International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-9, Issue-2, April 2022
https://doi.org/10.55524/ijirem.2022.9.2.80
Article ID IJIR-2283, Pages 496-502
www.ijirem.org

Water Quality Assessment of Dal Lake and Impact of STP's on Health of Dal Lake

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ABSTRACT- Lakes all across the world have been severely altered or deteriorated at a rate far faster than their rehabilitation. Dal Lake, in the heart of Srinagar, Jammu and Kashmir's summer capital, has seen a dramatic decline in water quality due to anthropogenic stresses over the previous four decades, rendering it unfit for domestic usage and aesthetic purposes. The problems of sewage disposal and contamination of surface waters in lakes are rapidly rising as a result of urbanization, modernization, and population development. The discharge of untreated sewage, agricultural runoff, and silt from adjacent catchments has degraded the lake's water quality even more. Variations in water quality can be seen in the physio-chemical characteristics of the lake waters. Substances such as phosphates, nitrates, and chlorides have increased while the lake's transparency and dissolved oxygen levels have decreased. The goal of this project is to look into and explain how sewage treatment plant effluent affects water quality, as well as to describe the current state of the lake's water quality.

KEYWORDS- Dal Lake, Biochemical Oxygen demand (BOD), Chemical Oxygen demand (COD), Sewage Treatment plant, FAB Technology.

I. INTRODUCTION

Dal Lake situated at an altitude of 1800 m (ASL) between 34°5´-34°7´ N latitude and 74°8´-74°9´ E longitudes, in the heart of Srinagar City, is the most stunning of these water basins. It is the second largest lake in the state of Jammu and Kashmir, and one of India's most beautiful lakes. The word Dal is derived from a Tibetan term that means "still". A prominent historic peak known as Shankaracharya Hill may be observed on the eastern side of the lake. Hariparbat, hill in the west also adds its grace. It is linked to the Jhelum River through chuntkoul via Dal lock gate at Dalgate and with Anchar Lake via Amir Khan Nallah respectively. The Lake was surveyed, using Electronic Total Station, by the Deputy Commissioner Srinagar in 2009 AD which suggested that the total area of lake as 49432 Kanals 18 Marla's (25 Sq. Km) with water surface as 39226 Kanals (19.83 Sq. Km) and 10206 Kanals 18 Marla's (5.17 Sq. Km) as land mass, cultivation etc. The Satellite image of 2009 got from National Remote Sensing Department (GOI) and analyzed by Department of Ecology, Environment and Remote Sensing (J&K) had revealed total area of lake as 25.76 Sq. Kms with the breakup of 20.21 Sq. Kms as water and 5.55 Sq. Kms as land mass, cultivation etc. The digitized image of 1924 map (courtesy: Town Planning Organization Kashmir) using computer software reveal that clear waters have been only 12.44 Sq. Kms (50.83%) of a total area of 24.465 Sq. Kms. Numbal/wetlands have been 7.87 Sq. Kms (32.16%). Gardens/Malyari land has been 3.33 Sq. Kms (13.61%). Road Network 0.26 Sq. Kms (1.06%) and the built-up area as 0.57 Sq. Kms (2.33%). The gross breakup of water and watery area as such would add up to 20.305 Sq. Kms (83%) and land mass as 4.16 Sq. Kms (17%). The Satellite Image of 2013 as analyzed by Department of Ecology, Environment & Remote Sensing reveals that the total area of the Lake is 24.789 Sq. Kms. Nigeen, Gagribal, Lokut Dal and Bod Dal are the four basins of the Lake. Nigeen and Gagribal, with depths of roughly 6 m and 2.25 m, respectively, are the deepest and shallowest basins. [15].

