. Bacteriological parameters were analysed using H_2S Vial.

The results suggest that the lake is polluted with respect to the biological wastes which affect the overall water quality and dissolved oxygen in the lake.

Several reports have studied the lake on different aspects. Samie and Khan (2022) observed higher values of concentration of major elements in the Dal lake nearer to the sewer drains, restaurants and other commercial activity areas. Similar observations of the lake degradation was reported by Kumar et al. (2022). Heavy metal contamination causing toxicity in the Dal Lake has been reported by several researchers (Mukhtar and Chisti, 2018; Shah et al. 2021). Discharges and releases of untreated water from houseboats and motorboats have contaminated the lake with hydrocarbons and heavy metals (Kumar et al. 2022).

4.13 Findings of the Awareness Program:

Dal Lake is not only a popular tourist attraction but also a critical source of water and livelihood for many residents. The program highlighted the ecological significance of the lake and its role in supporting biodiversity. Discussions were held on the various factors contributing to the pollution of Dal Lake, such as sewage discharge, waste disposal, and the use of non-biodegradable materials. The participants were made aware of how these practices negatively impact the water quality and the lake's overall health.

4.14 Role of Houseboat Owners and Local Residents:

The program emphasized the responsibilities of houseboat owners and local residents in maintaining the cleanliness of the lake. Participants were encouraged to adopt eco-friendly practices, such as proper waste management and minimizing the use of harmful chemicals (Figure 14).

Figure 14: Various dustbins & hoardings installed at various points around the lake.

Community Involvement in Conservation Efforts: The importance of community participation in conservation efforts was underscored. Residents were encouraged to form local groups to monitor and maintain the cleanliness of their surroundings, and to report any activities that might harm the lake's ecosystem.

Government Initiatives and Support: Information was provided on the various government initiatives aimed at preserving Dal Lake, including financial assistance for adopting eco-friendly practices and the implementation of stricter regulations on waste disposal. The program also highlighted the role of government agencies in supporting the community's efforts.

Interactive Sessions and Feedback: The program included interactive sessions where participants could voice their concerns and suggestions. This feedback was crucial for understanding the challenges faced by the community and for developing more effective conservation strategies.

Outcome: The program successfully raised awareness among the participants about the critical need to preserve Dal Lake. The active involvement of the community and the commitment shown by the houseboat owners were promising steps towards ensuring the lake's long-term sustainability. Follow-up initiatives are planned to maintain momentum and ensure continuous community engagement in the conservation of Dal Lake. This awareness programme marks a significant effort in the mission to protect and maintain the pristine condition of one of Kashmir's most treasured natural resources.

Overall perception of the current state of Dal Lake: Participants generally expressed concern about the deteriorating state of Dal Lake. Many noted that the water quality has significantly declined due to pollution, encroachments, and unchecked tourist activities. However, some participants were optimistic about recent conservation efforts, though they emphasized that much more needs to be done. Most participants observed a noticeable decline in the lake's health over the past few years. They pointed to increased algae blooms, reduced water clarity, and the shrinking size of the lake as evidence of ongoing environmental degradation. Some noted that the lake has lost much of its former beauty and ecological balance (Figure 15, 16).

Figure 15: Sampling sites where aquatic weeds, silt & untreated sewage was found.

Figure 16: Sampling sites with high turbidity and other contaminant.

4.15 Personal and Community Involvement: Participants shared various personal efforts, including reducing plastic use, participating in clean-up drives, and educating others about the importance of preserving the lake. Houseboat owners mentioned efforts to improve waste management, while local residents discussed using organic methods in their nearby gardens to reduce runoff. Many participants described their community's involvement in initiatives such as regular clean-ups, awareness campaigns, and advocacy for stricter environmental regulations. Some communities have formed local groups dedicated to monitoring and reporting pollution sources, while others collaborate with NGOs to implement sustainable practices. Participants expressed a strong emotional and cultural connection to Dal Lake as their primary motivation. The desire to preserve the lake for future generations and the recognition of its importance to their livelihood, culture, and environment were also frequently mentioned.

4.16 Awareness and Environmental Education: Most participants felt moderately informed about the issues. They acknowledged that while they are aware of the general problems, there is a need for more detailed and accessible information, especially regarding effective conservation methods.

Some participants had attended workshops and training sessions organized by local NGOs and government agencies. However, many noted that such programs are not widespread, and access to educational resources is often limited. Suggestions included launching more targeted awareness campaigns, using social media platforms, involving schools in environmental education, and organizing community event focused on lake conservation (Figure 17). Participants also emphasized the importance of continuous education rather than one-time events.

Figure 17: Awareness Programmes Conducted.

4.17 Challenges and Grievances: Participants identified several challenges, including a lack of resources, and the difficulty of changing long-established practices among the local residents. The influx of tourists and the resulting waste were also significant concerns. Many participants voiced concerns about the lack of enforcement of existing regulations.

4.18 Government and Organizational Support: While participants acknowledged the efforts of both government and NGOs. There was a call for more proactive and transparent actions from the government, as well as greater collaboration between NGOs and local communities. Some participants reported receiving technical support, training, and resources from NGOs, while others mentioned government schemes aimed at improving waste management. Participants highlighted the need for more financial assistance, better infrastructure for waste management, and stronger enforcement of environmental laws. There was also a call for more inclusive planning processes that involve local communities in decision-making. Further extraction of the weeds and using them as biofertilizers is also being in the lake (Figure 18).

Figure 18: Sampling sites where tones of weeds, silt are extracted and used as biofertilizers.

