IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 10, Issue 7 Ver. I (July 2016), PP 95-101
www.iosrjournals.org

Assessment of Water Quality of Dal Lake, Srinagar by Using Water Quality Indices

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Abstract: *The water quality of Dal Lake has tremendously been affected in the past three to four decades and has rendered it to useless from many aspects like drinking, aesthetic view, etc. The paper is an attempt to present the condition of water quality in the study area through water quality indices water quality index is a method of generating a number by assessing various physiochemical parameters which describes the water quality of a waterbody which usually ranges from 0 to 100. The drinking water quality index and the general water quality index have been calculated by use of Weighted Arithmetic Index and National Sanitation Foundation index respectively. The drinking water quality index values at the seven sites in the four basins obtained are 168.02, 148.22, 103.34, 122.36, 113.56, 162.22 and 180.02 which show that the water was unfit from the perspective of drinking. The general water quality index values in the four basins at the selected sites were 57, 60, 65, 62, 64, 63, 61 and depicted medium quality of water. Both the methods point towards the degradation of the quality of water and measures should be initiated by the government for saving the lake otherwise the time is not far when we would see the city of Srinagar without Dal lake.*

Keywords: *Dal Lake, NSF, Srinagar, Water Quality, WQI,*

I. Introduction

Water is the most abundant as well as a critical resource which is found in nature and covers approximately ¾th of the earth's surface. Although being so abundant many factors have contributed for its limitation to be actually utilized for human use. Ninety-eight percent of the planet's water comprises of the oceans which can't be used for drinking as the salt content is very high. The remaining 2 percent of the planet's water is fresh out of which 1.6 percent is stored up in the polar ice caps and glaciers. Aquifers and wells contain 0.36 percent of world's water; Lakes and rivers comprise of only about 0.66 percent of the planet's total water supply. After air, water can be stated as the second most important resource which is important to sustain life and a simply put it's the absolute necessity for life be it any respect. The desirable characteristics of water vary with intended use. Everybody has their own interests related with water for their particular use, which may involve many uses like commercial, industrial or recreational insights. Water used for drinking purpose known as potable water must be essentially clear, free from turbidity, colour, odour and bacteria.

The emergence of civilization and subsequent industrialization by man has caused a great damage to our ecosystem and disturbed the natural environment. Wastes in the form of solid, liquid and gaseous emissions are being continuously discharged. Pollutants come into river from various types of sources like point sources (especially discharges of wastewater), non-points sources, and diffuse sources and also from atmospheric deposition. Lakes and ponds don't hold back as most of the lakes in major cities have been polluted. Water pollution has posed a serious challenge due to its effect on economic activities. The problem of water pollution holds greater relevance in the context of a developing country like India. While the intensity of the problem is huge and widely spread, the losses due to its impact are quite gigantic. This is mainly due to its straight and direct impact on the human health and livelihood which we rather term as "survival". The rising and never ending demand and the limited resource of clean and pure water as a result of the growth in population, droughts and industrialization is an issue that has gained a lot of hue and cry in the world today. Various modern practices, as a result have been developed and adopted to gain usage into better and cleaner water resources. Dal Lake is situated in the Srinagar city and a lot people draw their employment from the lake in terms of agriculture, fisheries, tourism etc. It connects a lot of people through the various activities and can be stated as a source of cultural heritage which holds a lot of importance in itself. But the same activities that provide revenue, employment, residence, food and recreation to the people become a threat to the lake. The lake has suffered a lot in terms of encroachments, nutrient enrichment and degradation of water quality. The water quality of lakes

and reservoirs can be described in various forms, such as water quality index and trophic index. Although the two definitions seem very similar they cannot be used synonymously. They are two different criteria, one describing the condition of a waterbody from the perspective of human needs or values while the other defining the health of a waterbody from the point of view of nutrient status/ biological condition and eutrophication. Water quality index is a way of combining the various important parameters that determine the health of a particular waterbody. The amalgamation of parameters would happen in such a way that one would generate a single number which would describe the status of the waterbody. The indices could be increasing or decreasing , multiplicative or additive , or be specific referring to any particular use such as drinking, swimming, fisheries, bathing, recreation , aesthetic or simply general.

