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Assessment of surface water quality by evaluating the physico-chemical parameters and by checking the water quality index of Nigeen Basin and Brari Nambal Lagoon of Dal Lake, Kashmir

Faizanul Mukhtar, Mudassir Ahmad Bhat, Rafia Bashir, Hamida Chisti*
Department of Chemistry, National Institute of Technology, Srinagar 190006, India

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**Corresponding Author: adimahnit@yahoo.com ; (+91-9469668449)*

Abstract
This work evaluates the surface water quality in terms of physio-chemical parameters of the Nigeen basin and Brari Nambal lagoon of the Dal lake Kashmir. Besides this, the work also highlights and draws attention towards the "Water Quality Index" in a simplified format which may be used at large and could represent the reliable picture of water quality. Some parameters were measured at the sampling sites while other were put for laboratory analysis. Water quality was surveyed from May 2013 to August 2013 at three different sites which were located on the Nigeen basin. Average values of the water quality parameters were obtained over a period of four months from May 2013 to August 2013 for Brari Nambal lagoon. A total of seven water quality parameters namely pH, Electrical Conductivity (EC), Salinity, Dissolved Oxygen (DO), Turbidity, Air temperature and Water temperature were measured at the sampling sites. While for laboratory analysis, there were fourteen parameters namely Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Dissolved Salts (TDS), Free Carbon-dioxide, Acidity, Nitrite, Phosphate, Sulphate, Colour, Total Hardness, Alkalinity, Chloride, Calcium and Magnesium ion concentration. Monthly changes in various physical and chemical parameters were analysed.

Keywords: Surface water quality, Brari Nambal Lagoon, Nigeen basin, water quality index, sampling sites, average values

1. Introduction
Water is an elixir of life. It is an important component of human survival. The fresh water is a fresh commodity. Water quality is considered the main factor controlling health and the state of disease in both man and animals. Surface water quality in a region is largely determined both by natural processes (weathering and soil erosion) and by anthropogenic inputs (municipal and industrial waste water discharge). The anthropogenic discharges constitute a constant polluting source, whereas surface run-off is a seasonal phenomenon, largely affected by climate within the basin [1]. Lakes are subjected to various natural processes taking place in the environment, such as hydrological cycle. Storm water run-off and discharge of sewage into the lakes are two common ways that various nutrients enter the aquatic ecosystems resulting in the death of those systems. One of the most famous and beautiful lakes of world, Dal lake, is a Himalayan urban lake surrounded by mountains on its three sides. Dal lake is situated at an altitude of 1,886m above sea level between 34°6'-34°10' N latitude and 74°8' -74°9' E longitude, in the heart of the Kashmir valley on the north east of the state summer capital Srinagar. The lake is multi-basined comprising of four basins viz., Hazratbal, Bod Dal, Gagribal and Nigeen as shown in figure 1 bathymetrically. Of all the four basins, the Nigeen basin is the deepest one. A lot of research has been carried out [2] on the limnology of Dal lake yet the deepest basin Nigeen basin has not so for been exclusively studied. Situated at the entrance of Shahr-e-Khaas in Srinagar, Brari Nambal is one of the outflow channels of Dal Lake. It is a lagoon i.e. a shallow body of water separated from a larger body of water as depicted in figure 3. The waters of Dal flow to river Jehlum through Brari Nambal via a conduit at Fateh Kadal area. In the absence of sustained conservation measures over the decades, Brari Nambal has shrunk from five to less than a square kilometer. In recent decades, population growth, agricultural practices and sewage-runoff from urban areas have increased nutrient inputs many folds than the level of natural occurance, resulting in accelerated eutrophication and pollution [3]. However, this process is accelerated by excess nutrients from human activities and is called "cultural eutrophication" [4]. The lagoon being in the the city centre, municipal and domestic effluents have altered the surface water composition, leading to increased eutrophication [5]. The present investigation were undertaken to determine various physico-chemical characteristics of Nigeen basin and Brari Nambal lagoon of Dal Lake. The suitability of water resources for human use has been described in terms of water quality index (WQI), which is one of the most effective ways to describe the quality of water. WQI utilizes the water quality data and helps in the modification of policies, which are formulated by

various environmental monitoring agencies. It has been realized that the use of individual water quality variable in order to describe the water quality for common public is not easily understandable [6]. That is why, WQI has the capability to reduce the bulk of the information into a single value to express the data in a simplified and logical form [7].

2. Experimental

2.1. Sampling site

Nigeen basin is the deepest basin of the world famous Dal Lake (Fig. 2). This study was conducted on this basin by choosing three sites which differ on the extant of pollution. The three sites selected from the basin were-site 1 Central Nigeen, site 2 Saderbal Area and site 3 Pokhribal Area.

