Assessment of Water Quality for Determining the Pollution Status of a Famous Lake of North India

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***Abstract*- Dal Lake has been under tremendous pressure and its pollution seems never ending. In this paper, an attempt has been made to describe the present pollution level in the lake environment with the use of water quality indices. Water quality index seems quite a rational tool in bringing a combination of various water quality parameter data into a single number describing the pollution level in a particular range usually from 0 to 100. Two water quality indices have been used, one is the Weighted Arithmetic Average method which is a specific water quality index used to describe the drinking water quality and the other one is the popular NSF (National Sanitation Foundation) method which describes the general water quality. According to this method, the values indicate that the quality of the water in the lake is of "medium" type. Both the methods indicate that Dal Lake is a dying heritage and immediate and effective restoration measures should be adopted to save this precious jewel otherwise the time is not far when we would find the city of Srinagar without Dal.**

***Index words*- BOD, Dal lake, Eutrophication, NSF, Water quality index.**

I. INTRODUCTION

Dal Lake known famously as the "Jewel of Kashmir" is a fresh water lake that is located in the heart of Srinagar city which is the summer capital of J&K. It is the main attraction of the city and develops a large amount of tourist attraction as well as providing drinking water to the city. The lake also serves as a source of fisheries and agriculture to the state and thus helps in providing capital to the government and employment to a large amount of the civil society and habitants living in or around the lake. It is very saddening to see that the lake has suffered huge amounts of loss in terms of encroachments, water quality and finally rehabilitation. The water quality of the lake has declined considerable in the past. A number of studies have been carried out on the lake by different agencies that show the declining water quality of the lake.

Water quality index is a tool or technique devised to integrate various parameter data into a single number that conveniently describes the status of the water quality of the water body. Abbasi states in his book that water-quality indices aim at giving a single value to the water quality of a source on the basis of one or the other system which translates the list of constituents and their concentrations present in a sample into a single value thus comparing different samples for quality on the basis of the index value of each sample.

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Also stated by Ott in his report to the U.S department of Research and Monitoring, E.P.A, there are possibly four ways to classify the water indices: (1) indices for general water quality (2) indices for specific water uses (3) indices for planning (4) indices for statistical approaches. The indices included in the general water quality index start with the work of Horton in 1965, using 10 variables, including dissolved oxygen, coli form count, pH, specific conductance, alkalinity, chloride content and temperature, carbon chloroform content, percentage population served and obvious pollution. Horton's index represented water quality based on a range from "0" to "100" with "0" representing poor water quality and "100" representing perfect water quality. Another general water quality index is the famous and most used "NSF water quality index" proposed by Brown, McClelland and Deininger. It was based on a nationwide survey of water quality experts. A panel of 142 persons were polled using mail questionnaires and were asked to include the appropriate water quality parameters they thought were important to be included in an index. Successively they were asked to give rating curves for each of the selected parameters. This approach that was used is known as the Delphi technique and was developed in the Second World War. This programme was supported by the RAND corporation and a total of nine parameters were selected namely pH, temperature, B.O.D, nitrates, phosphates, dissolved oxygen, total solids, turbidity and faecal coli form. These indices assumed that general water quality was a concept that was reported by a single numerical index, irrespective of the use for which the water was intended. The other approach is to develop water quality indices for specific water use like drinking, fisheries, recreation, agriculture, public water supply etc. The earliest works in this direction were made by O'Connor who developed water quality indices such as fish and wildlife index and public water supply index. He used the same Delphi technique to develop these indices. Ever since then a number of indices have come into existence such as the Weighted Arithmetic Average Method , Bhargava method, Canadian council of ministers of environment which is also known as the global water quality index, Tiwari and Mishra method for groundwater quality and many more.

II. STUDY AREA

Dal lake is situated in Srinagar (34°5'- 34°6' n latitude and 74°8'- 74°9'E longitudes) at the foot of Zabarwan mountains. The water surface area of the lake is 11.45 km^2 in which 4.1km^2 is the floating gardens, 1.51 km^2 is the land area and the marshy area is 2.25 km^2, the lake is divided into four basins namely Hazratbal, Bod Dal, Nigeen and Gagribal respectively. Nigeen is the deepest basin of around

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6m and Gagribal is the shallowest with 2.25 m. The site map is shown as under.

