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Research Article

Assessment of Surface Water Quality of the Himalayan Lake Beni Tal, India

Keshav Singh Rana, Ramesh C. Sharma, Vijayta Tiwari, Rahul Kumar*

Department of Environmental Sciences, H.N.B. Garhwal University, India

***Corresponding author:** Rahul Kumar, Department of Environmental Sciences, H.N.B. Garhwal University (A Central University), Srinagar-Garhwal 246174, Uttarakhand, India. Email: rahul.khadwalia@gmail.com

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Abstract

The Water Quality Index (WQI) has been considered as an important method for the assessment of water quality of a water body for its end users. This study was carried out to assess the quality of surface water of the Himalayan lake Beni Tal. Beni Tal is one of the major destinations for tourists and local inhabitants. The water samples were collected for a period of six months during January, 2016 to June, 2016. In order to develop the water quality index, the samples were subjected to a comprehensive analysis of 15 physico-chemical parameters which includes air temperature, water temperature, pH, conductivity, turbidity, dissolved oxygen, biochemical oxygen demand, total dissolved solids, total alkalinity, hardness, chlorides, sulphates, nitrates, Calcium and Magnesium. The WQI was calculated and recorded as 98.49. During the study period, most of the values of physico-chemical parameters were within the range of prescribed limits of WHO/BIS for drinking water. The calculated value of WQI was based on the weight values of these parameters also revealed the 'good' quality of lake water. The water of the lake is fit for human consumption. Keeping in view the importance of the lake and to provide the sustainable water quality for its end users, its conservation and management is on priority in the Himalayan region.

Keywords: Beni Tal; Garhwal Himalaya; India; Physico-Chemical Parameters; Water Quality Index

Introduction

Water quality has become increasingly more important in the management of lake for a number of reasons. Water quality index is closely related to the use of water that include water supply, fish and wildlife conservation, recreation, sanitation, etc. Water is considered as one of the most important and valuable natural resources on the Earth, which is commonly shared by all the living beings residing on the planet 'Earth'. India have various number of natural water resources distributed unequally all over the country, but their presence in the Himalayan region has a great importance as these resources are the important source of freshwater for the local villagers, tourists, trekkers, sages and wildlife.

The quality of a surface water body has direct and indirect effect on the groundwater level and its water quality. Lakes are the inland water bodies which have a great importance for the society as they are the sources of water for various human activities as well as for drinking purpose. The water quality of a surface water body is not only depending on the natural causes such as precipitation inputs, soil erosion, etc but also on the artificial causes such as urban, industries and agriculture practices [1]. The degradation of water quality due to various anthropogenic pressures has resulted in altered species composition and decreased overall health of water bodies. Natural lakes are mostly found in the mountain region.

Water Quality Index (WQI) is defined as a rating that reflects the composite influence of various water quality parameters [2]. The concept of WQI was first used in the year 1965. WQI is one of the most effective tools to communicate information on the quality of any water body. WQI is an aggregate value which is widely accepted as a rating that resembles the overall quality of the water. A Water Quality Index (WQI) helps in understanding the general water quality of any water body either it is natural or artificial, freshwater or marine water, either on hill region, ground water or surface water [3-5]. WQI is one of the most effective tools to assess the water quality of a water body [6-7] and communicates the information to the citizens and policy makers for the proper conservation and management of the water body.

Though some work has been done on different aspects of the lakes. This include the work of Shuchun et al. [8]; Ravikumar et al. [9]; Ramesh and Krishnaiah [10]; Lala et al. [11]; Singh and Hussian [2]; Joshi et al. [12] and Bouslah et al. [13]. But no work has been done so far on the water quality of the Beni Tal. Hence, the present work has been carried out with a vision to assess the water quality by analyzing various physico-chemical parameters and estimating water quality index. Obtained data on the water quality index of Beni Tal of Garhwal Himalaya can be used by the policy makers and wetland managers for its conservation and management.