The lake's catchment encompasses 317 square kilometres. Dal Lake is considered one of the world's most beautiful lakes. However, as we can see today, the Dal is in a horrible position, which may contradict the remark. However, the lake remains Srinagar's principal attraction, as well as a source of water for the city's domestic use. Dal Lake provides excellent social and economic services, but it is nearing the end of its life cycle. The Dal dwellers are primarily responsible for the encroachment of Dal Lake, which degrades the lake's ecosystem. According to Fazal and Amin, the hanji community's economic reliance on the lake caused a social revolution that resulted in the conversion of land use classes in and around the lake. They also claim that the increased tourist influx to the lake has resulted in city inhabitants gaining space to develop and run their businesses in the form of hotels and restaurants in and around the lake, resulting in the lake's land transformation. The marshy regions around the lake that have been transformed into construction land and floating vegetable fields are one of the primary drawbacks and from marshy areas and lake areas have also increased in plantation/orchards. Land under agriculture is also acquiring land from lake water and plantation/orchard, according to the findings of the study. According to reports, Dal Lake's 1200 house boats generate around 9000 metric tons of waste each year, which is discharged into the lake [7]. The Lake is ecologically rich in Emergent, Submerged and floating macrophytes and Phytoplankton. The lake is noted in particular for its Nelumbo nucifera which bloom in July and August every year, Major activities in Dal Lake are fisheries, harvesting of food and fodder plants The Lake is a major source of vegetable supply to the city apart from production of fish. Large quantity of Nadru (Lotus Stem) and vegetables are cultivated within the lake in water, on land masses and floating gardens. This lake has fallen victim to human greed as a result of which its entire ecosystem is rapidly changing. The lake once famous for its pristine beauty is losing its charm due to heavy pollution load, encroachments, unplanned growth of hamlets and ever-increasing anthropogenic pressure.

II. LITERATURE REVIEW

Some of the earlier reported studies on Dal Lake are enclosed below:

Adnan and Kundangar (2009) while studying the bacterial Dynamics of Dal Lake correlating the bacterial population density with physico-chemical parameters recorded high population density of faecal coliforms and Total coliforms around houseboat areas of Dal Lake, Adnan and Kundangar in a research paper entitled, “Three Decades of Dal Lake” recorded the changes in hydro-chemistry and biodiversity of Dal Lake during the last three decades besides giving the current ecological status of Dal Lake. The authors revealed that FAB based sewage system treatment for effluents entering the lake at Hazratbal, Habak are a total failure particularly during winter months. [1]

Er. Qazi Tanveer, Er. Kshipra Kapoor, Dr. M.R.D. Kundangar (2017) in their research paper entitled, “Impact of Houseboat Sanitation on Ecology and Health of Dal Lake Kashmir “concluded that the Sewage Treatment plants are potential source of Pollution than those of Houseboats as they are discharging loads of hazardous nutrients like nitrates and phosphates round the clock into the lake body hence warrant immediate solution including those of houseboats as well. [5]

J&K State Pollution Board (PCB) (2009) in a status report on Dal Lake described the ecological situation of Dal Lake visibly bad with intense overgrowth of weeds and algal patches. The water quality at many places was recorded septic in nature with high content of P, N and suggested tertiary treatment measures. [15]

Mudasir Ahmad wani, Ashit Dutta, M. Ashraf Wani, Umer Jan Wani in their research paper titled, “Towards conservation of world-famous Dal Lake- A Need of Hour”, stated that Pollutants that enter into Dal Lake are sewage, solid wastes, agricultural wastes, detergents and soaps, soil erosion from catchment area, animal wastes and wastes from houseboats, hotels and business establishments. Choking of Dal Lake has occurred due to closure of its natural drainage system called “Nalla Mar”, which has been converted into macadamized road. Immediate remedial measures are needed to salvage the lake and long-term rehabilitation measures are needed to preserve the lake for future generations. [11]

Murtaza (2010) while studying the impact of pollutants on physico-chemical parameters of Dal Lake reported increase in specific conductivity, total alkalinity and nitrate-nitrogen besides decrease in dissolved oxygen, silicates and phosphorous. [12]

III. MATERIALS AND METHODOLOGY

The study was carried out to determine the current water quality and effect of Sewage treatment plants on health of Dal Lake using some normal methods at Pollution Control Committee Srinagar J&K during the year 2021.The details of the sampling sites, techniques followed and materials used during the course of investigation are presented below.