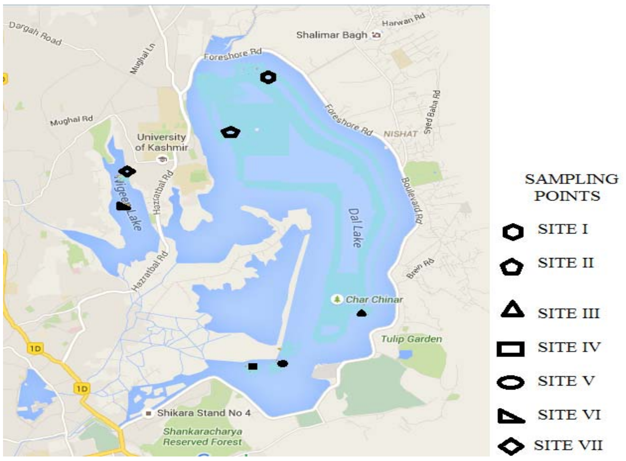

Fig. 1: Site map of Dal Lake with the locations of different sampling points

III. MATERIALS AND METHODS

The seven sites selected were analysed monthly. Samples were collected in 5 litre plastic cans and samples for B.O.D were collected in separate bottles which were covered immediately. The cans and bottles were put in a container immediately to prevent them from any exposure to sunlight. A total number of 15 parameters were analyzed during a period of four months for calculation of water quality index from both the methods as described. The tests performed on the samples were pH, total dissolved solids, total solids, conductivity, total hardness, calcium, magnesium, total alkalinity, chloride, turbidity, temperature, dissolved oxygen, B.O.D, nitrate-nitrogen, total phosphate and fecal coli form respectively. pH was measured by a digital pH meter. Conductivity and total dissolved solids were measured using a digital conductivity meter. Total solids were calculated using the oven dry method. Dissolved oxygen was measured using the standard D.O probe. Turbidity was measured using a digital turbidimeter. Nitrate nitrogen was analyzed using the Bruccine method.

Total phosphates were analyzed using the stannous chloride method. Total alkalinity, chloride, total hardness and calcium hardness were calculated using the titrometric analysis by the standard procedures of APHA.

A. *National Sanitation Foundation WQI*

For the determination of the water quality index two methods have been used. One is the Brown's National Sanitation Foundation Index which gives a general water quality index and not specific such as used for agricultural, drinking etc. This method is simply aimed at telling about the water quality of a water body irrespective from the perspective of drinking, agriculture, fisheries, public water supply or any other intended use. It would thus mean to give a simple idea about the water quality of any water body in a very general way. In the report submitted by Ott to the U.S E.P.A research wing, 7 agencies were using either the standard or the modified NSF method and the state agency of Indiana had applied the modified NSF method in determining the water quality of 52 lakes and streams. The method included nine parameters for calculation of WQI and it was a method based on the opinion of water quality experts. They gave the graphs and significant ratings of these nine parameter which were to be included in this index. The arithmetic means were calculated for the significance rating as obtained from experts. Ratings were converted into weights by assigning a "temporary weight" of 1 to the parameter which received the highest significance rating, i.e., dissolved oxygen. To preserve the ordering and relative ratios returned by the panellists, other temporary weights were obtained by dividing each individual mean rating into the highest rating. Each temporary weight was then divided by the sum of all weights to obtain the final weights, w_i.

After parameter selection, quality curves, and relative parameter determined, the project staff proposed the additive expression for WQI:

$$WQI(A) = \sum w(i).q(i)$$

Where,

WQI = the Water Quality Index, a number between 0 and 100.

q (i) = the quality of the i^{th} parameter, a number between 0 and 100.

w (i) = the unit weight of the i^{th} parameter, a number between 0 - 0.17.

