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ANALYZING PHYSICO-CHEMICAL CHARACTERISTICS OF DAL LAKE WATERS OF KASHMIR

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ABSTRACT
Fresh water is essential for agriculture, industry and human existence. Fresh water resources get depleted at a very faster rate. Water pollution is a global problem. The healthy aquatic ecosystem is depended on the biological diversity and physicochemical characteristics of water. As water is scarce and its demand is likely to increase further, preservation of water resources is a need of hour.

Keywords- *Dal Lake, Water, Water body, Water quality, Water chemistry, Eutrophication, Anthropogenic activity, Physicochemical characteristics, Organic pollutant, Inorganic pollutant, Jammu and Kashmir.*

I. INTRODUCTION
Fresh water is essential for agriculture, industry and human existence; it is a finite resource of earth. Without adequate quantity and quality of fresh water sustainable development will not be possible. [1] Fresh water resource are becoming deteriorate day-by-day at a very faster rate. Now water quality is a global problem. [2] The healthy aquatic ecosystem is depended on the biological diversity and Physico-chemical characteristics. [3]
Almost 71% surface area of the earth is covered with water in the form of streams, lakes, rivers, Seas and oceans. Water is most important geological agent that modifies the surface morphology of the planet on a very grand scale. [4]
As far as the environment is concerned, its quality has deteriorated drastically. The air that we breathe, the water that we drink, and the land that we walk on, is polluted. As water is scarce and its demand is likely to increase further, it needs more attention. After air pollution, water pollution is the most serious threat faced by the whole world. [5]
Domestic wastes, industrial effluents, agricultural wastes, etc are the major pollutants entering our water bodies. Even ground water is polluted from the soakage pits, septic tanks, manure, garbage, etc. [6] Most of the problems occur due to the lack of proper sanitation facilities and waste disposal system. [7] Loading and unloading of oil and petroleum in the tankers along the sea shore results in oil spills that are a menace as they affect not only water but aquatic life as well. [8] Agricultural wastes contain pesticides and chemicals, which add to water pollution as by way of filling them up with nitrates and phosphates. These pollutants obviously create an ecological imbalance in the water bodies. [9]
All the water pollutants are responsible for decreasing the self purifying ability of the water bodies and lose the capacity to recycle the wastes. As a result, water clarity is affected and the water bodies become shallower. [10] Contaminants may include organic and inorganic substances. Organic water pollutants include detergents, disinfection byproducts found in chemically disinfecteddrinking water, such as chloroform, Food processing waste, which can include oxygen demanding substances, fats and grease, insecticides and herbicides, a huge range of organohalides and other chemical compounds, Petroleum hydrocarbons, including fuels like gasoline, diesel and lubricants, and fuel combustion byproducts, from storm waterrunoff.
Tree and bush debris from logging operations, volatile organic compounds such as industrial solvents, from improper storage. Chlorinated solvents may fall to the bottom of reservoirs. Polychlorinated biphenyl, trichloroethylene, perchlorate, various chemical compounds are found in personal hygiene and cosmetic products.
Inorganic water pollutants include sulfur dioxide from power plants, ammonia from food processing waste, Chemical waste as industrial by products, fertilizers containing nutrients like nitrates and phosphates, which are found in storm water runoff from agriculture as well as commercial and residential use, heavy metals from motor vehicles and acid mine drainage, silt/sediment in runoff from construction sites, logging, slash and burn practices or land clearing sites. [11, 12]

Large visible items such as trash or garbage discarded by people on the ground and rubbish that are washed by rainfall into storm drains and eventually discharged into surface waters.
A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers. Elevated water temperatures decreases oxygen levels which can kill fish and affects ecosystem composition, such as invasion by new thermophilic species. Urban runoff may also elevate temperature in surface waters. [13]
Most water pollutants are eventually carried by rivers into the oceans. Many chemicals undergo reactive decay or chemically change especially over long periods of time in groundwater reservoirs. A noteworthy class of such chemicals is the chlorinated hydrocarbons such as trichloroethylene and tetrachloroethylene used in the dry cleaning industry. Both of these chemicals, which are carcinogens themselves, undergo partial decomposition reactions, leading to new hazardous chemicals including dichloroethylene and vinyl chloride.
Physico-chemical characteristics of water may be analyzed through several broad categories of methods, physical, chemical and biological. Most involve collection of samples, followed by specialized analytical tests. Some methods may be conducted in situ, without sampling, such as temperature. Government agencies and research organizations have published standardized, validated analytical test methods to facilitate the comparability of results from different testing events. [14]
Water samples may be examined using the principles of analytical chemistry. Many published test methods are available for both organic and inorganic compounds. Frequently used methods include pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrients (nitrate and phosphorus compounds), metals (including copper, zinc, cadmium, lead and mercury), oil and grease, total petroleum hydrocarbons (TPH), and pesticides. [15]
Dal Lake located at an altitude of 1587m above sea level and with an area of 1670 ha is one of a series of freshwater lakes of Kashmir valley. Dal Lake is a multi-basined, ox bow type of lake, with shallow saucer-shaped basins formed by the changing course of river Jhelum. The main source of water for the lake is Telbal Nalla in the Dachigam area, numerous springs arising from the bottom of lake and outwash from surrounding mountains. The outflow of lake occurs through a weir-n- lock system. The maximum depth is 6.5m, while the average depth is less than 3m. Water levels which fluctuate during the course of a year are maximum in April and minimum in November. The pH values of the lake fall within the alkaline range until recently. It is drained through Pir Panjal mountainous range at Baramula to the plains of the Punjab. Climate of Kashmir is montane valley climate with a pronounced cold season from October to March (Average temperature 7.5^{o}C) and warm summers (Average temperature 19.8^{o}C). January is the coldest month (-2^{o}C to 3^{o}C), and July the warmest (34^{o}C to 35^{o}C). The average annual rainfall is 551 mm. Most of the precipitation is in the form of snow (January–March). Summer monsoon rainfall is scanty. [16]
Jammu & Kashmir is one of the beautiful parts of this planet with rich water resources. There are many water bodies in Jammu & Kashmir and Dal Lake is a largest water body after Wular Lake situated in Srinagar, the capital of J & K which lies more than 5000 ft. above the sea level. Dal Lake is world famous water body which needs to be preserved. The Government of Jammu and Kashmir has commissioned an authority to preserve the pristine beauty of the water body called Jammu & Kashmir Lakes and Waterways Development Authority. [17]
Recognizing the importance of this world famous water body the governments as well as the public have to be conscious of preserving this water body from extinction besides maintaining its water quality.

II. MATERIALS & METHODS

The study was undertaken on the Dal lake of Srinagar, Kashmir on ten randomly selected sampling sites by simple random selection as under:

Sampling Site	Name of Site
S1	Near Telbal Nallah
S2	Dhobi Ghat area
S3	Near Sona Lank
S4	Near Nishat pipe line

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S5	Near char chinari
S6	Near Kabootar Khana
S7	Nigeen
S8	Saderabal area
S9	Pokhribal area
S10	Outlet site of (STP) Hazratbal

A prospective study for a period of two years duration was conducted to study the physicochemical properties of Dal Lake water with effect from May 2011-April 2013 after proper permission from concerned authorities.