II. Study Area

Dal comes from a Tibetan word which means "still". Dal lake is situated in Srinagar ($34^o5'$-$34^o6'$ n latitude and $74^o8'$-$74^o9'$E longitudes at the foot of Zabarwan mountains. the lake is fed by the "Arrah" river, which flows in a northerly extremity through a dark and deep channel called Tel Bal. 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 6m and Gagribal is the shallowest with 2.25 m. This lake was one of the most beautiful lakes of the world and Sir Walter Lawrence said in his book, "Perhaps in the whole world there is no corner as pleasant as the Dal Lake". This statement might not be actually believable if we see the Dal today as it has been eaten up in all senses and brought to a devastating state. However, the lake still serves as the main attraction of the city and develops a large amount of tourist attraction as well as providing drinking water to the city. The social and economic utility of Dal Lake can hardly be underestimated; still the lake has been eaten up in terms of encroachments and water quality deterioration. While talking about encroachments, the major blow to the Dal Lake in this aspect has been brought by the Hanji community inflicting degradation to the lake environment. Fazal and Amin states that the economic dependence of these people on the lake has triggered the social transformation which in turn led to the interchange of land use classes in and around the lake. Fazal and Amin also state that the increase in tourist flow to the lake has resulted in city residents acquiring space to establish and run their business in the form of hotels and restaurants in and around the lake and these factors have contributed to the land transformations in the environs of Dal Lake. One of the major drawbacks is that the marshy areas around the lake have been converted to built-up land and floating vegetable gardens, plantation/orchards has also recorded increases, gaining land from marshy area, lake area and agricultural land and the lake area and marshy area have also been in the process of getting converted into residential land. Land under agriculture has also recorded increases during the study period, gaining land from marshy lands, lake water and plantation/orchard. Fazal and Amin also reported that 1200 house boats inside the Dal Lake generated approximately 9000 metric tons of waste annually which was dumped into Dal Lake, 15 major drains emptied into the lake which withdrew 18.17 tons of phosphorous and 25 tons of inorganic nitrogen nutrients, waste generation in the Lokut and Bod Dal wards was about 97000 Kg/day, obstruction and blockade of inner water Channels which circulate and distribute the wastes resulting in emergence of diseases and epidemics like malaria, dengue as well as water borne diseases like cholera, rise in the mean maximum temperatures of Srinagar city. All that being said about the deterioration of the lake, it is very important to continuously monitor the condition of such water bodies.

III. Methodology

Seven sites in the four basins were analysed monthly from which samples were collected in 5 litre plastic cans. The B.O.D samples were collected in separate 300 mL bottles and care was taken to protect them from sunlight by immediately covering them. A total number of 15 parameters were analyzed during a period of six months for calculation of water quality index. The methods used for calculation of water quality index are as follows:

National Sanitation Foundation: This index was developed by Brown *et al.* in the earlier 1970's and it describes the general water quality index. The term "general water quality" means water quality of a water body irrespective of any specific use. This initiative was supported by the RAND Corporation. The method was based on a survey technique which included opinions of various water quality experts. A total number of 142 water quality experts were consulted and they gave water quality charts for 35 water quality parameters from which a total of 9 were selected in the end. The method was initially an arithmetic mean index; however multiplicative and geometric indices were later used as the former showed more sensitivity towards discontinuities. Also the modified NSF was later used which deleted the parameter "deviation from equilibrium temperature". The multiplicative form of WQI is as follows:

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

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
According to Ott, seven agencies of the E.P.A were using either the standard or the modified NSF method and the state agency of Indiana has applied the modified NSF method in determining the water quality of 52 lakes and streams. 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).