However in this study modified NSF has been used for the calculation of water quality index and the parameter "deviation from the temperature" has been deleted and the weights have been modified. Also instead of the additive model, the multiplicative model has been used. O'Connor also suggested the use of the multiplicative model instead of the additive one as the former was more sensitive to discontinuities. The multiplicative form of WQI is as follows:

$$WQI(M) = \prod_{i=1}^{n} q(i) \wedge w(i)$$

Where,

WQI (M) = the multiplicative water quality index, a number between 0 and 100,

q (i) = the quality of the ith parameter, a number between 0 and 100

w (i) = the unit weight of the ith parameter, a number between 0 and 0.19

n = the number of parameters

The rating according to NSF WQI has five classes with very bad (0-25), bad (25-50), medium (50-70), good (70-90) and excellent (90-100).

Table I: Relative weights and parameters used in Modified NSF

Dissolved Oxygen	0.19
Fecal Coliform	0.17
pH	0.13
Phosphate	0.11
BOD5	0.11
Nitrates	0.11
Total solids	0.08
Turbidity	0.10

B. Weighted Arithmetic Average Method

Weighted 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 the various scientists for the calculation of drinking water quality index.

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

$$Q_i = 100[(V_i - V_o / S_i - V_o)] \quad \text{Where,}$$

V_i is estimated concentration of i^{th} parameter in the analysed water.

V_o is the ideal value of this parameter in pure water

$V_o = 0$ (except pH = 7.0 and DO = 14.6 mg/l)

S_i is recommended standard value of i^{th} parameter.

The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$W = K / S_i \quad \text{Where,}$$

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

$$K = 1 / \sum (1 / S_i)$$

The rating of water quality according to this WQI in five classes such as Excellent (0-25), Good (26-50), Poor (51-75), Very Poor (76-100) and Unsuitable for drinking purpose(>100).

IV. RESULTS AND DISCUSSIONS

The results for various parameters discussed above have been shown in the tables below. The respective calculations have been done and the results have been framed by the two methods discussed above. Thus, one method showing the general water quality and the other shows the drinking water quality respectively.

A. Weighted Average Method

For the calculation of water quality index by weighted average method, a total number of 12 parameters were analyzed for a period of four months. In the first step the unit weights for these twelve parameters and the calculations have been showed in Table I. The recommended limits for drinking water have been taken from different agencies like BIS (Bureau of Indian Standards, 1991), ICMR (Indian Council of Medical Research, 1975) and WWF (World Wide Fund, 2007). The values of the twelve physiochemical parameters are enlisted in the Table II, followed by the subsequent calculations for quality rating and then finally the water quality index respectively.

B. National Sanitation Foundation Water Quality Index Method

A total number of eight parameters were analyzed for this method for a period of four months. For the calculation of the quality rating values by NSF method, an online calculator programme was used developed by the water treatment centre. The quality rating values were then multiplied by the unit weights and the multiplicative form of the NSF was used. The result at the seven sampling sites in the four months is in Table III.

Table II: Calculation for unit weight and standard permissible value

Sr. No	Parameter	Standard permissible value (Si) (BIS/ICMR/WWF*)	Unit weight
1	pH	6.5-8.5	0.124
2	Total dissolved solids	500	0.00186
3	Electrical conductivity	300	0.0031
4	Total hardness	300	0.0031
5	Calcium	75	0.0124
6	Magnesium	30	0.031
7	Total alkalinity	200	0.00465
8	Chloride	250	0.00372
9	Turbidity	5	0.186
10	Dissolved oxygen	6	0.155
11	Nitrate	45	0.02
12	B.O.D	2	0.465
TOTAL			1

Table III: Monthly and Average WQI values of the four month

Sr. No.	Month	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
1.	Dec	51	61	65	61	56	55	55
2.	Jan	54	63	69	63	60	64	57
3.	Feb	58	61	66	63	64	69	62
4.	Mar	63	65	66	69	66	63	56
Total		56	62	66	64	61	63	57

V. DISCUSSION

Some points are worthy of mention that were found out in the research and are discussed as under:

1. The pH of Site 1(at the point of entry of Telbal Nallah) is slightly acidic to alkaline and this is not a good sign. A Lake environment turning towards acidic pH show strong presence of sewage and is a threatening for the fish species. Other sites are mostly alkaline but the lake water is moving towards becoming more acidic.
2. Total dissolved solids seem to be under control but slightly more at Hazratbal basin in the month of February and at Nigeen basin in the month of March. Electrical conductivity seems to be higher at Nigeen and Telbal. This may reflect higher pollution as mentioned by Awasthi in his paper.
3. Dal water is slightly hard as found in this research in the Hazratbal basin at Site 1 and one of the samples seems to be exceeding the standards value as well.
4. Total alkalinity is within the standard permissible limits but seems to be higher in Hazratbal and Nigeen basins of the lake.
5. The Dal water seems to be turbid with some samples exceeding the value of 5 NTU at Telbal, Kabutar Khana and central Hazratbal sites. Nigeen also seems to be coming close to the turbidity level.
6. Calcium seems to be within standard limits but Nigeen basin shows higher range of calcium coming as close as 72 mg/l. The values of magnesium have also found to be exceeded in Hazratbal basin near the entry of Telbal Nallah.
7. Dissolved oxygen is found out to be in the range of 5.23 mg/l at Nishat (BOD DAL) in the month of March to 10.31 mg/l at Kabutar Khana (GAGRIBAL) in the

month of February respectively. According to the water quality standards by Yasumoto Magara VOL 1 in the encyclopaedia of life support system (EOLSS),the D.O in the lakes for the water supply class (I) should be around 7.5 mg/l and for fisheries and hatching of salmon a D.O of more than 7 is required. The dissolved oxygen for agriculture should be more than 5.0 mg/l and it is clearly seen here that the D.O of the lake has deteriorated to a significant level. According to the Indian standard quality tolerances for fresh water for fish culture the minimum tolerance level for D.O is 4 mg/l and according to CPCB the drinking quality (class water) should have a D.O content of 6 or more. So it is very obvious that the D.O level in the lake is even less as far at some sites as the drinking standards or a suitable environment for fish is concerned. Higher values of B.O.D also show presence of higher organic pollution.

8. As phosphates don't have any mention in the drinking water standards, we can't ascertain the amount to which it should be present. Also phosphates are not harmful for human consumption as such but their presence in lakes creates algal blooms and increases fertility. According to the book written by Bryon Shaw indicating the trophic pollution of the lake ,it is stated that a lake should have total phosphate level of 30 µg/l but in the current study the phosphate values are as higher as 5 mg/l .this amount of phosphate clearly indicated the eutrophic nature of the lake. Nitrates on the other hand are also doing their bit and Nigeen basin has recorded the highest concentration with 22 mg/l. Although it is within the permissible limits of drinking water by CPCB but it has been detrimental to the lake environment.

Table IV: Calculation for quality rating (Q_i)