A. Area Of Study

Dal Lake, a multi-basined lake, was chosen for the current study, which took place from October 2021 to December 2021.Water samples were gathered from seven sites. To check the extent of pollution, one polluted location near a Sewage treatment plant was chosen, along with an open water non-polluted site. STP Nishat, STP Habak and STP Hazratbal are the polluted sites, whereas Char-Chinari and Sonalak are open water sites. Two locations for entry (Tailbal) and exit (Dalgate) were also chosen. Samples were also collected from 3 STP’s namely STP Nishat, STP Habak and STP Hazratbal, after every 15 days during the research period.

B. Methodology

From October 2021 to December 2021, sampling was conducted for three months. Grab sampling was used in the research. Water samples were gathered every 15 days during the investigation from ten different locations. Water samples were taken at all of the locations in 1-liter plastic bottles which had been rinsed with distilled water before being filled with sample water for 3-5 times. To prevent sample misidentification, labels were utilized. Physical, chemical, biochemical, and chemical oxygen demand samples were all collected separately. Separate samples of dissolved oxygen (DO) were collected in BOD bottles, and the DO was fixed on site with Winkler's and Manganese reagent. COD samples were collected in 250ml bottles and stored in 2ml Sulphuric acid. Water samples were analyzed physically and chemically in accordance with protocols outlined by the American Public Health Association (APHA).

C. Details Of Sampling Locations

Sampling sites are situated in and around Dal Lake, details of which are given in Table 1. STP sites are designated as:
S8: STP Nishat
S9: STP Habak
S10:STPHazratbal

Table 1: Detail of Sample Sources

Sample No.	Sample Site	Latitude	Longitude	Depth	Transparency
1	Tailbal (S1)	34° 8' 45.9348" N	74° 50' 53.592" E	1.524 m	0.76 m
2	Char-Chinari (S2)	34° 7' 52.7088" N	74° 50' 53.538" E	2.514 m	0.63 m
3	Near STP Nishat (S3)	34° 6' 7.5672" N	74° 52' 2.532" E	1.320 m	0.66 m
4	Near STP Habak(S4)	34° 8' 44.0772" N	74° 50' 34.6632" E	1.044 m	0.50 m
5	Near STP Hazratbal (S5)	34° 7' 56. 3124" N	74° 50' 31.9776" E	1.168 m	0.60 m
6	Sonalak (S6)	34° 7' 52.7088" N	74° 50' 53.538" E	2.438 m	1.06 m
7	Dalgate (S7)	34° 4' 53. 9436" N	74° 49' 49.476" E	1.980 m	0.79 m

IV. RESULTS

A. pH

pH is defined as the logarithm of the reciprocal of hydrogen ion concentration. It ranges from 0 to 14, with 7 being neutral; less than 7 indicates Acidity whereas greater than 7 indicate Alkalinity. In general, water is a combination of positively charged hydrogen ions (H^+ions) and negatively charged hydroxyl ions (OH^-ions). In pure water the concentration of H^+ions is equal to that of OH^-ions. When some substance is dissolved in pure water the solution formed ionizes and the balance between the concentrations of H^+ions and OH^-ions is disturbed. If the concentration of H^+ions is in excess of the concentration of OH^-ions the water solution becomes acidic and vice-versa. The acidity in the water is caused by the presence of mineral acids, free carbon dioxide, sulphates of iron, aluminium etc. on the other hand the alkalinity in water is caused by the presence of bicarbonates of calcium and magnesium or by the presence of carbonates or hydroxides of sodium, potassium, calcium and magnesium. Lower pH is harmful to immature fish, insects and also accelerate the release of metals from rocks or sediments while as higher values can indirectly alter aspects of water chemistry.

Table 2: pH profile of chosen sites

pH	Ist Sampling	2nd Sampling	3rd Sampling	4th Sampling	5th Sampling	6th Sampling
S1	8.12	8.09	7.62	7.49	7.71	7.68
S2	7.30	7.29	7.69	7.73	7.59	7.42
S3	7.54	7.40	7.82	7.91	7.9	7.50
S4	7.38	7.45	7.35	7.49	7.4	7.32
S5	7.97	7.87	7.56	7.63	7.65	7.45
S6	7.85	7.91	7.90	7.97	7.95	7.85
S7	7.33	7.31	7.42	7.39	7.69	7.54
S8	7.30	7.35	7.35	7.50	7.12	7.37
S9	7.01	7.24	7.21	7.63	7.63	7.42
S10	7.51	7.62	7.24	7.73	7.69	7.52

During the months of the investigation, from October 2021 to December 2021 no significant changes in pH were found at any of the locations. The pH range recorded for all the sampling sites lies within the tolerance limit i.e., 6.5-8.5 as shown in Table 2.