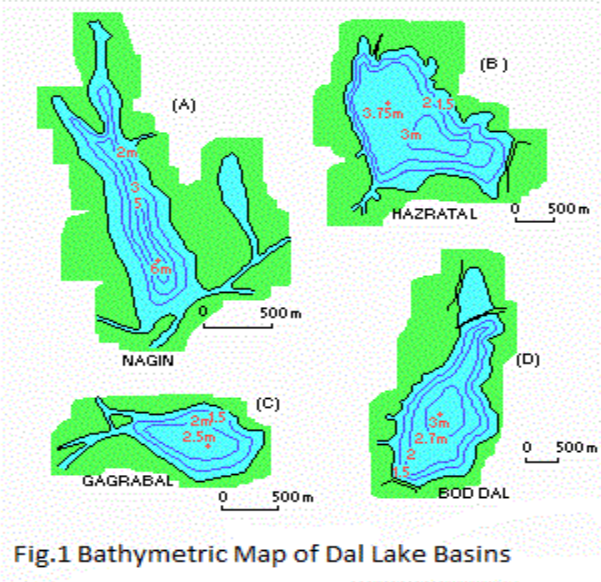


Fig.1 Bathymetric Map of Dal Lake Basins

Fig.2 Sampling Sites of Nigeen Basin of Dal Lake, Kashmir

2.2. Sample collection and pre-treatment

The sampling network was designed to cover a wide range of determinates of key sites, which reasonably represent the water quality of the lake system. Sampling for water quality parameters were carried out at the three sites on monthly basis between May 2013 to August 2013. The samples were collected from 8:00 A.M to 10:30 A.M during the four month period. Water samples were collected using open water grab sampler (1.5 L capacity) equipped with a simple pull-ring that allowed for sampling at various depths. In order to determine the water quality, water samples were kept in 5 L polythene cans wrapped with carbon. All water samples were stored in insulated cooler containing ice and delivered on the same day to laboratory and all the samples were kept at 4°C until processing and analysis [8].

2.3. Chemicals and reagents

Triple distilled water was used throughout the work. All chemicals and reagents were analytical grade, Merck (Darmstadt, Germany). Standard solutions of two elements (i.e. Ca and Mg) were prepared by dilution of 1000 ppm certified standard solutions.

2.4. Analytical procedure

Physico-chemical parameters of water, their units and method of analysis are summarized in Table 1. The air temperature, water temperature, pH, EC, salinity, DO, turbidity of each sample were measured at the sampling points following the standard procedures of [9], by using mercury thermometer, digital pH, EC, DO, turbidity meter respectively. In laboratory the water samples were analyzed for other physico-chemical parameters and detection of metal ions (i.e. Ca and Mg). These parameters were analysed within 48 h, COD determined on the same day of the sampling by utilizing spectroquant TR-320 of Merck at 148 °C for two hours for heating the COD voils containing mercury(II)sulphte, sulphuric acid and the water samples to be tested. Then the COD measurement was carried out by using Spectroquant NOVA-60 of Merck. While as for evaluating BOD, five day incubation time at 20°C is a must and is measured by subtracting DO on fifth day from DO on first day multiplied by appropriate dilution factor. Colour was analyzed visually by comparing the water samples with colour standards made of potassiumchloroplatinate (K_2PtCl_6) and cobaltous chloride ($CoCl_2 .6H_2O$) in triple distilled water.

TDS and sulphate (SO_4^{2-}) were determined gravimetrically. Total hardness was measured by EDTA complexometry titration and the indicator was Erichrome Black T (EBT) at pH 10 [10]. Total alkalinity determined by acid titration using

methyl-orange as end point indicator and chloride content was estimated by silver nitrate ($AgNO_3$) titration using Potasssium Chromate (K_2CrO_4) solution as an indicator. Free carbon dioxide and total acidity were measured volumetrically by making use of N/44 sodium hydroxide and N/50 sodium hydroxide as standard titrant respectively and phenolphthalein as an indicator in both the cases. Nitritre (NO_2^-) was measured by making use of Spectroquant NOVA-60 of Merck. Phosphate (PO_4^{3-}) was measured photometrically by making use of Paqualab photometer of ELE International and Palintest tablets of phosphate, HR 114. Calcium and magnesium were determined by Atomic Absorption Spectrometer (AAS) of Perkin Elmer Precisely, AAnalyst 800 at Kashmir University.