Parameter		Ph	TDS	EC	Total Hardness	Ca^{++}	Mg^{++}	Total alkalinity	Chloride	Turbidity	D.O	Nitrate	BOD
Site 1	Dec	-100	24.6	75.6	110.67	77.8	151.27	89	6	158.6	105.47	36.06	131.5
	Jan	160	28	93.3	83.33	57.6	86.53	87.5	6.8	138.6	118.03	20.02	245.5
	Feb	214	37.8	126	62.48	71.4	42	90	7.6	134.6	67.79	25.2	301.5
	Mar	160	24.2	80.3	93.33	29.8	71.57	52	6.8	59.4	96.27	48.57	126
Site 2	Dec	36	28	93.6	83.33	67.2	125.27	86	6.8	90	80.23	32.55	201.5
	Jan	126	25	83.3	61.33	34.1	52.06	81	6.8	108	78.95	29.75	219
	Feb	208	36.4	121	54.67	84.2	21	76	6.8	89.4	59.43	41.48	225.5
	Mar	166	31.6	105	56.67	48	60.16	68	8	54.8	103.25	43.24	101
Site 3	Dec	92	13.6	44.7	68	42.6	67.53	60	7.6	20	65.11	28.88	197
	Jan	140	12.5	41.6	56.67	34.6	52.86	65	7.2	26.2	71.97	35.22	100.5
	Feb	194	24.6	82.3	43.33	57.6	17.67	64	5.6	35.2	84.76	35.46	85.5
	Mar	166	25.6	86.3	44	42.6	42.26	62	6.8	42.8	108.95	32.28	100
Site 4	Dec	280	10.8	36	38	31.4	40.67	53	8.4	53.6	82.55	37.55	128
	Jan	260	12.2	40.8	46.67	40	27.67	57	8.4	43	79.06	24.75	140.5
	Feb	246	21.2	70.6	36.67	42.6	24.3	55	5.2	37	67.79	16.85	150
	Mar	260	21.4	71.3	46.67	34.1	61.8	49	5.6	41.6	94.18	16.17	100
Site 5	Dec	160	22.4	75.3	46	42.6	47.16	59	7.6	106	108.13	36.29	156
	Jan	180	24	80	42.67	48	30.9	65	6.8	102	102.32	29.68	110
	Feb	190	24.4	81.3	40	53.3	16	66	5.6	88	93.6	35.64	77.5
	Mar	150	24.4	81.3	56.67	44.8	69.94	58	6	69	115.34	25.06	104
Site 6	Dec	270	18	60.2	57.33	55.4	55.3	89	5.2	36	82.55	40.58	345
	Jan	242	22	73.3	52	74.6	41.46	78	5.6	58	69.76	40.29	265
	Feb	216	32.2	107	48	48	18	75	6	38	49.06	37.2	250.5
	Mar	260	35	116	76.67	89	50.4	81	10	86.6	90.11	45.82	133.5
Site 7	Dec	210	19	64	60.67	64	50.4	84	6	49.5	88.95	30.88	330.5
	Jan	304	19.8	66	60	58.6	40.27	82	8.4	42	87.44	49.51	250.5
	Feb	236	32	107	63.33	82	43.67	82	9.6	29.8	102.67	44.89	203
	Mar	270	35	117	63.33	96	8.13	82	8.8	89.4	87.55	3	292

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Table V: Calculation for water quality index