Our results coincide with the findings of references [9]-[21] who found the pH of the lake varies between 7.4 and 8.9. Since 1987, pH levels have been fluctuating. The pH of the lake, according to [22], ranged from 7.4 to 9.5 at various sites, with an average of 8.4.

B. Ortho Phosphate (PO_4)

Phosphorus is a common constituent of agricultural fertilizers, manure, and organic wastes in sewage and industrial effluent. It is an essential element for plant life, but when there is too much of it in water, it can speed up eutrophication (a reduction in dissolved oxygen in water bodies caused by an increase of mineral and organic nutrients) of rivers and lakes. Presence of phosphates in large quantities indicates pollution through sewage and industrial wastes. Phosphorus occurs in natural waters and in waste water in the form of various types of phosphates. Municipal sewage contains ortho phosphates, polyphosphates in soluble form, present either in the particles of detritus or in the bodies of aquatic organisms. Usually, polyphosphates undergo hydrolysis and revert to orthophosphate forms. Phosphate determination is useful in measuring the water quality since it is an important plant nutrient and may play a role of limiting factor among all other essential plant nutrients [4].

Table 3: PO4 profile of chosen sites

PO4	Ist Sampling	2nd Sampling	3rd Sampling	4th Sampling	5th Sampling	6th Sampling
S1	0.210	0.198	0.169	0.158	0.076	0.071
S2	0.112	0.103	0.085	0.079	0.100	0.125
S3	0.189	0.172	0.210	0.259	0.150	0.179
S4	0.232	0.250	0.165	0.170	0.180	0.195
S5	0.161	0.182	0.119	0.291	0.110	0.129
S6	0.163	0.184	0.075	0.089	0.062	0.079
S7	0.119	0.150	0.097	0.083	0.048	0.039
S8	0.707	0.661	0.535	0.713	0.502	0.590
S9	0.829	0.912	1.029	1.128	1.210	1.017
S10	0.329	0.416	0.812	1.210	0.910	1.112

The orthophosphate concentration ranges from 0.089 to 0.198 ppm at all seven locations, with higher values near STP Habak given in Table 3. This is due to the discharge of effluent from STP's having higher orthophosphate values than tolerance limits, resulting in it becoming a point source of pollution. Ortho-Phosphate is the most important limiting nutrient in freshwater systems, leading to eutrophication. It's a crucial nutrient that causes eutrophication and is only used in small amounts by algae [20].

C. Ammonical Nitrogen (NH3-N)

Ammonical nitrogen (NH_3-N) is a measure for the amount of ammonia, a toxic pollutant often found in landfill leachate and in waste products, such as sewage, liquid manure and other liquid organic waste products. It can also be used to assess the condition of water in natural bodies like rivers and lakes, as well as in man-made reservoirs. Because ammonia is the most important plant nutrient, its concentration influences the nutrient load and pollution level in a water body. It's made when organic nitrogenous matter is decomposed by microbes. Ammonia has the potential to poison individuals and disrupt water systems' equilibrium.

Table 4: NH3-N profile of chosen sites

pH	Ist Sampling	2nd Sampling	3rd Sampling	4th Sampling	5th Sampling	6th Sampling
S1	0.597	0.572	0.412	0.406	0.591	0.542
S2	0.552	0.510	0.385	0.410	0.520	0.610
S3	1.10	1.02	0.729	0.761	1.581	1.621
S4	1.52	1.61	1.119	0.135	1.370	1.385
S5	1.10	1.21	1.29	1.35	1.538	1.661
S6	0.490	0.512	0.395	0.410	0.442	0.499
S7	0.561	0.612	0.459	0.437	0.762	0.741
S8	8.862	8.574	6.911	7.041	7.542	7.710
S9	7.95	7.98	7.920	7.061	8.922	8.012
S10	8.72	8.91	5.421	7.023	8.621	8.101

Ammonical Nitrogen levels ranged from0.458 to 1.358 ppm during the research months with higher values near STP Hazratbal shown in Table 4. The release of Ammonical nitrogen into the water is accelerated by increased breakdown of organic materials in lakes [18]. Another factor contributing to this rise could be the influx of bottom Ammonical nitrogen to the surface caused by human activities such as dredging and de-weeding. It could also be attributed to rapid fertilizer overflow and direct sewage dumping from within and around the lake.