The samples were collected from ten selected sites of Dal Lake as mentioned above. The sampling sites were selected by simple random sampling. The samples were collected in prewashed sterile plastic bottles. After that samples were immediately brought to analytical laboratory and further analysis started without any delay. These samples were analyzed with respect to PH, EC,TDS, Free $Co_{2,}$ Alkalinity, Hardness, DO, Ca, Mg, Chloride, Nitrate, Phosphate, Silicates, Sulphates, Iron, Na^+, and K^+ . The purpose of analysis was to monitor the changes in the chemistry and physical properties of Dal lake water. Sample testing was conducted by fallowing methods to obtain the best results and the results were recorded on a predesigned, standardized proforma.

A Pearson's (Chi-square) statistical test was used to ascertain the strength of correlation between different variables. The arithmetic means (overall as well as seasonal) of each parameter were, therefore, calculated for each site to obtain representative values for use in statistical analyses. The data was compared with other studies conducted earlier which are available in published literature to investigate the trend of pollution of Dal Lake water.

The methodology adopted for analysis of physio-chemical characteristics of water is as under:

S.No.	Parameter	Method
1	PH	PH meter
2	Electrical cond.	Electrometric method
3	TDS	APHA, 1998
4	Free Co_2	APHA, 1998
5	DO	Winkler's Iodometric method
6	Alkalinity	Titrimetric method
7	Hardness	APHA, 1998
8	Calcium	EDTA Titrimetric method
9	Magnesium	EDTA Titrimetric method
10	Chloride	Argentometric method
11	Nitrate	Spectrophotometric method
12	Phosphate	Spectrophotometric method
13	Silicates	Spectrophotometric method
14	Sulphates	Spectrophotometric method
15	Iron	Spectrophotometric method
16	Na^+	Flame Photometer
17	K^+	Flame Photometer

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III. RESULTS

Dal Lake is a Himalayan Urban Lake, located in the heart of Srinagar (Latitude 34^{o} 18'N Longitude 74^{o} 91'E) at an average altitude of 1,583 M. Srinagar is summer capital of Jammu & Kashmir. Dal Lake is located at an altitude of 1730 mtrs. above sea level and with an area of 1670 ha. The findings of research are as under:

Table 1: Physical Dimensions of Dal Lake

Surface area	24 Sq Km
Volume	12.37mm^{3}
Maximum depth	6 – 9 m
Water level	Regulated (1.20 mm)
Catchment area	316 Sq Kms

Physiographic Features

Geographical: Name of main basins- Nagain Lake, Hazratbal, Bod Dal and Gagribal.

Name of main islands- Sona Lank and Rupa Lank.

Number of out flowing channels- Dal Gate and Nalla Mar

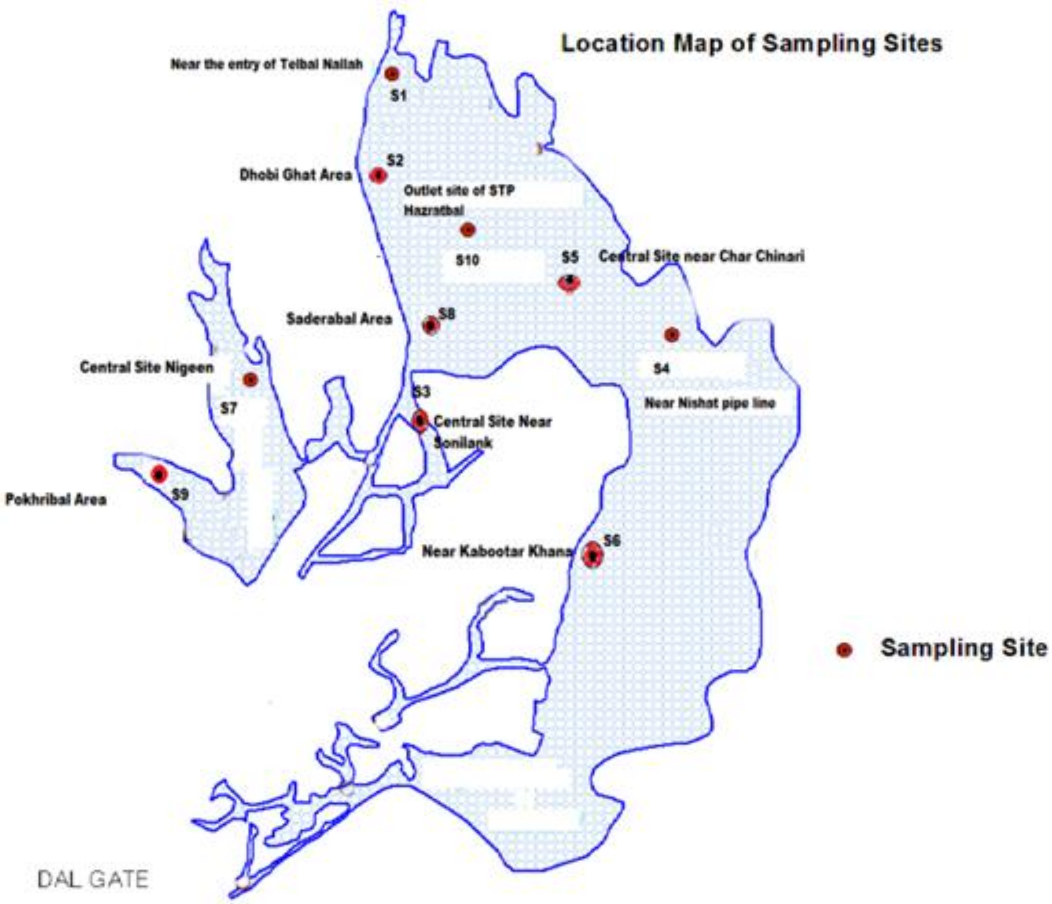

Figure 1: Site Map of Dal Lake

Table 2: Showing physico-chemical parameters (mean values) of ten selected sites (May, 2011- April, 2013)