Table 1: Water quality parameters associated with their abbreviations, units and analytical methods used

Parameters	**Abbreviations**	**Units**	**Analytical methods**
pH	pH	pH unit	pH meter
Air temperature	A –Temp	°C	Thermometric
Water temperature	W –Temp	°C	Thermometric
Colour	Colour	Hazen	Visually
Electrical conductivity	EC	μScm^{-1}	Electrometric
Salinity	Salinity	ppm	Electrometric
Total Dissolved Solids	TDS	ppm	Gravimetric
Total Hardness	T-Hard	ppm	Titrimetric
Turbidity	Turbidity	NTU	Turb metric
Dissolved Oxygen	DO	ppm	Prob method
Chemical Oxygen Demand	COD	ppm	Spectroquant photometric
Biochemical Oxygen Demand	BOD	ppm	Prob method (5 days later)
Total Alkalinity	T-Alk	ppm	Titrimetric
Phosphate	PO_4	ppm	Photometric
Sulphate	SO_4	ppm	Gravimetric
Nitrite	NO_2	ppm	Spectroquant NOVA 60
Free carbon dioxide	Free CO_2	ppm	Titrimetric
Acidity	Acidity	ppm	Titrimetric
Total Chloride	T-Cl	ppm	Titrimetric
Calcium	Ca	ppm	AAS
Magnesium	Mg	ppm	AAS

2.5. Graphical treatment

All the graphical depictions were made using Excel 2007 (Microsoft Office®).

3. Results

The results of various water quality parameters of the Nigeen basin of Dal lake quarterly (May 2013 to August 2013) are based on twelve water samples (3 sampling × 4 months) are summarized in Table 2, 3, 4 and 5.

Considerable fluctuations in pH were observed during the month of june across the three sites. The pH range falls well within WHO limits. The average range of TDS and EC in the lake water was found 185.5-293.5 ppm and 265-302.5 μScm^{-1} respectively. The salinity average range was 169.75-268.5 ppm. DO average range was 3.40-4.00 ppm across the three sites of the Nigeen basin of Dal lake. COD and BOD were having an average range of 16.4-19.5 ppm and 1.85-2.19 ppm respectively. Free carbon dioxide and acidity average range was 2-5.75 ppm and 4.5-9 ppm respectively. Turbidity and colour has an average range of 1.76-2.08 NTU and 18.75-20 hazen respectively. Air temperature and water temperature were having an average range of 20.75-21.75 °C and 24.75-25.25 °C respectively. Alkalinity average range was 84.5-119 ppm. Chloride concentration was found in the average range of 14.5-26.25 ppm. The phosphate and nitrite values were found in the average range of 1.02-3.07 ppm and 0.020-0.1922 ppm respectively. Sulphate was in the average range of 16.45-23.48. The average concentration range of calcium and magnesium ions was 27-33 ppm and 8.25-19.25 ppm respectively and was well within WHO limits.

Table 2: First sampling, May 2013

Parameters	**Site-1 Central Nigeen**	**Site-2 Saderbal Area**	**Site -3 Pokhribal Area**
pH	7.75	7.69	7.69
Air temperature (°C)	19	20	19

Water temperature (°C)	20	21	21
Colour (hazen)	15	15	10
Electrical conductivity (µS cm^{-1})	274	540	246
Salinity (ppm)	176	346	158
Total Dissolved Solids (ppm)	192	378	172
Total Hardness (ppm)	114	202	86
Turbidity (NTU)	0.01	0.01	0.01
Dissolved Oxygen (ppm)	3.59	3.36	4.53
Chemical Oxygen Demand (ppm)	11.8	13.7	11.6
Biochemical Oxygen Demand (ppm)	0.66	1.06	1.07
Total Alkalinity (ppm)	92	150	74
Phosphate (ppm)	0	1.8	0.7
Sulphate (ppm)	21.12	44.16	13.44
Nitrite (ppm)	0.023	0.032	0.022
Free carbon dioxide (ppm)	1	3	1
Acidity (ppm)	5	8	3
Total Chloride (ppm)	12	28	9
Calcium (ppm)	31	40	25
Magnesium (ppm)	9	25	6

Table 3: Second sampling, June 2013

Parameter	**Site-1 Central Nigeen**	**Site-2 Saderbal Area**	**Site -3 Pokhribal Area**
pH	8.16	7.98	7.84
Air temperature (°C)	20	21	19
Water temperature (°C)	27	26	26
Colour (hazen)	20	15	20
Electrical conductivity (µS cm^{-1})	200	364	229
Salinity (ppm)	128	234	147
Total Dissolved Solids (ppm)	140	255	160
Total Hardness (ppm)	96	158	112
Turbidity (NTU)	4.05	1.94	2.88
Dissolved Oxygen (ppm)	3.90	3.58	3.73
Chemical Oxygen Demand (ppm)	16.6	23.5	13.2
Biochemical Oxygen Demand (ppm)	2.31	2.39	2.77
Total Alkalinity (ppm)	78	114	94
Phosphate (ppm)	0	0	0
Sulphate (ppm)	15.36	51.84	11.52
Nitrite (ppm)	0.018	0.025	0.086
Free carbon dioxide (ppm)	1	2	4
Acidity (ppm)	3	6	7
Total Chloride (ppm)	15	27	13
Calcium (ppm)	22	28	31
Magnesium (ppm)	11	22	8