Study Area

Beni Tal is a beautiful lake of oval shape having scenic beauty as well as valuable ecosystem services, located at an altitude of 2,083 m a.s.l. and between latitude 30˚09'37.34" N; longitude 79˚14'46.34" E (Figure 1). The length of the lake is about 134 m whereas; the width is around 70 m with a circumference of 220 m. The maximum depth of the lake is at the centre which 2.7 m. is around This lake is situated in the south-eastern part and 6 km from Adi Badri (famous shrine of Hindu's) in Chamoli district of Uttarakhand, India. This lake is surrounded by two mountain ranges. First range is Beni Tal range and second one is Dudatoli range. The highest peak in the area is Dudatoli peak which is around 3,114 m a.s.l.. Beni Tal is surrounded by a beautiful meadow and dense forest of Rhododendron and Oak trees [14]. The main source of water in Beni Tal is precipitation, groundwater discharge and natural springs (Figure 2). The annual precipitation in the area of study area is about 175 to 200 cm. The area is rich in vegetation which is characterized by temperate flora. The dominated species are *Rhododendron arboretum, Glochidian velutinum, Myrica nagi, Pieris ovalifolia* and *Cedrus deodara.* The fauna of Beni Tal is represented by both the wild and domestic animals. The dominated faunal species are *Nemorhaedus goral, Odocoileus virginiana, Macaca mulata, Semnoptiecus priamus, Fellis pardus, Felis chaus.*

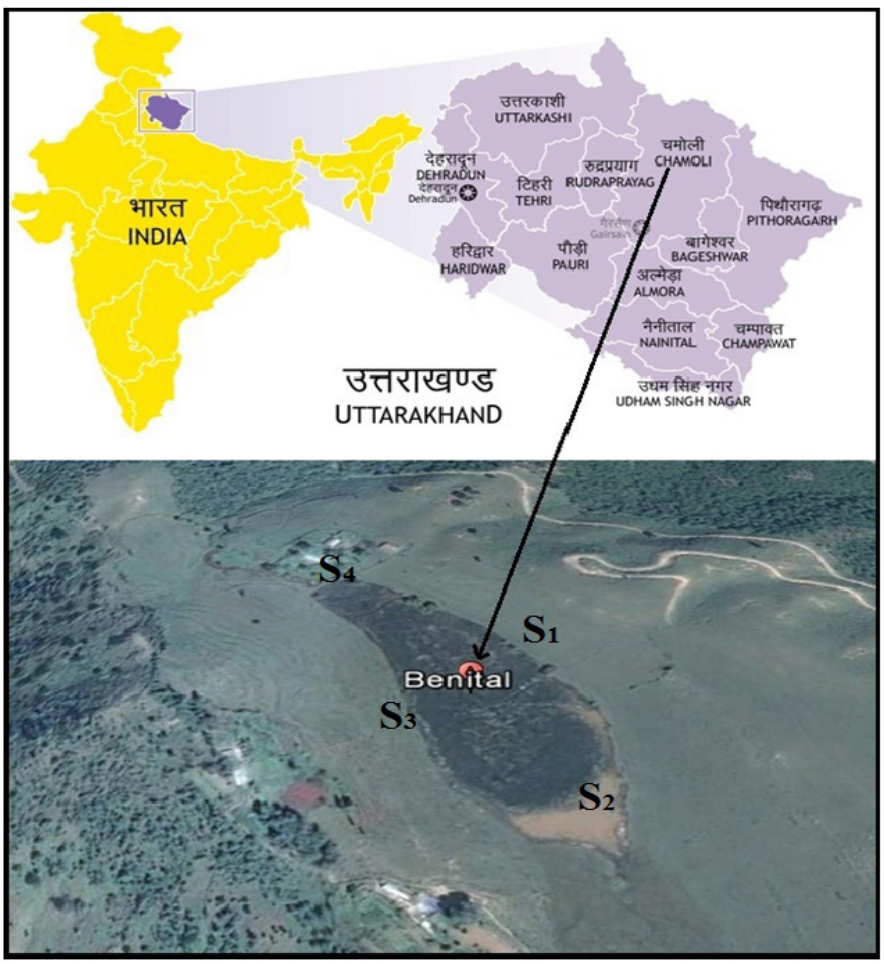

Figure 1: The study area (Location map of Beni Tal).

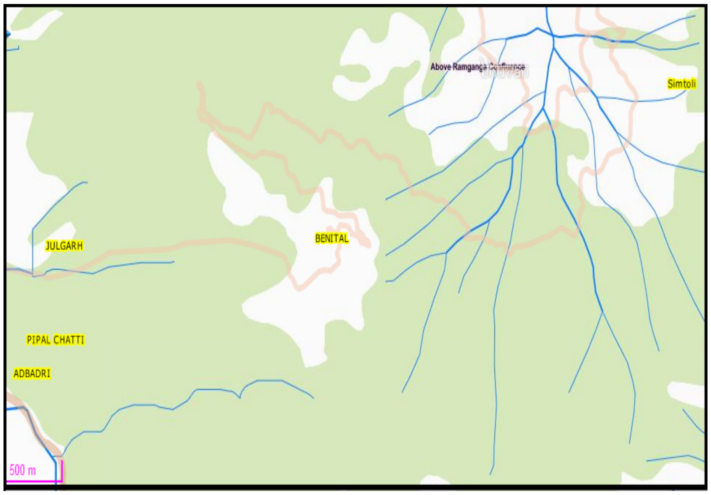

Figure 2: Hydrological map of Beni Tal.