Parameter	***Sampling Sites***									
	S1	***S2***	***S3***	***S4***	***S5***	***S6***	***S7***	***S8***	***S9***	***S10***
PH	*8.0*	*7.9*	*8.3*	*8.1*	*8.0*	*8.0*	*7.8*	*7.8*	*8.0*	*8.0*
E.C	*272.05*	*293.05*	*248.05*	*245.59*	*237.46*	*246.50*	*310.00*	*343.67*	*286.63*	*345.80*
TDS	*360*	*345*	*280*	*385*	*225*	*310*	*230*	*310*	*235*	*220*
Free CO_2	*8.9*	*9.5*	*6.5*	*6.8*	*4.5*	*5.3*	*10.2*	*9.0*	*9.8*	*7.5*
DO	*7.78*	*5.94*	*7.18*	*6.58*	*7.47*	*6.50*	*7.55*	*6.2*	*5.93*	*5.80*
Alkalinity	*208.20*	*214.08*	*162.96*	*175.42*	*161.80*	*181.84*	*224.20*	*226.20*	*230.88*	*290.08*
Hardness	*213*	*165*	*103*	*117*	*105*	*147*	*140*	*144*	*137*	*141*
Ca^{2+}	*40.78*	*41.25*	*35.00*	*35.38*	*33.88*	*35.13*	*33.38*	*36.59*	*38.63*	*44.09*
Mg^{2+}	*4.72*	*4.60*	*3.73*	*4.02*	*3.50*	*3.78*	*3.57*	*4.19*	*4.39*	*5.80*
Chloride	*14.8*	*18.4*	*12.7*	*15.9*	*13.2*	*14.7*	*17.7*	*19.1*	*17.7*	*16.3*
Nitrate	*465.3*	*340.7*	*250.7*	*155.9*	*248.8*	*269.6*	*481.1*	*352.2*	*485.7*	*344.9*
Phosphate	*208.8*	*124.1*	*89.2*	*90.9*	*82.2*	*115.7*	*152.6*	*143.2*	*122.6*	*158.0*
Iron	*281.46*	*326.38*	*221.88*	*187.67*	*117.46*	*172.67*	*282.92*	*276.21*	*280.21*	*254.30*
Silicates	*2.59*	*2.00*	*1.06*	*1.53*	*1.34*	*1.57*	*1.29*	*1.95*	*2.36*	*2.56*

Sulphates	*9.27*	*10.83*	*7.13*	*8.05*	*6.67*	*7.98*	*7.63*	*8.30*	*9.67*	*14.08*
Na^+	*2.1*	*1.9*	*1.9*	*2.4*	*2.0*	*1.8*	*1.9*	*2.1*	*2.2*	*2.3*
K^+	*2.4*	*2.7*	*1.8*	*2.1*	*1.7*	*1.6*	*3.5*	*1.7*	*1.9*	*2.3*

The lake is characterized by highly alkaline pH during summer as well as in the winter season. The central site near Sona Lank (S3) shows high range of pH (8.3). The central site Nageen (S7) and Saderabal area (S8) show low range of PH (7.8).The Lake shows high value of electrical conductivity of (345.80µS/cm) at outlet site of (STP) Hazratbal (S10), and shows low value of EC (237.46µS/cm) at Central site near Char Chinari (S5).The study reveals that there is high value of TDS (385mg/l) Near Nishat Pipe line (S4) and low values of TDS near outlet site of STP Hazratbal (S10).

The Lake shows high value of free CO_2 near Central site Nigeen (S7) 243 mg/land low value at Central site near Char Chinari (S5) 108 mg/l .The study reveals that site near Telbal Nallah (S1) shows high value of DO (7.78 mg/l) and the Outlet site of (STP) Hazratbal (S10) shows low value of DO (5.80 mg/l). The outlet site of STP Hazratbal (S10) shows high total alkalinity (290.08 mg/l) and the central site near Char Chinari (S5) shows low values for total alkalinity (161.80 mg/l). The site inside lake near the entry of Telbal Nallah (S1) shows high values of hardness (213mg/l) and Central site near Sonalank (S3) shows low values (103mg/l). High values of calcium are seen near the outlet site of STP Hazratbal (S10) (44.09 mg/l) and the central site Nigeen (S7) shows low values of calcium (33.38mg/l).

Magnesium is high in concentration near outlet site of STP Hazratbal (S10) (5.80mg/l) and low in concentration at central site near Char Chinari (S5) (3.50mg/l). High values of chloride (458 mg/l) are found near Saderabal Area (S8) and low values at Central site near Sonalank (S3) (306 mg/l).
The site Pokhribal (S9) shows high value of nitrate 485.7µg/l and site Char Chainari (S5) shows low values of nitrate 155.9µg/l. The site inside lake near the entry of Telbal Nallah (S1) shows high value of phosphate 208.8µg/l and low value is found near Central site near Sonalank (S3) 82.2 µg/l. The site near Telbal Nallah (S1) shows high values for the reactive silicate ions (2.59 mg/l) and central site near Sona Lank (S3) shows low values for silicate ions (1.06 mg/l). The outlet site of STP Hazratbal (S10) shows high value for Sulphate ions (14.08mg/l) and the central site near Char Chinari (S5) shows low value for Sulphate ions (6.67 mg/l).

The site near Dhobi Ghat area (S2) shows high concentration of iron (326.38µg/l) and low concentration of iron (117.46µg/l) is found at central site near Char Chinari (S5). The site near Nishat Pipe line bund (S4) shows high value of Na^+ 2.4 mg/l and site near Kabootar Khana (S6) shows low value 1.8 mg/l. The central site Nigeen (S7) shows high value of K^+ 3.5 mg/l and low value is found near Kabootar Khana (S6) 1.6 mg/l.

The results of various physico-chemical characteristics of Dal Lake water samples for the two seasons (summer and winter) are presented in the (table 3 and 4). Natural water is usually alkaline due to presence of high concentration of carbonates. Considerable fluctuations in pH can be observed in natural water during day, season to season and within years because of exposure to the air and biological activities. The lake is characterized by highly alkaline pH during summer as well as in the winter season. The site near Nishat pipe line S_4 shows high range of PH during summer (8.2) and the site near Dhobi Ghat area S_2 shows low range of PH (7.8). During winter there are not evident changes in the PH. During the summer season Saderabal area S_8 shows high values of E.C (321µS/cm) and low value near kabootar khana S_6 (178µS/cm). There is further decrease in the E.C. during the winter season because of temperature variation in the winter season there might be sudden fall in the electrolytic conductivity. During winter Saderabal area S_8 shows high value (305µS/cm) and low value (201µS/cm) near Dhobi Ghat area S_2. The site near Nishat pipe line S_4 shows high value during summer (16.1mg/l) and low value (9mg/l) near outlet site of STP Hazratbal S_{10}. During winter the site near Nishat pipe line S_4 shows high value (16.6mg/l) and Nigeen S_7 shows low value (9.3mg/l). During summer Pokhribal area S_8 shows high value of free Co_2 (10.3mg/l) and low value near Char Chinari S_5 (4mg/l). During winter the site near Telbal Nallah S_1 shows high value of free Co_2 (11.1mg/l) and low value near Kabootar khana S_6 (4mg/l). During summer Nigeen S_7 shows high value of DO (7.4mg/l) and Dhobi Ghat area S_2 shows low value (5.7mg/l). High values of DO are seen near Telbal Nallah S_1 (7.8mg/l) and low value near Pokhribal area S_9 (5.5mg/l). High values of alkalinity are seen during summer near STP Hazratbal S_{10} (247mg/l) and low value near Sona Lank S_3 (118mg/l), during winter outlet site of STP Hazratbal S_{10} shows high value (332mg/l) and low value near Sona Lank S_3 (192mg/l). During summer site near Telbal Nallah S_1 shows high value of Total

Hardness (276mg/l) and site near Sona Lank S_3 shows low value (111mg/l), high values of Total Hardness are seen in winter near Telbal Nallah S_1 (159mg/l) and low value near Sona Lank S_3 (96mg/l). During summer high values of

Ca^{2+} are seen near outlet site of STP Hazratbal S_{10} (44.3mg/l) and low value near Sona Lank S_3 (33.8mg/l), during winter high values are seen near outlet site of STP Hazratbal S_{10} (43.8mg/l) and low near Char Chinari S_5 (33.2mg/l).