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 (Dhakad *et al*., 2008; Chauhan *et al*., 2010; Rao *et al*., 2010; Chowdhury *et al*., 2012; Balan *et al*., 2012, Ahmad *et al*, Deepika *et al*., Behmanesh *et al*., Mukhtar *et al*., Saleh, Yogendra *et al*., Ramesh *et al.*, Singh *et al*., Thakur *et al*., Singh et al, Tiwari *et al*, Barki *et al*.) for the calculation of drinking water quality index. The calculation of WQI is done by using the following equation.

$$WQI = \Sigma Qi .Wi / \Sigma Wi$$

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

$$Q_i = 100[(V_i - V_o / S_i - V_o)]$$

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:

$$W = K/S_i$$

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

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

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 Discussion

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 six months. In the first step the unit weights for these twelve parameters and the calculations have been showed in Table No. 1.The recommended limits for drinking water have been taken from different agencies like BIS (Bureau of Indian Standards) and ICMR (Indian Council of Medical Research). The WQI calculations are in Table No. 2.

Table No. 1: Calculation for unit weight and standard permissible value.

Sr.No.	Parameter	Standard permissible value (Si) (BIS/ICMR)	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	0.020
12.	B.O.D	2	0.465
Total			1.0000

Table No. 2: Monthly WQI values at all sites (Weighted arithmetic index)

Sr. No.	Month	Site 1	Site 2	Site3	Site4	Site 5	Site 6	Site 7
1.	December	102.17	130.4	120.6	119.9	132.12	217.34	205.6
2.	January	183.3	150.11	83.52	120.21	111.26	178.61	216.09
3.	February	196	134.09	86.17	119.88	92.98	159.14	149.14
4.	March	107.06	97.15	95.16	102.6	101.44	128.91	200.81
5.	April	186.12	177.45	123.77	143.34	107.89	148.91	174.57

6.	May	233.5	200.1	110.87	128.25	136.67	140.42	133.95
AVERAGE		168.02	148.22	103.34	122.36	113.56	162.22	180.02

National Sanitation Foundation Water Quality Index Method: A total number of eight parameters were analyzed for this method for a period of six 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 as described in the method above was used. The result at the seven sampling sites in the six months is shown in Table No. 3:

Table No. 3: WQI values at all sites (National Sanitation foundation Method)

Sr. No.	Month	Site 1	Site 2	Site3	Site4	Site 5	Site 6	Site 7
1.	December	51	61	65	61	56	55	55
2.	January	54	63	69	63	60	64	57
3.	February	58	61	66	63	64	69	62
4.	March	63	65	66	69	66	63	56
5.	April	59	61	62	63	64	62	61
6.	May	55	58	66	60	66	64	64
AVERAGE		57	60	65	62	64	63	61

Graphical representation of WQI throughout the study period at the seven selected sites by Weighted Arithmetic Method and NSF method:

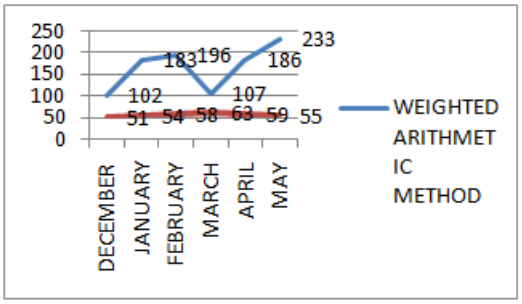

Fig. 1: for site 1 near entry of telbal nallah.