Material and Methods

Water Sampling

The water of Beni Tal was sampled for a period of January 2016 to June, 2016. Water samples were collected from four different sites (S_1, S_2, S_3 and S_4) of the lake (Figure 1) from surface water dipping the sterilized sample bottles 20 cm below water surface in the lake during 8:00 to 10:00 hrs. Some of the physico-chemical parameters required for water quality analysis like pH, air temperature, water temperature and dissolved oxygen were measured at each sampling site of the lake. For the analysis of remaining physico-chemical parameters, the water samples were brought to Srinagar Garhwal by the earliest at its possible and analyzed in Laboratory of Freshwater Biology, Department of Environmental Sciences, H.N.B. Garhwal University (A Central University), Srinagar Garhwal, Uttarakhand, India. All the physico-chemical parameters were analyzed by following the standard methods outlined in Wetzel & Likens [15] and APHA [16]. Water samples from all the four sampling sites were analyzed for a predefined set of physical and chemical parameters to resemble that how these parameters and environmental changes affect the water quality. Water temperature was measured by dipping the digital thermometer 10 cm below surface in the lake carefully. The temperature range of digital thermometer was (-50 ˚C to +300 ˚C). pH was measured both at the site by using litmus paper and portable pH meter of Electronics India (Model No. 7011) and in the Laboratory by using the Toshcon Bench Top Multiparameter analyzer (Model No. TPC-17). Dissolved oxygen was measured by using the Modified Winkler method at the sampling site. Biochemical Oxygen Demand (BOD) was also measured by the standard method. Conductivity and total dissolved solids (TDS) were measured by using the Toshcon Bench Top Multiparameter analyzer (Model No. TPC-17). Total alkalinity, hardness, chlorides, Calcium and Magnesium were measured by following the protocols available in APHA [16]. Nitrates and sulphates were measured by spectrophotometric method by using the Systronic UV-VIS Spectrophotometer (model No. 117). The statistical mean with standard deviation of all the replicates of the samples for each site was also calculated. Pearson's correlation coefficients between various physico-chemical parameters were also computed.

Water Quality Index (WQI)

WQI is an abyssal number that combines the various water quality values into a single number by normalizing values to subjective rating curves. All these parameters or characteristics occur in variable ranges and expressed in various units. The WQI takes the complex scientific information into a single number. For this purpose, thirteen water quality parameters were selected. Values used for each parameter were the mean value of the four sites of four replicates of each site. In the formulation of WQI, the 'standards' (permissible values of various parameters) for the drinking water used in this study were those recommended by the WHO [17]. The calculation and formulation of the WQI involved the following steps [6]:

First step: Each of the thirteen parameters has been assigned a weight (AWi) ranging from 1 to 4 depending on the collective expert opinions taken from different previous studies [6-7,18-19]. The mean values for the weights of each parameter have been shown in Table 1. However, a relative weight of 1 was considered as the least significant and 4 as the most significant.

Parameters	Sampling sites				Mean value
	S_1	S_2	S_3	S_4	
pH	3	3	3	3	3.0
DO (mg/l)	4	4	4	4	4.0
B.O.D. (mg/l)	4	4	4	4	4.0
Conductivity(µS/cm)	3	3	3	3	3.0
TDS (mg/l)	3	3	2	3	2.75
Chlorides (mg/l)	3	3	2	3	2.75
Total alkalinity (mg/l)	2	2	3	2	2.25
Total hardness (mg/l)	3	3	3	3	3.0
Calcium (mg/l)	3	3	2	3	2.75.
Magnesium (mg/l)	3	3	3	3	3.0
Nitrates (mg/l)	3	3	2	2	2.5
Sulphates (mg/l)	3	2	2	2	2.25
Turbidity (NTU)	3	3	3	3	3.0

Table 1: Assigned weight values of water quality parameters adopted from the literature (Ramakrishnaiah et al., 2009; Alobaidy et al., 2010; Sharma et al., 2016 and Sharma and Kumar, 2017).

Second step: The relative weight (RW) was calculated by using the following equation:

$$RW = \frac{AWi}{\sum_{i=1}^{n} AWi} \quad (1)$$

Where, RW = the relative weight, AW = the assigned weight of each parameter, n = the number of parameters. The calculated relative weight (RW) values of each parameter have been given in Table 2.