Table 4:Third sampling, July 2013

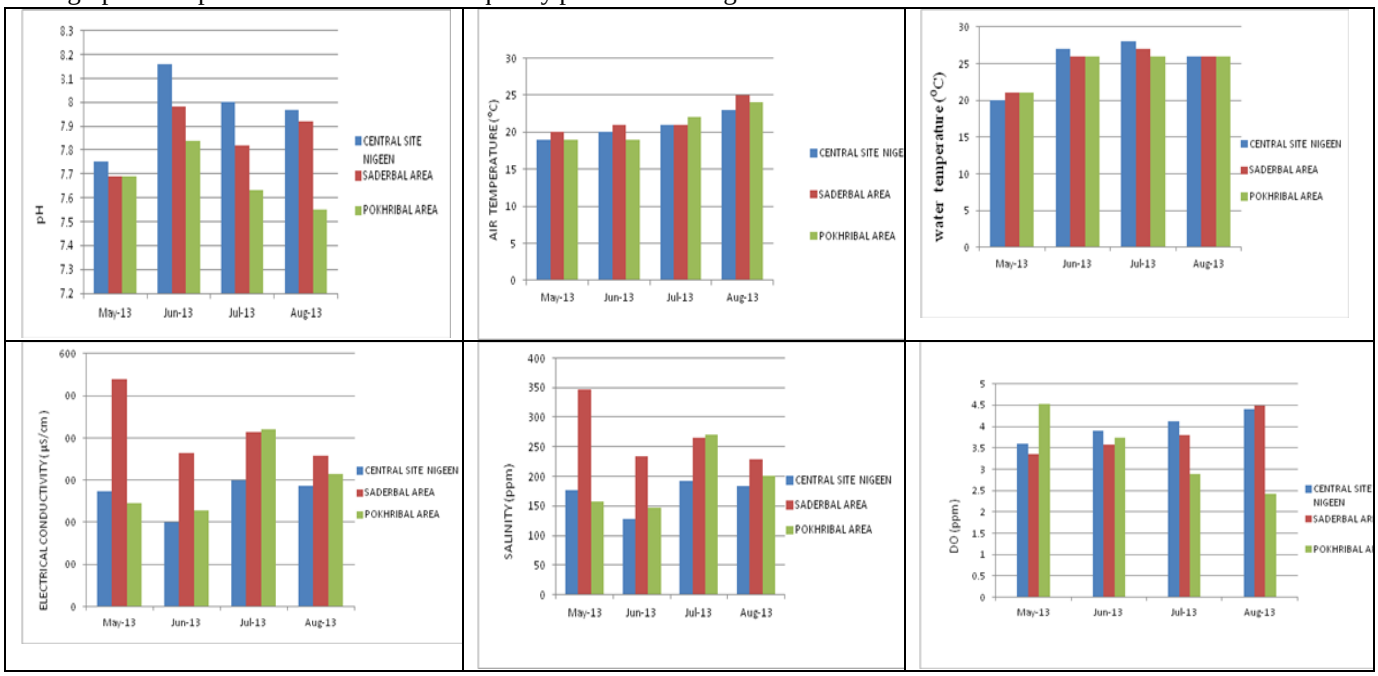
Parameter	**Site-1 Central Nigeen**	**Site-2 Saderbal Area**	**Site -3 Pokhribal Area**
pH	8.00	7.82	7.63
Air temperature (°C)	21	21	22
Water temperature (°C)	28	27	26
Colour (hazen)	25	25	25
Electrical conductivity (µS cm^{-1})	300	414	421
Salinity (ppm)	192	265	270
Total Dissolved Solids (ppm)	210	290	295
Total Hardness (ppm)	104	132	134
Turbidity (NTU)	2.31	3.22	4.74
Dissolved Oxygen (ppm)	4.13	3.80	2.89
Chemical Oxygen Demand (ppm)	18.1	21.5	21.3
Biochemical Oxygen Demand (ppm)	3.47	3.09	2.13