D. *Chemical Oxygen Demand* (COD)

Chemical oxygen demand test determines the oxygen requirement equivalent of organic matter that is susceptible to oxidation with the help of a strong chemical oxidant. It is a means of measuring organic strength for streams and polluted water bodies.

Table 5: COD profile of chosen sites

pH	Ist Sampling	2nd Sampling	3rd Sampling	4th Sampling	5th Sampling	6th Sampling
S1	26.40	27.19	21.52	23.80	25.8	25.4
S2	23.63	23.40	31.01	30	23.63	22.12
S3	54.54	52.15	35.7	34.9	54.54	53.10
S4	67.26	70.10	53.55	54	76.35	76.90
S5	36.36	39.20	57.12	56.11	54.54	53.61
S6	18.18	19.50	26.77	25.20	25.45	24.21
S7	29.8	26.5	31.5	30.9	28.32	26.9
S8	85	100	56.9	73.17	105	109.6
S9	135	141.5	144	89.1	92	145.2
S10	115	119.7	118	109.2	132	120

The current analysis discovered that the mean COD value ranged from 23.21 to 66.36 ppm, with the highest COD levels near STP Habak and the lowest near Sonalak given in Table 5. Less COD is found near open water areas because there is less organic contact due to less activity.

E. *Bio-Chemical Oxygen Demand (BOD)*

It is an empirical standardized laboratory test which measures oxygen requirement for aerobic oxidation of decomposable organic matter and certain inorganic materials in water and wastewater under controlled conditions of temperature and incubation period. The quantity of oxygen required for the above oxidation process is a measure of the test. It is used for finding out the level of pollution, assimilative capacity of water body and also the performance of waste treatment plants.

Table 6: BOD profile of chosen sites

pH	**Ist Sampling**	**2nd Sampling**	**3rd Sampling**	**4th Sampling**	**5th Sampling**	**6th Sampling**
S1	2.9	2.6	2.1	2.3	2.7	2.6
S2	3	2.8	3.1	2.9	2.9	2.5
S3	6	5.4	3.8	3.9	5.2	5
S4	8	9	6	5.7	8	8.2
S5	4	5	6	5.6	5.6	5.2
S6	2	3	2.5	2.4	2.2	2
S7	3.2	2.6	3	3	2.8	2.6
S8	27.2	22	13.4	19.2	23.1	24.2
S9	29	31	35	17.4	21	40
S10	33.2	35.5	32.3	28.2	30	24

During the study period, BOD levels ranged from 2.35-7.48 ppm, with greater levels near STP Habak and lower levels near Sonalak shown in Table 6. Higher levels are due to the mixing of effluent from STPs with lake water, while lower levels are due to less anthropogenic activities in the open water area of Sonalak. The higher the BOD, the faster the oxygen in the lake is lost. This means that higher types of aquatic life have less oxygen available to them. High BOD has the same effects as low dissolved oxygen, which causes aquatic organisms to become stressed, suffocate, and die. Since the 1990s, the amount of dissolved oxygen in Dal Lake has steadily decreased. The principal cause of this reduction is thriving weeds and abundant macrophytes development in the lake as a result of increased nitrogen load. The oxygen demand for macrophytes and their decomposition, as well as bacteria and aquatic animals' respiration, rapidly depletes the available oxygen. One of the most prominent effects of lake contamination [13] has been a decrease in dissolved oxygen.

F. *Transparency*

The ease with which light can travel through a substance is referred to as transparency. This refers to how far sunlight penetrates the water in lakes. Plants and algae require sunlight to grow, thus they can only thrive in lake areas where the sun shines. The number of particles in the water determines its transparency. These particles could be algae or debris from erosion, and the more particles there are, the less transparent the water becomes. A Secchi disc is used to determine the transparency of water.