Parameters	Water quality standard (WHO)	Water Quality standard (BIS)	Assigned weight (AW)	Relative weight (RW)
pH	6.5-8.5 (8.0)	6.5-8.5	3.0	0.078431
DO (mg/l)	5.0	6.0	4.0	0.104575
B.O.D. (mg/l)	N.A	2.0	4.0	0.104575
Conductivity(µS/cm)	250	N.A	3.0	0.078431
TDS (mg/l)	600	500	2.75	0.071895
Chlorides (mg/l)	250	250	2.75	0.071895
Total alkalinity (mg/l)	200	200	2.25	0.058824
Total hardness (mg/l)	200	200	3.0	0.078431
Calcium (mg/l)	75	75	2.75.	0.071895
Magnesium (mg/l)	30	30	3.0	0.078431
Nitrates (mg/l)	45	45	2.5	0.065359
Sulphates (mg/l)	200	200	2.25	0.058824
Turbidity (NTU)	0.5	1.0	3.0	0.078431
Total			**38.25**	**1.0**

Table 2: Relative weight values of the water quality parameters of the Beni Tal, Garhwal Himalaya.

Third step: A quality rating scale (Qi) for all the parameters except pH and DO was assigned by dividing its concentration in each water sample by its respective standard according to the drinking water guidelines recommended by the WHO, the result was then multiplied by 100.

$$Qi = [Ci / Si] \times 100 \quad (2)$$

While, the quality rating for pH or DO (Q_{pH}, DO) was calculated on the basis of,

$$Q_{pH}, DO = \left[\frac{Ci - Vi}{Si - Vi}\right] \times 100 \quad (3)$$

Where, Qi = the quality rating, Ci = value of the water quality parameter obtained from the laboratory analysis, Si = value of the water quality parameter obtained from recommended WHO, Vi = the ideal value which is considered as 7.0 for pH and 14.6 for DO.

Equations (2) and (3) ensures that Qi = 0 when a pollutant is totally absent in the water sample and Qi = 100 when the value of this parameter is just equal to its permissible value. Thus, the higher the value of Qi is, the more polluted is the water.

Fourth step: Finally, for computing the WQI, the sub indices (SIi) were first calculated for each parameter, and then used to compute the WQI as in the following equations:

$$SI\,i = RW \times Qi \quad (4)$$

$$WQI = \sum_{i=1}^{n} SIi \quad (5)$$

The computed WQI values could be classified as <50 = Excellent; 50-100 = Good; 100-200 = Poor; 200-300 = Very poor; >300 = Unsuitable [6-7,18-19].

Results and Discussion

Physico-Chemical Characteristics of Water

The values of all the physico-chemical parameters were obtained after analyzing the water samples of Beni Tal collected from four different sites of the lake during January 2016 to June, 2016. These values refer to the mean value of all the four sites along with minimum, maximum, mean and value of standard deviation of water samples collected in different months (Table 3).

Parameters/Month	Jan	Feb	Mar	Apr	May	Jun	Min.	Max.	Mean±SD
AT (˚C)	17.1	11.1	11.3	21.5	20.5	22.0	11.1	22.0	17.25±4.99
WT (˚C)	14.6	8.6	8.7	17.9	16.1	18.9	8.6	18.9	14.1±4.50
pH	7.1	7.1	6.4	6.6	6.3	6.5	6.3	7.1	6.7±0.35
DO (mg/l)	6.8	6.6	6.4	5.8	5.6	5.2	5.2	6.8	6.1±0.63
B.O.D. (mg/l)	1.0	1.4	2.6	1.8	2.0	2.2	1.0	2.6	1.8±0.57
Conductivity(µS/cm)	116	119.5	143.5	176.8	198.3	224.5	116	224.5	163.1±44.05
TDS (mg/l)	69.8	95.3	123.0	145.0	160.5	182.0	69.8	182	129.3±41.79
Chlorides (mg/l)	4.26	4.16	5.40	5.32	4.86	4.98	4.16	5.40	4.83±0.52
Total alkalinity (mg/l)	72.3	68.5	52.0	45.3	27.0	27.8	27.0	72.3	48.82±19.39
Total hardness (mg/l)	42.0	47.8	46.3	53.3	63.5	77.0	42.0	77.0	54.98±13.08
Calcium (mg/l)	10.04	9.21	11.43	11.63	14.07	20.39	9.21	20.39	12.80±4.07
Magnesium (mg/l)	4.13	6.04	4.32	5.91	6.92	6.37	4.13	6.92	5.62±1.13
Nitrates (mg/l)	0.23	0.33	0.60	1.55	3.15	3.63	0.23	3.63	1.58±1.48
Sulphates (mg/l)	2.83	3.13	4.0	5.28	5.03	5.48	2.83	5.48	4.29±1.14
Turbidity (NTU)	7.3	6.9	7.2	9.9	10.2	10.84	6.9	10.84	8.72±1.77

Table 3: Monthly variations in mean values of physico-chemical parameters of Beni Tal, Uttarakhand from January 2016 to June 2016 (Mean value of all sites, minimum, maximum and Mean ±SD).