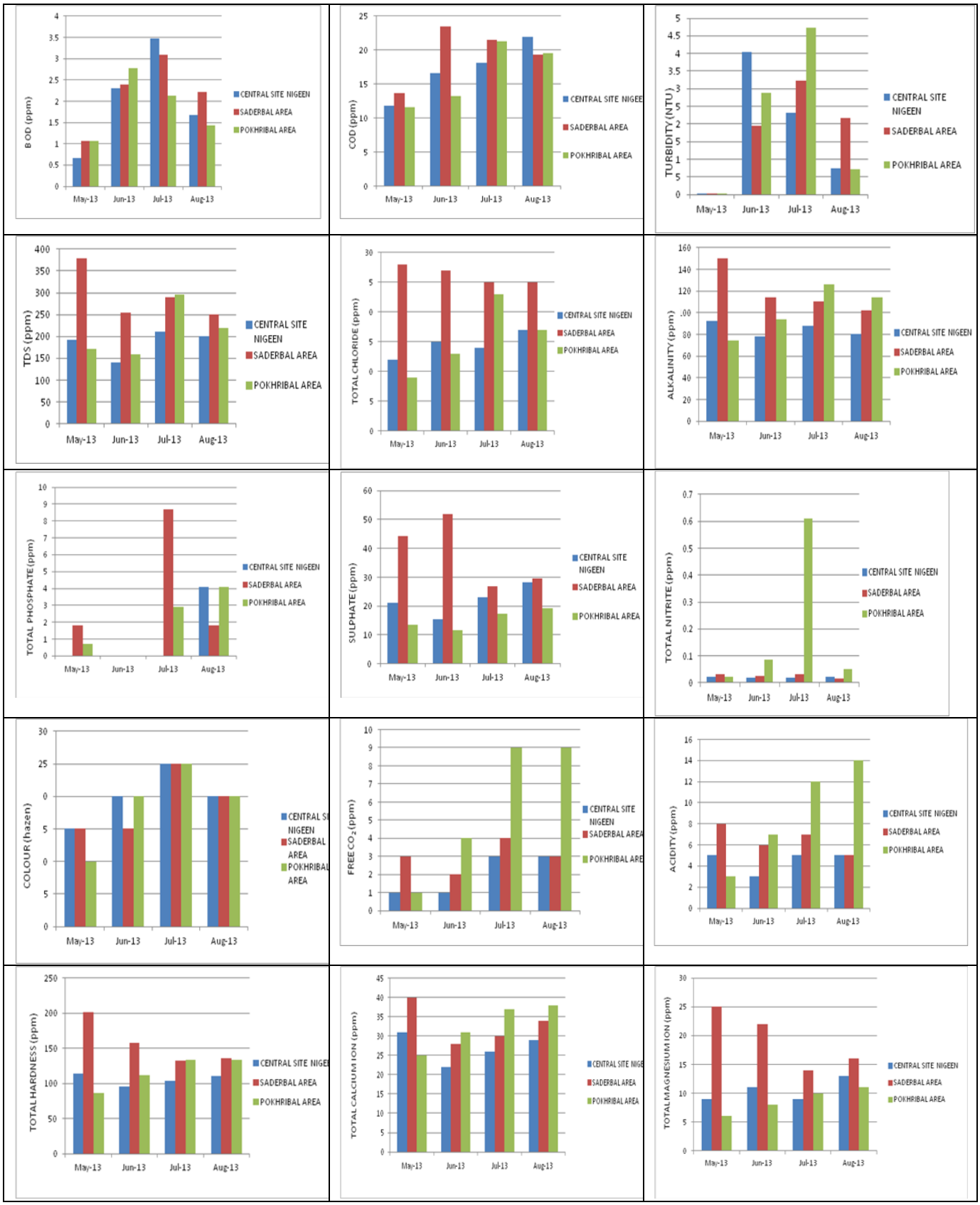
Total Alkalinity (ppm)	88	110	126
Phosphate (ppm)	0	8.7	2.9
Sulphate (ppm)	23.04	26.88	17.28
Nitrite (ppm)	0.020	0.032	0.61
Free carbon dioxide (ppm)	3	4	9
Acidity (ppm)	5	7	12
Total Chloride (ppm)	14	25	23
Calcium (ppm)	26	30	37
Magnesium (ppm)	9	14	10

Table 5: Fourth sampling, August 2013

Parameter	**Site-1 Central Nigeen**	**Site-2 Saderbal Area**	**Site -3 Pokhribal Area**
pH	7.97	7.92	7.55
Air temperature (°C)	23	25	24
Water temperature (°C)	26	26	26
Colour (hazen)	20	20	20
Electrical conductivity (µS cm^{-1})	286	357	314
Salinity (ppm)	183	229	201
Total Dissolved Solids (ppm)	200	250	220
Total Hardness (ppm)	110	136	134
Turbidity (NTU)	0.73	2.16	0.71
Dissolved Oxygen (ppm)	4.40	4.48	2.42
Chemical Oxygen Demand (ppm)	21.9	19.3	19.5
Biochemical Oxygen Demand (ppm)	1.68	2.22	1.43
Total Alkalinity (ppm)	80	102	114
Phosphate (ppm)	4.1	1.8	4.1
Sulphate (ppm)	28.11	29.44	19.21
Nitrite (ppm)	0.021	0.017	0.051
Free carbon dioxide (ppm)	3	3	9
Acidity (ppm)	5	5	14
Total Chloride (ppm)	17	25	17
Calcium (ppm)	29	34	38
Magnesium (ppm)	13	16	11