During summer high values of Mg^{2+} are seen near outlet site of STP Hazratbal S_{10} (6.2mg/l) and low value in Nigeen S_7 (3.3mg/l), during winter high values are seen near Char Chinari S_5 (8.2mg/l) and low value in Nigeen (3.5mg/l). High values of Chloride (20.5mg/l) are seen near pokhribal area S_9 during summer and low values near Sona Lank S_3 (12.7mg/l), during winter site near Dhobi Ghat area S_2 shows high value (19.7mg/l) and site near Char Chinari S_5 shows low value (13.3mg/l). During summer site near STP Hazratbal S_{10} shows high values of Nitrate (897.6µg/l) and Nigeen S_7 shows low value (118.8µg/l), during winter high value are seen near Nishat pipe line S_4 (827.4µg/l) and low values near Saderable area S_8 (219µg/l). During summer site near Telbal Nallah S_1 shows high values of Phosphate (219.7µg/l) and low value are seen near Char Chinari S_5 (93.8µg/l), High values are seen during winter near Telbal Nallah S_1 (208.9µg/l) and low value near Sona Lank S_3 (71.3µg/l).

During summer the outlet site of STP Hazratbal S_{10} shows high values of Iron (279.9mg/l) and low values are seen near Sona Lank S_3 (209.1mg/l), during winter high values are seen near Telbal Nallah S_1 (251.1mg/l) and low values are seen in Dhobi Ghat area S_2 (30mg/l). High values of Silicate (2.4mg/l) are seen during summer near Telbal Nallah S_1 and low values (1.0mg/l) near Sona Lank S_3, during winter outlet site of STP Hazratbal S_{10} shows high values (2.7mg/l) and low value (1.0mg/l) are seen near Sona Lank S_3. During summer outlet site of STP Hazratbal S_{10} shows high values of Sulphate (22.3mg/l) and low values (7.1mg/l) are seen near Char Chinari i.e. S_5.

Sites	*S1*	*S2*	*S3*	*S4*	*S5*	*S6*	*S7*	*S8*	*S9*	*S10*
Ph	*8*	*7.8*	*8.1*	*8.2*	*8*	*8.1*	*8*	*8.1*	*7.9*	*7.9*
E.C	*220*	*245*	*198*	*181*	*199*	*178*	*278*	*321*	*258*	*310*
TDS	*15.4*	*13.5*	*10.5*	*16.1*	*9.1*	*13*	*9.5*	*13*	*9.8*	*9*
CO2	*6.6*	*8.8*	*5*	*7.8*	*4*	*6.5*	*9*	*10.3*	*102*	*9.8*
DO	*7.1*	*5.7*	*7*	*6.4*	*7.3*	*6.4*	*7.4*	*6*	*6.2*	*5.8*
ALK	*170*	*163*	*118*	*161*	*130*	*140*	*178*	*203*	*175*	*247*
T.H	*276*	*183*	*111*	*125*	*112*	*166*	*134*	*152*	*137*	*149*
Ca^{2+}	*41.3*	*41.1*	*33.8*	*36.6*	*34.5*	*35.8*	*33.1*	*36.5*	*38.2*	*44.3*
Mg^{2+}	*4.8*	*4.5*	*3.8*	*4.3*	*3.6*	*3.9*	*3.5*	*4.3*	*4.5*	*6.2*
Cl	*13*	*16.7*	*12.5*	*16.6*	*12.6*	*14*	*18.5*	*20.3*	*20.5*	*17.8*
N	*338.7*	*178.3*	*207*	*176.6*	*194.8*	*201.6*	*118.8*	*247.1*	*124.4*	*897.6*
P	*206.7*	*140*	*96.9*	*99.6*	*93.8*	*95*	*135*	*173.5*	*131*	*176.6*
Fe	*211.4*	*219.7*	*209.1*	*218*	*215*	*272*	*223.4*	*276.2*	*265.3*	*279.9*
Si	*2.4*	*2.2*	*1*	*1.4*	*1.2*	*1.4*	*1.1*	*2*	*2.1*	*2.3*
Su	*9.1*	*11.6*	*7.5*	*8.9*	*7.1*	*7.8*	*8*	*8.5*	*9.2*	*22.3*
Na^{+}	*1.8*	*1.9*	*2.1*	*2.2*	*1.8*	*1.7*	*1.9*	*1.8*	*2.1*	*2.1*
K^{+}	*2.4*	*2.6*	*1.4*	*1.7*	*1.7*	*1.4*	*3.5*	*1.7*	*1.9*	*2.2*

Table 3: Physico-chemical parameters (mean values) of different sites during summer

Table 4: Physico-chemical parameters (mean values) of different sites during winter.

Sites	*S1*	*S2*	*S3*	*S4*	*S5*	*S6*	*S7*	*S8*	*S9*	*S10*
Ph	7.9	7.9	7.8	8.1	7.9	7.8	7.8	7.9	7.8	7.9
E.C	224	201	297	209	275	289	278	305	301	304
TDS	14.5	15.2	12.5	16.6	9.6	12.5	9.3	12.3	9.8	9.6
CO2	11.1	10.3	5.3	5.5	4.8	4	9.9	8.6	9	5
DO	7.8	6.1	7.2	6.8	7.5	6.6	7.6	6.3	5.5	5.8
ALK	246	265	207	207	192	223	270	249	286	332
T.H	159	123	96	108	97	138	131	136	136	133
Ca^{2+}	40.2	41.3	33.3	34.1	33.2	34.4	33.5	36.6	39	43.8
Mg^{2+}	4.6	4.6	3.5	3.6	8.2	3.6	3.5	4	4.2	5.3
Cl	17.2	19.7	13.6	15	13.3	15.5	16.1	16.8	17.5	14.2
N	594.6	502	320.4	827.4	315	322.5	327.4	219	810	228.3
P	208.9	97.41	71.5	71.5	68.3	133.2	165.9	133	161.2	136.4
Fe	251.5	30	144.5	157.2	116.3	139.9	14.1	176	195	228.6
Si	2.6	1.7	1	1.5	1.3	1.6	1.4	1.7	2.5	2.7
Su	9.5	9.9	6.6	7.1	6.1	8	17	8	10	13.2
Na^{+}	2.3	1.7	1.7	2.2	1.7	1.7	1.9	2.2	2.1	2.1
K^{+}	2.2	2.6	2.1	2.3	1.3	1.2	3.4	1.4	1.8	2

During winter Nigeen S_7 shows high values of Sulphate (17mg/l) and low values (6.1mg/l) near Char Chinari S_5. During summer high values of Na^{2+} (2.2mg/l) are seen near Nishat pipe line S_4 and low values (1.7mg/l) near Kabootar Khana S_6, during winter high values of Na^{2+} (2.3mg/l) are seen near Telbal Nallah S_1 and low values (1.7mg/l) near Char Chinari S_3. During summer Nigeen shows high values (3.5mg/l) of K^+ and low values (1.4mg/l) near Kabootar Khana, High values of K^+ (3.4mg/l) are seen in Nigeen S_7 and low values (1.2mg/l) near Kabootar Khana.