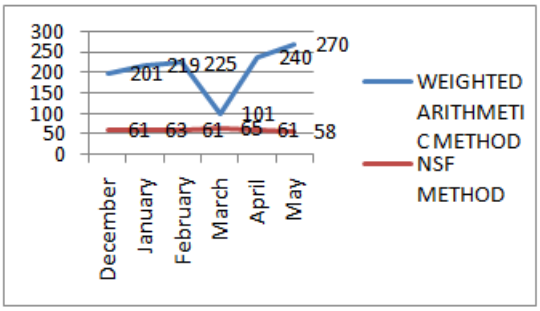

Fig. 2: site 2 central hazratbal near sona lank

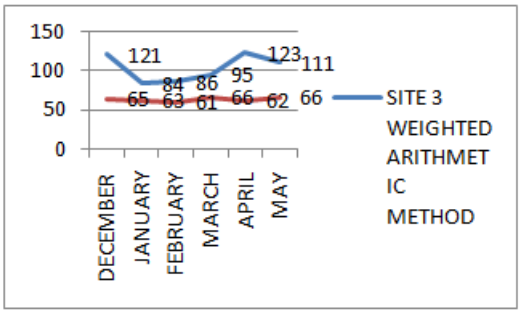

Fig. 3: site 3 central nishat near char chinari

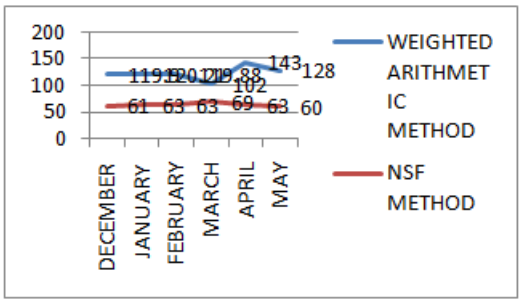

Fig. 4: site 4 gagribal central

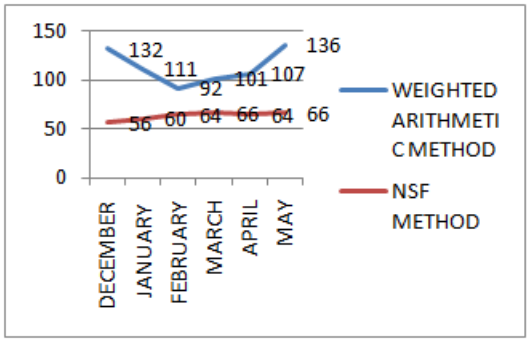

Fig. 5: site 5 near kabutar khana

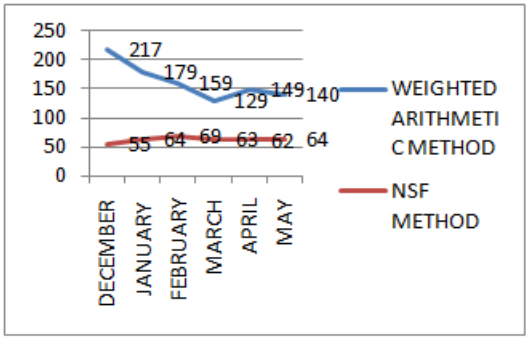

Fig. 6: site 6 nigeen central

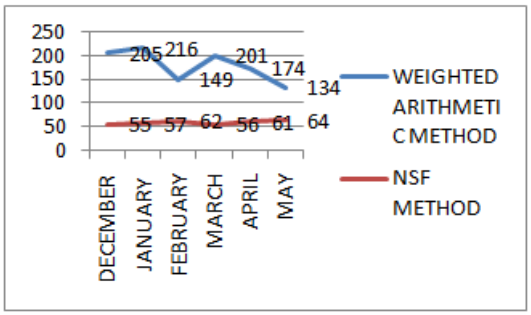

Fig. 7: site 7 sadrebal

V. Discussions

By using the weighted arithmetic index method, "38" water samples fell in the category of "unfit for drinking water" and only "4" samples fell into the category of "very poor drinking water". This comes out to be a 90.47 % of water samples falling into the category of "unfit for drinking" and 9.53 % falling into the category of very poor drinking water. The water quality index (weighted index method) in the Hazratbal basin was found unfit for drinking in all the months of the study. However the calculated WQI values showed that the best water quality was recorded in the month of March and the worst in the month of May. It can be said that the water quality at these sites was better in March which is a spring month in Kashmir than in May which comes under the summer season. The same trend was seen at site Gagribal which comes in the Lokut Dal basin of the lake. However the worst quality recorded at Gagribal from the point of view of drinking has been calculated in the month of April.The Nishat basin has been observed as the best basin if compared with other basins from the point of drinking. The water quality has been observed comparatively better with the lowest values observed at January, February and March with values of 84, 86 and 95 respectively. These values according to the method fell under the category of poor drinking water. Seeing the quality of water at other sites, these values are seen as better as compared to other values at different sites in different seasons. Kabutar Khana recorded the best water quality in the month of February calculated to be 92 and the worst in the month of May with a value of 136.Nigeen basin seems to have the best water quality in the month of April but all the values in this basin seem to be unfit for drinking. The WQI values found from the modified NSF method indicated the "medium quality" of the lake. However this method doesn't characterize the water quality specifically and is a general water quality descriptor. All the samples fell into the category of medium water quality.