The graphical depictions for various water quality parameters are given as:




B OD (ppm)
COD (ppm)
TURBIDITY (NTU)
TDS (ppm)
TOTAL CHLORIDE (ppm)
ALKALINITY (ppm)
TOTAL PHOSPHATE (ppm)
SULPHATE (ppm)
TOTAL NITRITE (ppm)
COLOUR (hazen)
FREE CO_2 (ppm)
ACIDITY (ppm)
TOTAL HARDNESS (ppm)
TOTAL CALCIUM ION (ppm)
TOTAL MAGNESIUM ION (ppm)
May-13
Jun-13
Jul-13
Aug-13
CENTRAL SITE NIGEEN
SADERBAL AREA
POKHRIBAL AREA

4. Discussion

4.1. Chemistry of lake water

The minimum and maximum values of all physico-chemical parameters of water samples collected from the three sites are represented in Table 6. The results are compared to the World Health Organisation recommended maximum permissible limits [11].

Table 6: A range and average of water quality parameters at different sites of Nigeen Basin of Dal Lake during May 2013-August 2013

4.1.1. Water quality parameters

Parameters	**WHO limits**	**Site-1 Central Nigeen**	**Site-2 Saderbal Area**	**Site -3 Pokhribal Area**
pH	6.5-8.5	Range 7.75-8.16 Average 7.97	Range 7.69-7.98 Average 7.85	Range 7.55-7.84 Average 7.68
Air temperature (°C)		Range 19-23 Average 20.75	Range 20-25 Average 21.75	Range 19-24 Average 21
Water temperature (°C)		Range 20-28 Average 25.25	Range 21-27 Average 25	Range 21-26 Average 24.75
Colour (hazen)		Range 15-25 Average 20	Range 15-25 Average 18.75	Range 10-25 Average 18.75
Electrical conductivity (µS cm^{-1})	1500	Range 200-300 Average 265	Range 357-540 Average 418.7	Range 229-421 Average 302.5
Salinity (ppm)		Range 128-192 Average 169.75	Range 229-346 Average 268.5	Range 147-270 Average 194
Total Dissolved Solids (ppm)	1000	Range 140-210 Average 185.5	Range 250-378 Average 293.25	Range 160-295 Average 211.75
Total Hardness (ppm)		Range 96-114 Average 106	Range 132-202 Average 157	Range 86-134 Average 116.5
Turbidity (NTU)		Range 0.01-4.05 Average 1.76	Range 0.01-3.22 Average 1.83	Range 0.01-4.74 Average 2.085
Dissolved Oxygen (ppm)		Range 3.59-4.40 Average 4.00	Range 3.36-4.48 Average 3.80	Range 2.42-4.53 Average 3.40
Chemical Oxygen Demand (ppm)	10	Range 11.8-21.9 Average 17.1	Range 13.7-23.5 Average 19.5	Range 11.6-21.3 Average 16.4
Biochemical Oxygen Demand (ppm)	6	Range 0.66-3.47 Average 2.03	Range 1.06-3.09 Average 2.19	Range 1.07-2.77 Average 1.85
Total Alkalinity (ppm)	200	Range 78-92 Average 84.5	Range 102-150 Average 119	Range 74-126 Average 102
Phosphate (ppm)		Range 0-4.1 Average 1.02	Range 0-8.7 Average 3.07	Range 0-4.1 Average 1.92
Sulphate (ppm)	250	Range 15.36-28.11 Average 23.48	Range 26.88-51.84 Average 19.12	Range 11.52-19.2 Average 16.45
Nitrite (ppm)	3	Range 0.018-0.020 Average 0.020	Range 0.017-0.032 Average 0.026	Range 0.022-0.61 Average 0.1922
Free carbon dioxide (ppm)		Range 1-3 Average 2	Range 2-4 Average 3	Range 1-9 Average 5.75
Acidity (ppm)		Range 3-5 Average 4.5	Range 5-8 Average 6.5	Range 3-14 Average 9
Total Chloride (ppm)	250	Range 12-17 Average 14.5	Range 25-28 Average 26.25	Range 9-23 Average 15.5
Calcium (ppm)	100	Range 22-31 Average 27	Range 28-40 Average 33	Range 25-38 Average 32.75
Magnesium (ppm)	50	Range 9-13 Average 8.25	Range 14-25 Average 19.25	Range 6-11 Average 8.75

Air and water temperature showed a very characteristic cycle, with higher values during august and july respectively. The pH values of collected water samples were within those defined by WHO guidelines of 6.5-8.5 [9]. The EC was appreciable due to significant amount of dissolved salts. The annual rainfall in the basin is little so a little variation was observed during the interval. EC increases with temperature. The EC is attributed to high salinity and high mineral content in all sampling sites. It also corresponds to the highest concentration of dominant ions, which are the result of ion exchange and solubilization in the aquifer [12]. The major cations (Ca and Mg) and major anions (Cl and SO_4) in the lake water increase EC, is consistent with other study [13]. Alkalinity values fluctuated among all sampling sites.