Table 5: Pearson correlation matrix for measured variables of all ten sites of Dal Lake

	PH	E.C	TDS	Co_2	DO	Alk	TH	Ca^{2+}	Mg^{2+}	Cl^-	N	Po_4	Si	So_4	Fe	Na^+	K^+
PH	1																
E.C	-0.62	1															
TDS	0.11	-0.27	1														
Co_2	-0.53	**0.63**	0.04	1													
DO	0.14	-0.46	0.01	-0.18	1												
Alk	-0.47	**0.89**	-0.34	0.57	-0.53	1											
TH	-0.39	0.28	0.41	0.51	0.07	0.36	1										
Ca^{2+}	-0.0	0.51	0.07	0.35	-0.5	**0.72**	0.56	1									

	7				1												
Mg^{2+}	-0.07	**0.60**	-0.01	0.30	-0.54	**0.81**	0.46	**0.96**	1								
Cl^-	-0.76	**0.74**	0.06	**0.78**	-0.56	**0.61**	0.30	0.29	0.29	1							
N	-0.52	0.51	-0.32	**0.78**	0.07	0.56	0.59	0.31	0.25	0.47	1						
Po_4	-0.45	0.55	0.09	0.59	0.13	**0.61**	**0.87**	0.55	0.55	0.33	**0.73**	1					
Si	-0.27	0.52	0.07	0.44	-0.42	**0.72**	**0.69**	**0.87**	**0.85**	0.40	0.52	**0.70**	1				
So_4	-0.15	**0.63**	-0.12	0.32	-0.64	**0.85**	0.36	**0.92**	**0.96**	0.38	0.26	0.45	**0.77**	1			
Fe	-0.42	**0.66**	0.12	**0.93**	-0.30	**0.61**	0.59	0.55	0.47	**0.73**	**0.69**	**0.62**	0.52	0.49	1		
Na^+	0.10	0.23	0.11	0.10	-0.32	0.37	-0.41	0.37	0.51	0.18	-0.10	0.09	0.47	0.41	0.01	1	
K^+	-0.44	0.35	-0.06	**0.64**	0.22	0.36	0.33	0.12	0.11	0.40	0.51	0.45	0.04	0.21	0.57	-0.09	1

Statistical analysis

Pearson Correlation coefficients were calculated to obtain relations between the variables (Table 5). The E.C showed positively significant correlation with free Co_2 (0.63), alkalinity (0.89), Mg^{2+} (0.60), Cl^- (0.74) Sulphates (0.63) and with Fe (0.66). Free Co_2 is found positively correlated with Chlorides (0.78), Nitrates (0.78), Fe (0.93) and with K^+ (0.64). Alkalinity is found positively correlated with Ca^{2+} (0.72), Mg^{2+} (0.81), Cl^- (0.61), Po_4 (0.61), Si (0.72), Sulphates (0.85), and with Fe (0.61). Total Hardness is positively correlated with Po_4 (0.87) and with Si (0.69). Ca^{2+} is positively correlated with Mg^{2+} (0.96), Si (0.85) and with So_4 (0.92). Mg^{2+} is positively correlated with Si (0.85) and So_4 (0.96). Cl^- showed positive correlation with Fe (0.73). Nitrate is positively correlated with Phosphate (0.73) and Fe (0.69). Phosphate showed positive correlation with Si (0.70) and Fe (0.69). Si showed positive correlation with Sulphates (0.77)

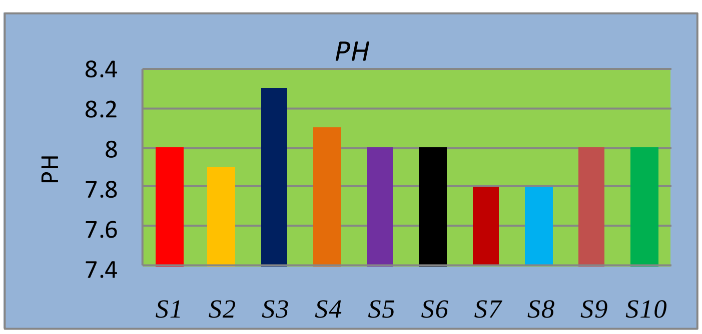

Figure 2: pH variation (May 2011 - April 2013)

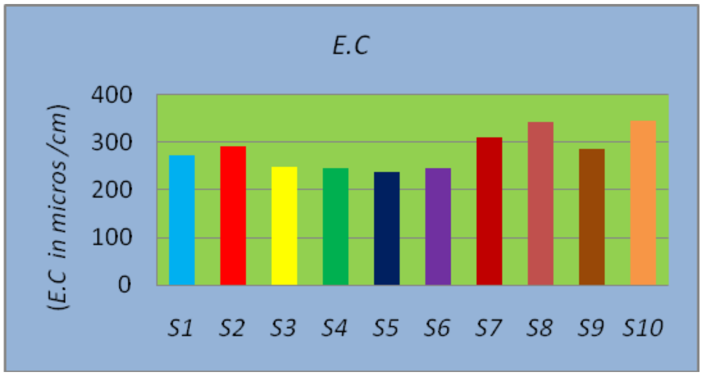

Figure 3: EC variation (May 2011 - April 2013)

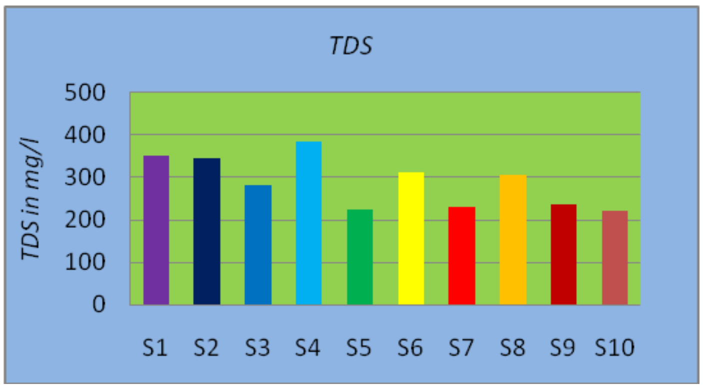

Figure 4: TDS variation (May 2011-April 2013)

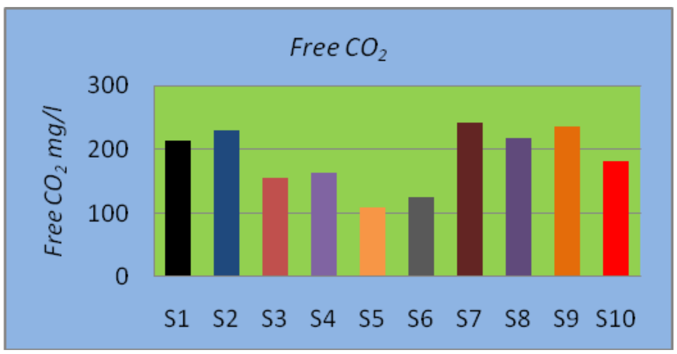

Figure 5: Free CO_2 variation (May 2011 - April 2013)