4.19 Impact of Tourism: Participants generally agreed that tourism significantly impacts the lake's health, particularly through waste generation and increased boat traffic. The seasonal influx of tourists often leads to higher levels of pollution, which are difficult to manage with the current infrastructure. Suggestions included implementing stricter regulations on waste disposal, promoting eco-friendly tourism, and educating tourists about the importance of preserving Dal Lake. Participants also suggested creating designated areas for tourist activities to minimize their impact on the rest of the lake.

4.20 Houseboat Owners and Residents: Houseboat owners mentioned efforts to improve waste disposal practices, such as using bio-digesters and reducing the use of harmful chemicals. Some residents discussed community-driven initiatives to clean the lake and reduce household waste. Participants mentioned the use of both traditional and modern waste management practices. However, many noted that the infrastructure is still inadequate, leading to some waste inevitably ending up in the lake. There was a strong desire for more effective waste management solutions. Houseboat owners and residents expressed a need for better access to waste disposal facilities, more frequent waste collection services, and financial assistance to adopt eco-friendly technologies. There was also a call for more educational programs to help residents understand the best practices for waste management.

4.21 Suggestions for Improvement: Participants suggested a range of initiatives, including introducing stricter environmental regulations, launching large-scale clean-up operations, and developing better waste management infrastructure. They also emphasized the importance of continuous monitoring and research to track the lake's health. Participants recommended establishing community-led conservation groups, increasing the frequency of community meetings, and involving local leaders in decision-making processes. They also suggested that more resources be allocated to community education and empowerment.

Participants saw schools as crucial in educating the next generation about the importance of Dal Lake. Religious institutions were seen as potential leaders in promoting eco-friendly practices during rituals, while local businesses could support conservation efforts through funding and sustainable practices.

4.22 Future Outlook: Opinions were mixed, with some participants expressing optimism that the lake could recover if efforts are intensified and sustained. Others were more pessimistic, fearing that without significant changes, Dal Lake could continue to degrade. Participants emphasized the need for a multi-faceted approach, combining strong regulations, community involvement, and continuous monitoring. They also highlighted the importance of integrating traditional knowledge with modern conservation techniques to ensure the lake's long-term sustainability. Based on feedback from locals living around Dal Lake, the following species contribute to water pollution in different ways:

1. **Mangola:** This plant species tends to grow rapidly in the lake, forming dense mats that block sunlight and reduce oxygen levels, leading to poor water quality and harming aquatic life.
2. **Kandil:** Similar to mangola, kandil's dense growth blocks sunlight, which disrupts the natural ecosystem of the lake. It also decays in the water, releasing nutrients that lead to further algae blooms and deoxygenation.
3. **Shallot:** Shallot species, when overgrown, can contribute to nutrient overload in the lake. The decaying matter from these plants adds to the organic load in the water, worsening the water quality.
4. **Khor:** Khor contributes to the sedimentation of the lake, making the water murky. It also interferes with the natural flow of the water, trapping pollutants and contributing to the overall degradation of water quality.
5. **Oov:** This species tends to accumulate organic matter, which decays and depletes oxygen in the water. The resulting eutrophication leads to the growth of harmful algae and a decline in water quality.
6. **Goor:** Goor species are known to form thick mats on the water surface, which block sunlight and reduce the oxygen levels in the water. This leads to the death of fish and other aquatic organisms, further polluting the lake.
7. **Zud:** Zud contributes to nutrient overload in the lake, especially when it decomposes. This leads to algal blooms and the depletion of oxygen, which can cause dead zones in the lake.
8. **Bumb:** Bumb species, by growing excessively, block sunlight and reduce oxygen levels in the water. Their decay further adds to the organic load, worsening the overall water quality.
9. **Nadhil:** Nadhil species trap sediment and organic matter, which decay and contribute to the eutrophication of the lake. This results in the growth of harmful algae and a decrease in water quality.
10. **Batikhor:** Batikhor also contributes to sedimentation and nutrient overload, leading to water pollution. Its dense growth blocks sunlight and disrupts the natural ecosystem of the lake.
11. **Pumbich:** Pumbich species can quickly cover large areas of the lake, blocking sunlight and reducing oxygen levels. Their decay adds to the organic load in the water, leading to poor water quality.
12. **Lotus:** While lotus is aesthetically pleasing, its large leaves can block sunlight, affecting underwater plant growth. The decay of lotus plants adds organic matter to the lake, contributing to eutrophication and pollution.
13. **Azola:** Azola is an invasive species that grows rapidly, covering the water surface and blocking sunlight. This leads to reduced oxygen levels in the water and the death of aquatic organisms, further degrading the water quality.
14. **Weed:** Various weed species contribute to the nutrient load and organic matter in the lake, leading to eutrophication. Their overgrowth can also block sunlight and reduce oxygen levels, harming aquatic life.

On the other hand, Khel is considered beneficial as it removes weeds from the lake, helping to maintain the water quality. Additionally, the STP sump (containing drainage and trench water) is a significant source of pollution in Dal Lake. It introduces untreated or poorly treated wastewater into the lake, which carries organic pollutants, chemicals, and pathogens. This further deteriorates the water quality, harming aquatic life and making the water unsuitable for human use.

5. CONCLUSION

The current analysis demonstrates that the parameters examined fall within the acceptable thresholds along the Dal Lake. There is evidence of biological contamination at all locations. The Government should consistently take measures to ensure the impeccable quality of the Dal. During the focused group talks, it was noted that most individuals exhibited a significant level of awareness and were

also highly motivated to contribute to the preservation of clean water. For maintaining the cleanliness of Dal Lake, it is necessary to have contributions and assistance from both the organised and unorganised sectors, in addition to the efforts made by our governments.

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