The oxygen in surface water comes from air or is produced by photosynthetic organisms like algae and plants in a water body. The oxygen content is decreased with increase in water temperature. It has negative impact on organic waste processing by the aerobic micro-organisms.The monitoring of oxygen concentration in aquatic system is an important subject [14], as the physical, chemical and biological processes involved in oxygen fluactuation in lake are numerous. The highest value of COD was recorded at the Saderbal site and lowest at the Pokhribal site. COD is widely used for determining waste concentration and is applied primarily to pollutant mixtures such as domestic sewage, agricultural and industrial waste. In case of BOD the higher values were observed at Saderbal, due to local anthropogenic pollution. The phosphate concentration also varied across the three sites. The phosphate concentrations were high near Saderbal site. Nitrites did not vary much across the three sites. If in excess i.e >1 ppm, nitrites can produce a serious condition in fish called 'brown blood disease'. Nitrites can also react directly with hemoglobin in human blood to produce methemoglobin. Methemoglobin destroys the ability of the red blood cell to transport oxygen. Chlorides are well below permissible limits of WHO. Chlorides get into surface water from agricultural runoffs and effluent waste water from waste water treatment plants. Water temperature also changes during the four month period. Water temperature regulates the metabolism of aquatic ecosystem. High water temperature stresses aquatic ecosystem by reducing the ability of water to hold essential dissolved gases like oxygen. Besides, enzyme inactivation, change in lipid state, increase in cell membrane permeability, protein denaturation and release of toxic substances from damaged cells also occur at high temperature. Fish kills may also occur in water bodies because of depletion of oxygen. Total hardness of lake water at the three sites fall more or less within 60-120 and 120-180 ppm and hence the water can be regarded as moderately hard to hard. Free carbon dioxide and acidity did show small fluctuations at the sites.

4.1.2. Dissolved metals in lake

The concentrations of calcium and magnesium ions are well within the permissible limits [11]. In a watery solution calcium is mainly present as $Ca^{2+}_{(aq.)}$ but it may also occur as calcium hydroxide, $Ca(OH)_{2(aq.)}$. Calcium is an important determinant of water hardness, and it also functions as a pH stabilizer, because of its buffering qualities. Calcium also gives water a better taste. Water hardness influences aquatic organisms concerning metal toxicity. In softer water, membrane permeability in gills is increased. Calcium also competes with other ions for binding spots in the gills. Consequently, hard water better protects fish from direct metal uptake.

Magnesium is mainly present as $Mg^{2+}_{(aq.)}$ in watery solutions. It also occurs as magnesium sulphate, $MgSO_4$. $MgSO_4$ adds a bitter flavor to water. Environmental problems indirectly caused by magnesium in water are caused by applying softeners.