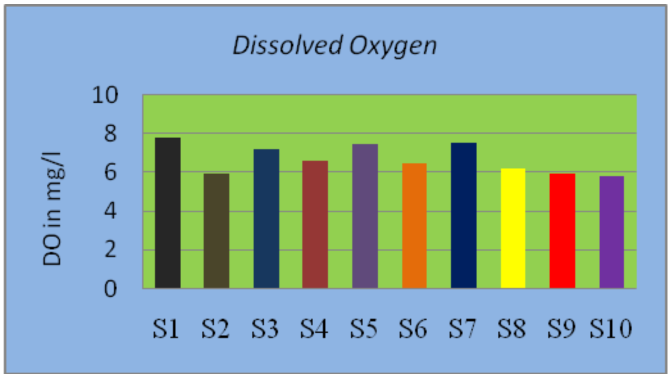

Figure 6: DO variation (May 2011 - April 2013)

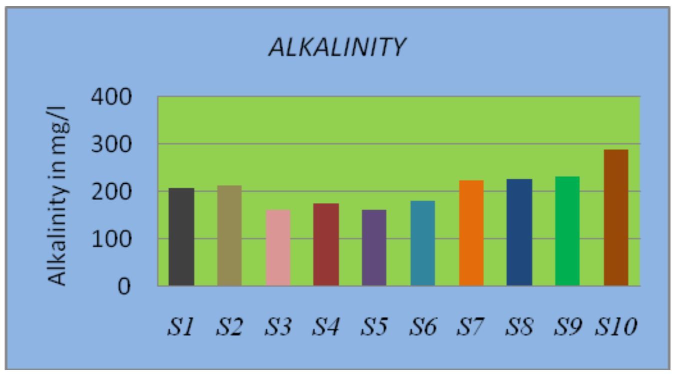

Figure 7: Alkalinity variation (May 2011 - April 2013)

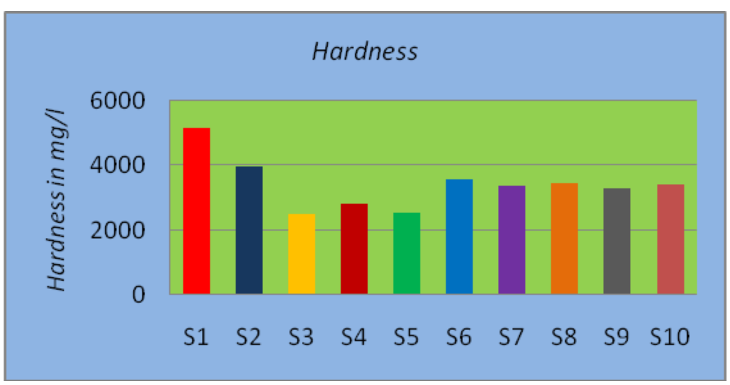

Figure 8: Total Hardness variation (May 2011 - April 2013)

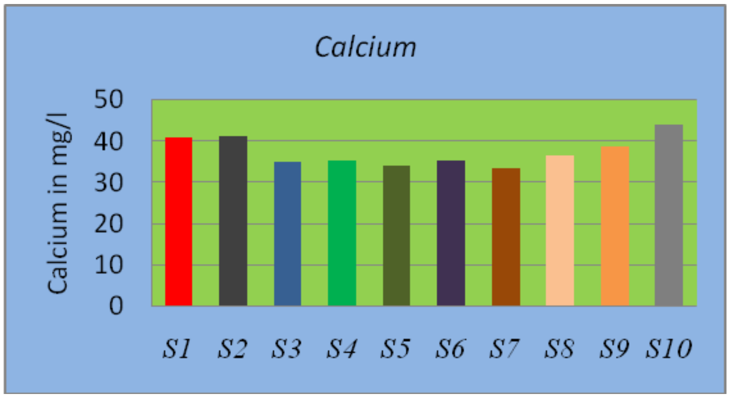

Figure 9: Calcium variation (May 2011 - April 2013)

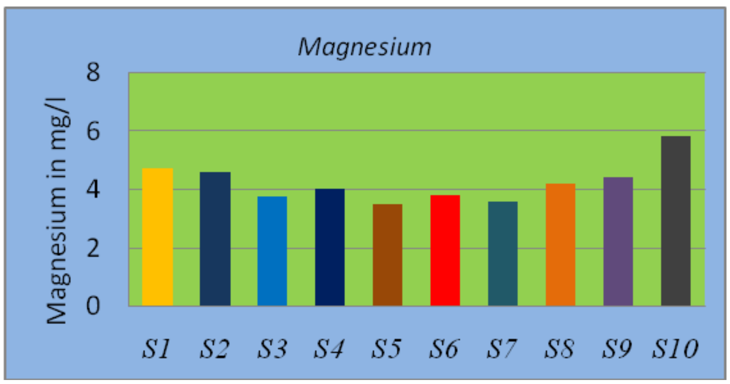

Figure10: Magnesium variation (May 2011 - April 2013)

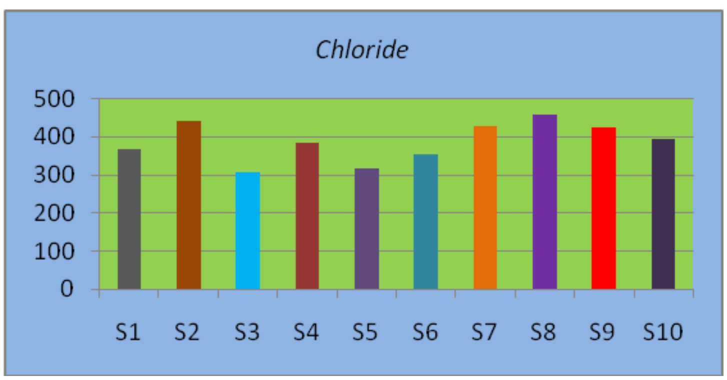

Figure 11: Chloride variation (May 2011 - April 2013)

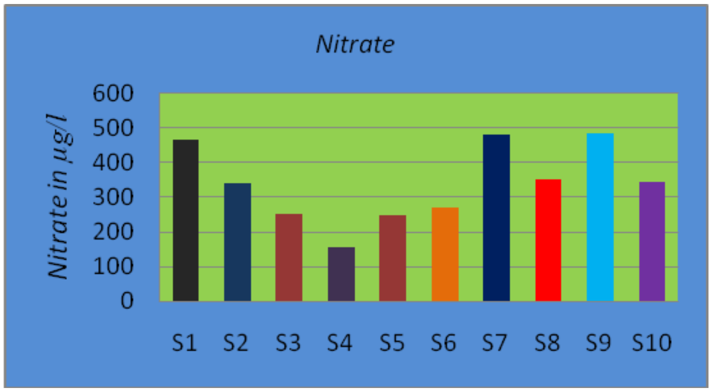

Figure 12: Nitrate variation (May 2011 - April 2013)