PARAMETERS:

The pH at site 1 was found in the range of 6.5 to 9.33 with the lowest in December to the highest in May (mean pH = 7.9). The same trend was observed at site 2 and site3. The Lokut Dal basin showed a pH range of 7.8 to 8.88 with the lowest pH recorded in the month of December at Site 4 and the highest in May at Site 5. The Nigeen basin also showed the same trend. This shows that the lake is mostly alkaline with fluctuations in different seasons. Lori et al had similar findings and states that higher pH indicated higher productivity of the lake which he confirmed with the findings of Zafar and Vyas. Khan *et al.* states the alkaline nature of the lake due to high concentration of carbonates and the geological features of the catchment which comprises of a karewa bed (calcium carbonate rocks); considerable fluctuations in pH in different seasons were stated due to air and biological activities. Reid also states that the high pH range in limestone regions is due to dissolved carbonates. The total dissolved solids at site 1 (near the entry of Telbal Nallah) were found in the range of 67mg/l in the month of May to 189 mg/l in the month of February. The other sites also showed the same trend with higher values in winter to the lowest in summer. The amount of T.D.S was usually found to be more in the winter season than in the spring and summer. Awasthi had the same findings and has attributed the higher value of T.D.S in the winter season due to the decreased water levels which results in increased concentration of different salts in water. Electrical conductivity was also seen to show the same trend and it proves that there is a direct relationship between T.D.S and electrical conductivity. The values of total solids were found to be the highest in the winter season at Hazratbal with the reading of 340 mg/l to the lowest in May with a value of 150 mg/l. The values at site 2 recorded a minimum of 190 mg/l at February and highest of 281 mg/l in December. The Nigeen basin also showed the same trend. The Nishat basin however showed an increase in the value of total solids from winter to summer with the lowest recorded at 87.5 mg/l to a highest of 247 mg/l in April. The Lokut Dal basin recorded the highest values in March with an average of 226.5 mg/l and the lowest of 143 mg/l in December. The water is hard. At Site 1, one of the samples exceeded the desirable limit as well. The total hardness was seen maximum in the month of December with a value of 332 mg/l with the lowest recorded in May with the value of 80 mg/l. Awasthi states that hardness of the water is mainly contributed by

calcium and magnesium ions which are because of the presence of dolomites in the catchment area. The chloride values remained fairly constant and within the desired standard limits. The values of total alkalinity was found to be a maximum of 180 mg/l recorded in the month of February and the lowest value of 98 mg/l in March and May at sites 4 and 1 respectively. The highest turbidity was measured at Hazratbal basin (7.93 N.T.U) while the lowest being recorded at Nishat basin with a value of 1 N.T.U. the water at Nishat basin seems to be the most clear out of all the four basins. Calcium is within standard limits; however Nigeen basin showed higher range of calcium. The lake is calcium rich which has been found for most of the lakes in the region around Jammu and Kashmir a reported by Lori *et al.* and Khan *et al.* The range of magnesium is seen higher in the Hazratbal basin. Dissolved oxygen is found out to be in the range of 5.23 mg/l to 10.31 mg/l. 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 the drinking quality (class water) should have a D.O content of 6 or more. Some sites have reported lesser values than the prescribed limits which deems the levels of the lake water dangerous from the drinking point of view as far as D.O is concerned. The values of B.O.D were found in the range of 1.55 mg/l in the month of February to 7.65 mg/l in the month of May. Higher B.O.D indicates higher organic pollution.

VI. Conclusions

The results have by and far cried out the dying status of the lake when looked at from the point of view of water quality. The lake water is unfit from the purpose of drinking and the general water quality is not even "GOOD". So all in all the conclusion is quite straightforward that the lake is about to see it's near death unless and until government, local bodies and most importantly the people who live in and around the lake do something for its saviour.

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