Parameter		pH	TDS	EC	Total Hardness	Ca^{++}	Mg^{++}	Total alkalinity	Chloride	Turbidity	DO	Nitrate	BOD	Σ Qi*Wi	ΣWi*Qi/ΣWi	Average
Site 1	Dec	12.4	0.04	0.23	0.34	0.96	4.68	0.41	0.022	29.49	16.34	0.72	61.14	102.17	102.17	147
	Jan	19.84	0.05	0.29	0.26	0.71	2.68	0.4	0.025	25.77	18.29	0.4	114.15	183.3	183.3	
	Feb	26.536	0.07	0.39	0.193	0.88	1.302	0.41	0.028	25.03	7.79	0.5	140.19	196	196	
	Mar	19.84	0.04	0.25	0.29	0.36	2.21	0.24	0.025	11.04	11.07	0.97	58.59	107.06	107.06	
Site 2	Dec	4.464	0.05	0.29	0.26	0.83	3.88	0.4	0.025	16.74	9.22	0.65	93.7	130.44	130.44	123
	Jan	15.62	0.04	0.258	0.19	0.42	1.61	0.38	0.025	20.08	9.07	0.59	101.83	150.11	150.11	
	Feb	25.79	0.06	0..38	0.17	1.04	0.651	0.35	0.025	16.62	9.21	0.83	104.8	134.09	134.09	
	Mar	20.58	0.05	0.33	0.18	0.59	1.11	0.31	0.029	10.19	16	0.86	46.96	97.15	97.15	
Site 3	Dec	11.4	0.02	0.138	0.21	0.53	2.09	0.279	0.028	3.72	10.09	0.58	91.6	120.6	120.6	96
	Jan	17.36	0.02	0.13	0.18	0.43	1.63	0.3	0.026	4.87	11.15	0.7	46.73	83.52	83.52	
	Feb	24.05	0.045	0.26	0.134	0.71	0.54	0.297	0.02	6.54	13.12	0.7	39.75	86.166	86.166	
	Mar	20.58	0.047	0.27	0.136	0.53	1.31	0.29	0.025	7.96	16.88	0.64	46.5	95.16	95.16	
Site 4	Dec	34.72	0.02	0.11	0.12	0.39	1.26	0.24	0.031	9.96	12.79	0.751	59.52	119.9	119.9	116
	Jan	32.24	0.022	0.13	0.144	0.49	0.85	0.27	0.031	7.99	12.25	0.495	65.33	120.21	120.21	
	Feb	30.5	0.039	0.22	0.113	0.53	0.75	0.25	0.019	6.88	10.5	0.337	69.75	119.88	119.88	
	Mar	32.24	0.039	0.22	0.144	0.422	1.91	0.227	0.02	7.73	14.59	0.32	46.5	102.6	102.6	
Site 5	Dec	19.84	0.041	0.23	0.142	0.53	1.46	0.27	0.028	19.71	16.76	0.72	72.54	132.12	132.12	109
	Jan	22.32	0.044	0.25	0.32	0.59	0.95	0.3	0.025	18.97	15.85	0.59	51.15	111.26	111.26	
	Feb	23.56	0.045	0.25	0.124	0.66	0.496	0.3	0.02	16.36	14.5	0.7	36.03	92.98	92.98	
	Mar	18.6	0.045	0.25	0.113	0.55	2.16	0.27	0.022	12.83	17.87	0.5	48.36	101.44	101.44	
Site 6	Dec	33.48	0.03	0.19	0.175	0.68	1.71	0.4	0.019	6.69	12.79	0.81	160.42	217.34	217.34	171
	Jan	30	0.04	0.23	0.161	0.92	1.28	0.36	0.02	10.78	10.81	0.8	123.22	178.61	178.61	
	Feb	26.78	0.059	0.33	0.15	0.59	0.558	0.34	0.022	7.06	7.6	0.744	115	159.14	159.14	
	Mar	32.24	0.06	0.36	0.24	1.1	1.56	0.38	0.03	16.1	13.96	0.92	62	128.91	128.91	
Site 7	Dec	26.04	0.03	0.2	0.19	0.79	1.56	0.4	0.022	9.2	13.78	0.617	153.6	205.6	205.6	193
	Jan	37.7	0.036	0.2	0.19	0.73	1.24	0.38	0.031	7.812	13.55	0.99	115	216.09	216.09	
	Feb	29.26	0.05	0.33	0.196	1.01	1.35	0.38	0.035	5.54	15.91	0.89	94.3	149.14	149.14	
	Mar	33.48	0.06	0.36	0.196	1.19	0.25	0.38	0.032	16.62	13.57	0.68	134	200.81	200.81	

VI. CONCLUSION

1. The reason for calculating the water quality index from both the methods was to ascertain the fitness of the lake water from both specific as well as general quality perspectives. The water quality index using the weighted arithmetic method shows that the water quality of the lake is not fit for drinking from six out of seven sites and just one site fell into the category of poor drinking water. So all in all it is obvious that the lake water has become polluted to an incredible extent and requires extensive treatment before consumed by a human soul.

2. The water quality index calculated by the NSF method shows that the water quality of the lake falls in the "medium" category which is neither good nor bad. Although this is just a general water quality it also reflects the poor water quality of the lake because we can see in the results that water quality at some of the sites falls just above the poor quality level. Dinius however extended this approach and gave a descriptor language for different index ranges. According to him a water quality level between 50 to 80 had treatment becoming more extensive for public water supply, levels of 50 to 70 indicated waters becoming polluted for recreation and levels of 50 to 60 were doubtful for sensitive fish. All of this is threatening to the lake environment because it's a source for all the three activities listed above. The more polluted the lake, the more is the cost of treatment, recreation not feasible and fish life becomes is threatened.
3. Some parameters do seem to cross the permissible limits in some months and this factor is alarming. Control is required to save this lake.

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