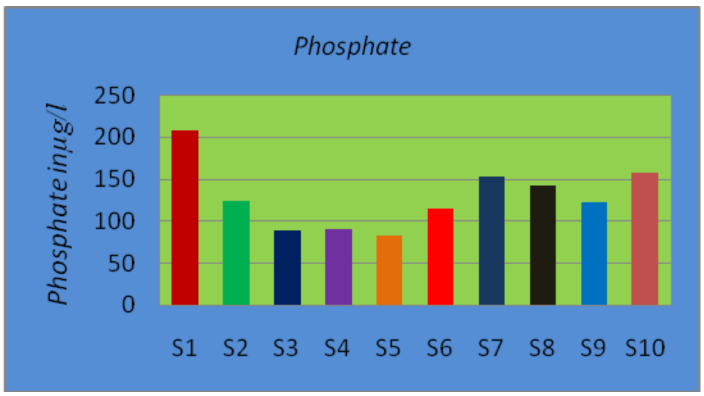

Figure 13: Phosphate variation (May 2011 - April 2013)

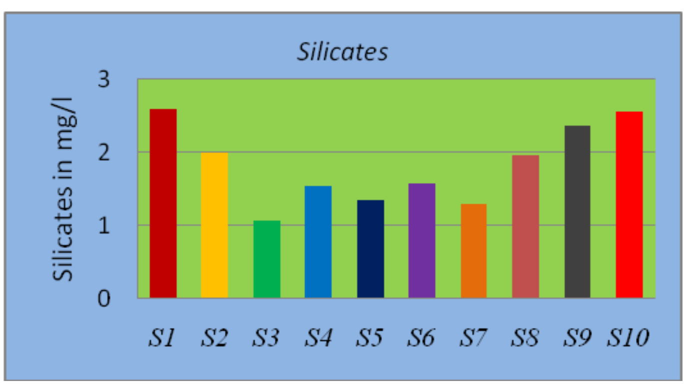

Figure 14: Silicate variation (May 2011 - April 2013)

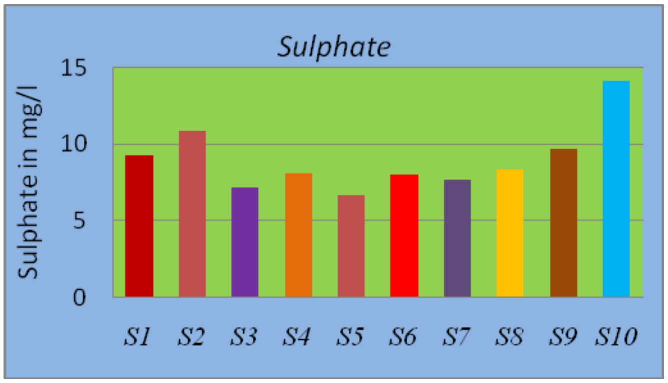

Figure 15: Sulphate variation (May 2011 - April 2013)

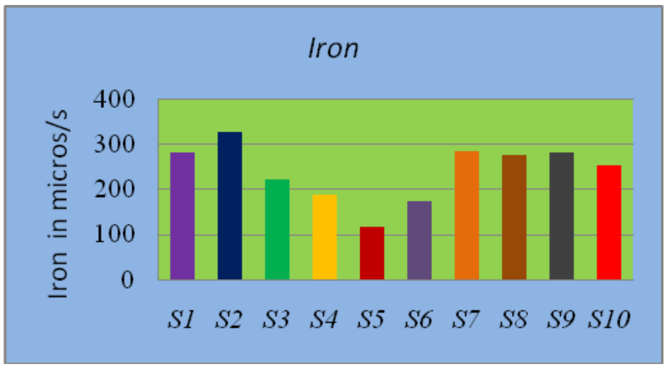

Figure 16: Iron variation (May 2011 - April 2013)

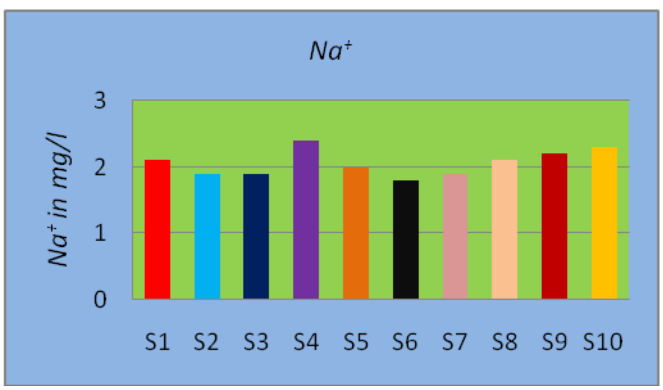

Figure 17: Na^+ variation (May 2011 - April 2013)

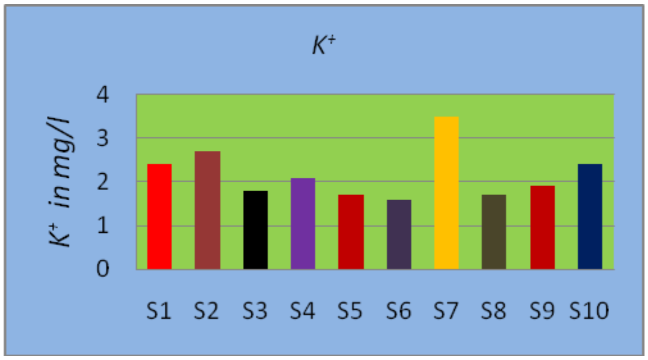

Figure 18: K^+ variation (May 2011 - April 2013)

IV. DISCUSSION

Due to discharge of large quantities of Wastes from human settlements, agricultural runoff and house boats remarkable changes have occurred in the water chemistry of Dal Lake.

A prospective design was used to study the physicochemical characteristics of Dal Lake water. A wide spectrum of physical and chemical changes have occurred in Dal Lake waters such as elevated temperature, pH, electric conductivity, alkalinity etc. While many of the chemicals and substances that are regulated may be naturally occurring (calcium, sodium, iron, manganese, etc.) the concentration is often the key in determining what is a natural component of water, and what is a contaminant. High concentrations of naturally occurring substances can have negative impacts on aquatic flora and fauna. [18]

The main indicators of pollution include the amount of total suspended solids, biochemical oxygen demand (BOD) at 20 deg. C, concentration of chlorides, nitrogen and phosphorus and absence of dissolved oxygen. [19]

The pH recorded during the present study (mean 7.8-8.3) is indicative of alkaline nature of water which may be due to high temperature that causes reduction in solubility of CO_2. Our study shows increase in pH during summer months. A Study conducted by Mahananda et al., (2010) also shows that temperature is one of the most significant parameter which reduces the solubility of CO_2 which increases the alkaline nature of water. [2]In our study average electrical conductivity value recorded was (237.46µs/cm-345.80µs/cm) which is thus above eutrophic levels of 200µs/cm. Increased electrical conductivity is regarded as pollution indicator in shallow lakes. Das R. *et al* (2006) also support the similar findings in their study. [20]Site S_4 (near Nishat pipeline) showed high values for TDS in our study. In water, total dissolved solids (TDS) can be used to check the accuracy of analyses when dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles. [2]