During the study period, the transparency found in all the seven locations lies between 0.5 to 1m as shown in Table 1. The clarity of the lake has significantly reduced. The introduction of raw sewage and silt into the lake has resulted in a reduction in visibility. Eutrophication and abundant weed growth in the lake have aggravated the situation.

Other experts have linked the fluctuations in the lake's transparency to a variety of causes, including plankton populations and foreign objects [8]-[23]. Seasonal changes in transparency were also reported by these studies. The lake's mean visibility had dropped from 1.96 m in 1987 [19] to 1.49 m in 2005[7]. In 2013 [14], the value was 1.46 m, and in 2020, it was 1.32 m [6].

G. Parameters Of Stp's Evaluated

STPs at Nishat, Habak, and Hazratbal, all near Dal Lake, are fluidized aerobic bio-reactor-based treatment plants with capacities of 4.5 MLD, 3.2 MLD, and 7.5 MLD, respectively. Different metrics of effluent discharged in Dal Lake from all three STPs were studied and compared to Lake Water parameters. The characteristics of effluent water are greater than allowed limits, as shown in this study, and as a result, these STP's are becoming a point source of pollution, contributing to the degradation of Lake. The sewage treatment plants that deal with the final sewage entering Dal Lake have been a source of contention since their inception, as the technology used (FAB) has been criticised for its poor performance [10]. Instead of the predicted decrease in nutrients, the treated sewage showed a considerable rise. According to the CAG report and audit scrutiny, the Union Urban Development Ministry of India has voiced reservations about the efficiency of STPs in cold weather and the long-term viability of high maintenance expenses. Similar investigations on the FAB-based STP by [2]-[3] found a 44 % rise in nitrate-nitrogen concentration of the treated sewage, indicating that the STPs deployed were failing.

V. DISCUSSION

In the present investigation we reviewed that most of the parameters are high near STP locations, the effect of partially treated effluents from Sewage Treatment Plants (STPs), which are important to handle sewage but have tragically not been of much assistance in alleviating the Dal Lake's pollution problem and is the reason for parameters being over acceptable limits around STP locations. Dal Lake has been divided into two separate zones based on water quality indicators, one contaminated near STP's and the other unpolluted open water part of the lake, according to the findings of this study. The discharge of partly treated effluent from STPs is the major reason for this. In the polluted zone, higher amounts of PO4-P, NH3-N, COD, BOD, and a low concentration of D.O dominated water quality measures. As a result, the worse water quality in this zone has been confirmed.

Dal Lake, on the other hand, needs more STPs and better solid waste management in the area. New STPs, as well as upgrades to existing ones, are required in hyper-Eutrophic locations like Nehru Park and the Nigeen basin. Lake Eutrophication has increased as a result of these STP's incapacity to operate several times and incorrect seepage [16]. Small-scale waste-water treatment systems for communities or individual households can be set up on-site for at-site treatment.

VI. CONCLUSION

Despite the fact that Conservation and Management of Dal Lake have been ongoing for more than three decades, much efforts were made by LCMA by way of installation of six STP's around Dal Lake to treat the waste water generated from the Catchment area, regular Deweeding of Macrophytes, Demarcation of Dal Lake boundary, management of solid waste, but there is no discernible improvement in Lake's biological state. The Lake still is in ecological stress and the water quality of Lake has not improved significantly. The main reason may be due to mis-match water quality of Dal Lake with discharge of effluent from the STP's that has made Lake highly productive. Eutrophication has begun in certain areas of the Lake and the day is not far off when entire Lake will succumb to Eutrophication. When viewed in respect of water quality data, which indicate that the quality of water does not match to Class B category in most of the sampling locations and overall, the water quality of Lake is not good, so much efforts are still needed by way of

- Enhancement in treatment technology of STP's by extending of Tertiary treatment facility at all the STP's.
- Management of solid waste as per Solid waste (management) rule 2016.
- The relocation of Dal dwellers and realignment of house boats is need of hour so that the waste water generation from these spots can be checked.

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