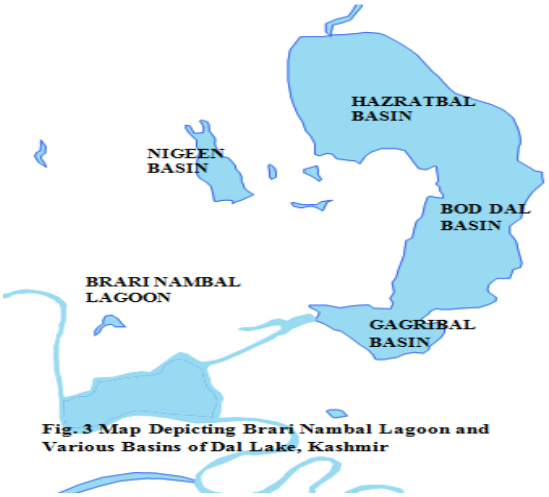


Fig. 3 Map Depicting Brari Nambal Lagoon and Various Basins of Dal Lake, Kashmir

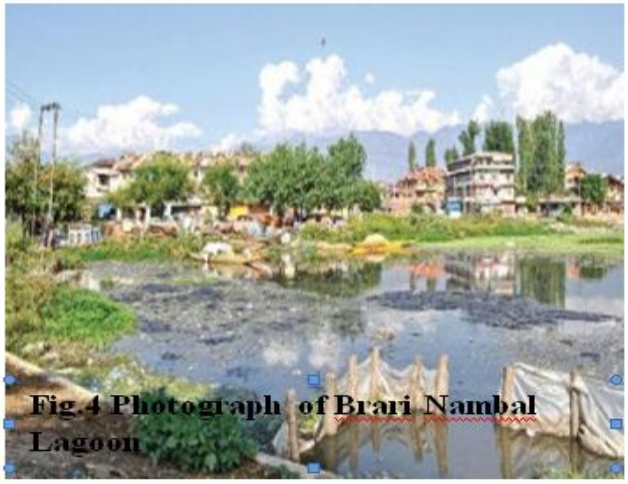


Fig.4 Photograph of Brari Nambal Lagoon

Brari Nambal Lagoon

Brari Nambal is a famous lagoon of Dal Lake. It remained one of the famous tourist spots but the pollution and encroachment have taken toll of the sparkling water body. Figure 4 shows the pathetic condition of the lagoon. For Brari Nambal lagoon all those water quality parameters were evaluated which were in case of the Nigeen basin of the Dal Lake following the same standard procedures. Average values for these physico-chemical parameters over a period of four months (May 2013 to August 2013) were achieved as depicted in the table 7.

Table 7: Average values of water quality parameters of Brari Nambal Lagoon over the period of four months

Parameter	WHO limits	Average Values
pH	6.5-8.5	7.52
Air temperature (°C)		17
Water temperature (°C)		15
Colour (hazen)		60
Electrical conductivity (µS cm^{-1})	1500	543
Salinity (ppm)		348
Total Dissolved Solids (ppm)	1000	380
Total Hardness (ppm)		158
Turbidity (NTU)		5.74
Dissolved Oxygen (ppm)		1.04
Chemical Oxygen Demand (ppm)	10	52
Biochemical Oxygen Demand (ppm)	6	0.90
Total Alkalinity (ppm)	200	154
Phosphate (ppm)		4.1
Sulphate (ppm)	250	27
Nitrite (ppm)	3	0.04
Free carbon dioxide (ppm)		11
Acidity (ppm)		25
Total Chloride (ppm)	250	26
Calcium (ppm)	100	43
Magnesium (ppm)	50	12

Unabated encroachments and pollution have drastically affected the flora and fauna of Brari Nambal Lagoon of the Dal lake pushing the water quality to the verge of extinction. If the pollution remains unchecked it could also prove detrimental to the Dal as the lagoon forms one of its outflow. Sewage treatment plant (STP) constructed on the southern banks has become main source of pollution for the lagoon. The sewage of most areas of the Srinagar city is treated at the Brari Nambal STP. The STP has failed to operate according to the prescribed norms, as a result it pumps untreated sewage directly into the Brari Nambal and thereby polluting it and turning it to a cesspool.

Water quality index method

Weighed arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables. The method has been widely used by various scientists [15] and the calculation of WQI was made by using the following equation:

$$WQI = \sum QiWi / \sum Wi$$

The quality rating scale (Qi) for each parameter is calculated by using this expression

$$Qi = 100[(Vi-Vo/Si-Vo)]$$

Where,
Vi is estimated concentration of ith parameter in the analyzed water
Vo is the ideal value of this parameter in pure water
Vo = 0 (except pH = 7.0)
Si is the recommended standard value of ith parameter
The unit weight (Wi) for each water quality parameter is calculated is calculated by using the following formula:

$$Wi = K/Si$$

Where,
K = proportionality constant and can also be calculated by using the following equation:

$$K = 1/\sum(\frac{1}{Si})$$

The rating of water quality according to this WQI is given below in table.

Table 8: Water Quality Rating as per Weight Arithmetic Water Quality Index Method

WQI Value	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking	E

By employing important physico-chemical parameters like COD, EC, TDS, BOD, nitrite, total alkalinity, sulphate, chloride, Ca and Mg ions for which the recommended standard values are available in arithmetic water quality index equation and doing the required simulations for the Brari Nambal Lagoon, the WQI value was found to be 77.57 i.e. the water quality was very poor and it falls under grade "D" while for the three sites of Nigeen Basin i.e. Central site Nigeen, Saderbal area and Pokhribal area the WQI values obtained were 34.27, 43.87 and 30.56 respectively which means the water quality is good and falls under grade "B".

Conclusion

In this study, different water quality parameters of the surface water of Nigeen basin and Brari Nambal lagoon of Dal lake were evaluated. The information drawn from the data reveals that it is possible to formulate viable strategies which could reduce the pollution load of the lake water. The main cause of degradation of the lake is the discharge of agricultural wastes and municipal sewage water. Fishing and boating activities among the major source responsible for lake water deterioration. This study helps in identification of pollution sources and understanding variations in water quality for effective lake water management. Interventions like reduction in anthropogenic discharge, rehabilitations of households in the vicinity of Lake Basin and lagoon, reforestation and stoppage of encroachments should be made possible, otherwise high level pollution will greatly influence the population.

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