Alkalinity is generally associated with presence of carbonates and bicarbonates in natural waters. Our study revealed that alkalinity is in the range between161.80 to 290.08 which is higher than acceptable range. Highly alkaline water is unpotable as with alkalinity beyond 200mg/l, the taste of water becomes unpleasant. Goel et al (1985) reported same results in Yelgaon Dam Maharashtra. [21] Hardness plays an important role in the distribution of aquatic biota and many species are identified as indicators for hard and soft waters. Hardness of water is due to major cations present in the water body. Calcium and magnesium are principle cations that impart the hardness to water. The mean value of hardness was maximum at site $S_{1,}$ which may be due to the outflow of sewage treatment plant at this particular site. Hardness of water also depends on geological nature of drainage basin. [22] Free CO_2 depicted well marked fluctuations at all the sites, registering a minimum mean value (4.5 mg/L) and a maximum (11.1 mg/L). High value of free CO_2 content is an indication of high degree of pollution, a fact supported by Todda (1970) also. [23]Among the various cations, Ca^{2+} and Mg^{2+} were found abundant almost at all sites in our study. Ca^{2+} and Mg^{2+} concentration of freshwater bodies of Kashmir Valley has been associated with thick population of plankton, especially Cyanophyceae. [16] The concentration of nitrates and phosphates also showed great variations among various sites in our study. Pandit et al (2002) argue in their study that increased concentration of nitrates and phosphates in lakes resulted in enhanced productivity. Alteration of water's physical chemistry including acidity (change in pH), electrical conductivity, temperature and eutrophication where eutrophication is an increase in the concentration of chemical nutrients (nitrate, phosphate) in an ecosystem to an extent that increases in the primary productivity of the ecosystem.

Silicate remains low in different months at different sites in the present study. This fact was also supported by Sarwar (1986) who argue that the silicate content in the lake water gets depleted as it is taken up by the abundance of diatoms. [24]
Our study revealed that the dissolved oxygen remains almost low at each site. It may be due to highly eutrophic conditions of Dal Lake. The low level of DO is again indicative of polluted nature of water body. Such low level of dissolved oxygen was also noted in other lakes by Iqbal et al (2006). [25]
The maximum mean sulphate concentration was recorded as 14.08 mg/L at site S_{10} and minimum as 6.67 mg/L at site S_5. The high concentration of sulphate at site S_{10} may be due to drainage of untreated sewage from sewage treatment plant into the lake. This agrees with Renn (1968) observation on the abundance of sulphate ions into the freshwaters is due to untreated sewage. [22]The chloride content was observed higher in summer than in winter in our study. The same results have been revealed by Jana (1973) and Govindan et al (1979). According to them higher concentration of chloride in the summer period could be due to sewage mixing, increased temperature and evaporation by water. [26, 27]
Iron in surface water is generally present in the form of ferric state. Surface waters in a normal pH range of 6 to 9 rarely carry more than 1 mg of dissolved iron per liter.S_2 (near dhobi ghat) shows high concentration of iron (3.2mg/l) and S_5 (near Char Chinari) low concentration (1.1mg/l) which reveals that S_2 is disturbed.
Remarkable changes have taken place in water chemistry of Dal lake over the past few decades which are revealed by comparing the present water quality with that of the past (Table 6).

Table.6. Comparison of physico-chemical characteristics of Dal lake water (Present and Past)

Parameter	*Year(2011-13)*	*Year(2007)*	*Year (1977)*
PH	*7.8-8.3*	*7.6-8.6*	*7.5-9.7*
E.C	*237.46-345.80*	*122-317*	*115-283*
TDS	*220-385*	*78-201*	*183-289*
Free CO_2	*4.5-10.2*	*4.9-14*	*7.7-19.3*
DO	*5.80-7.78*	*5.8-10*	*1.2-10.7*
Alkalinity	*161.80-290.08*	*46-372*	*17-269*
Hardness	*105-213*	*42-164*	*38-63*
Ca^{2+}	*33.38-44.09*	*14-46*	*1.7-61*
Mg^{2+}	*3.50-5.80*	*2-12*	*0.4-18.3*
Chloride	*12.7-19.1*	*6-18*	*8.11-15.89*
Nitrate	*155.9-485.7*	-	*26-135.7*
Phosphate	*82.2-208.8*	-	*121-418.2*
Silicates	*1.06-2.59*	*1.6-3.2*	*0.2-32.5*
Sulphates	*6.67-14.08*	*2-9*	*1.3-3.4*
Iron	*1.1-3.2*	-	*0.39-0.98*
Na^+	*1.8-2.4*	*2-8*	*0.4-3.8*
K^+	*1.6-3.5*	*0.2-4*	*0-2.2*

The overall physicochemical parameters of Dal Lake water show an increasing trend when we compare it with previous data (Table 6). It is clear from the data that values of EC, TDS, TH, Chloride, Nitrate, Sulphate and K^+ have significantly increased and value of DO has decreased over past few decades. It has been prophesized that within next fifty years period the Dal Lake will disappear. [28] Scientific research also reveals that Telbal Nallah, Botkal, and sewage drains are responsible for a substantial influx of nitrogen and phosphorus into the lake. A large Quantity of phosphorus and inorganic nitrogen has been discharged into the lake. Non point sources, such as seepage and diffused runoff, have been recorded as adding 4.5 tones of total phosphates and 18.14 tones of nitrogen (NO_3–N and NH_4–N) to the lake. [29] Based on this, it has been inferred that the water quality of the lake has deteriorated. The water quality has also deteriorated due to intense pollution caused by untreated sewage and solid wastes that is fed into the lake from peripheral areas and from settlements and houseboats. Besides, some experts believe that deforestation in the catchment of Dal Lake and Telbal stream may have led to more nitrogen and phosphorus rich run off, further aiding eutrophication. Encroachments of water channels and consequent clogging have diminished the circulation and inflows into the lake, so with the building up of phosphates and nitrogen, this has led to extensive weed growth and consequences on the biodiversity of lake. [30]

An assessment of physicochemical characteristics of Dal Lake water from time to time is important so far as preventive and treatment measures are concerned. The knowledge of this will also guide us in assessing the pollution load. Besides, this may also prove useful for providing data (both primary and secondary) for environmental impact assessment.

V. CONCLUSION

Drastic changes have taken place in the water chemistry of Dal Lake over the past few decades. Correlation with available data shows an increasing trend of different physicochemical parameters which lead to deterioration in water quality.

The lake water is characterized by highly alkaline pH and medium electrical conductivity and TDS. The overall calcium and magnesium content of lake is high. It is clear from the study that values of EC, TDS, TH, Chloride, Nitrate, Sulphate and K^+ have significantly increased and value of DO has decreased over past few decades.

Dal Lake is undergoing rapid eutrophication due to rapid anthropogenic disturbances. The addition of various chemicals particularly nitrogen and phosphorus increases the pollution load. The organic and inorganic pollutant load in the Dal has accelerated the macrophytic growth which in turn has reduced the water quality of the lake.

An assessment of physicochemical characteristics of Dal Lake water from time to time is important so far as preventive and treatment measures are concerned. The knowledge of this will also guide us in assessing the pollution load. Besides, this may also prove useful for providing data (both primary and secondary) for environmental impact assessment.

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