Air and Water Temperature

Monthly variations in the mean values of air and water temperature were quite high. The air temperature ranged from 11.1˚C to 22.0˚C (Figure 3). The mean value of air temperature during the study period recorded 17.25˚C. However, the recorded water temperature was minimum (8.6˚C) in the month of February and maximum (18.9˚C) in the month of June (Figure 4). Similar observations were recorded by Mushatq et al., [20]. The water and air temperature are directly proportional to each other. Increase in the air temperature causes an increase in the water temperature.

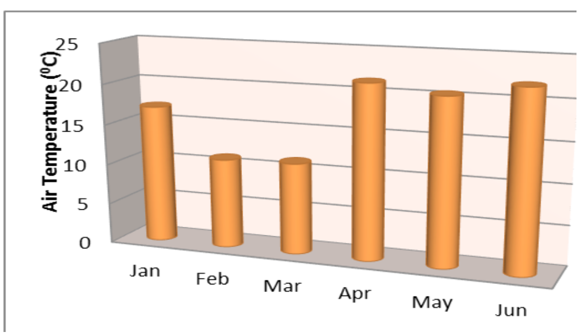

Figure 3: Variation in Air Temperature.

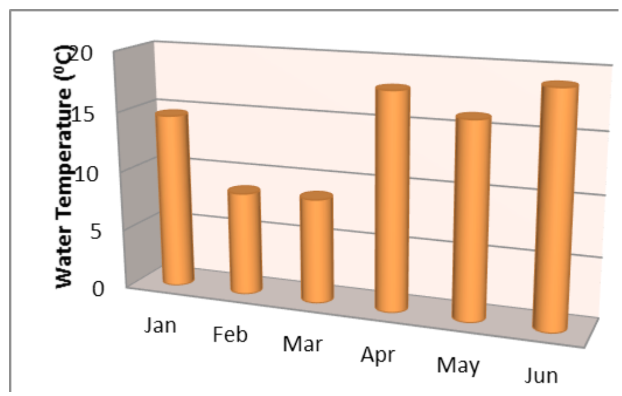

Figure 4: Variation in Water Temperature.

pH

The pH or hydrogen ion concentration is considered as one of the most important factors that indicates the level of pollution. During the entire study, the water of the lake was found slightly acidic to slightly alkaline. It ranged from 6.3 to 7.1 (Figure 5). The permissible range of pH for drinking water was specified as 6.5 to 8.5 as per WHO and BIS standards for drinking water.

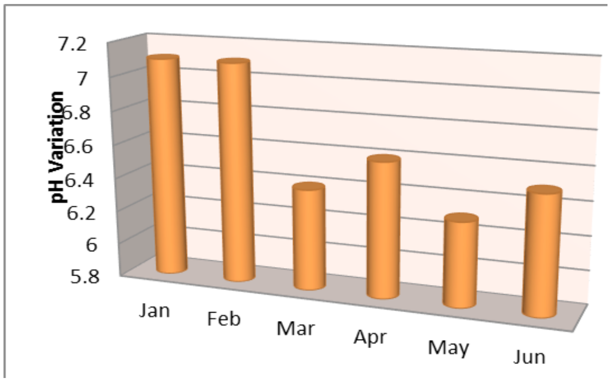

Figure 5: Variation in pH.

Dissolved Oxygen

Dissolved oxygen is considered as the most important parameter for assessing the health of a water body. It is considered as a direct indicator of water quality. The concentration of dissolved oxygen depends on the physical, chemical and biological characteristics of water body. The concentration of dissolved oxygen is inversely proportional to the temperature of the water body. Higher the temperature, lower is the dissolved oxygen in the water body. The concentration of dissolved oxygen recorded minimum (5.2 mg/l) in the month of June and maximum (6.8 mg/l) in the month of January (Figure 6). The permissible limit of dissolved oxygen concentration for drinking water is more than 5. 0 mg/l as per WHO standards. Dissolved oxygen is the value that represents the quality of water and to evaluate the water whether is fit for consumption or not. Similar observation was recorded by Bhat and Pandit [21]; Mushatq et al. [20].

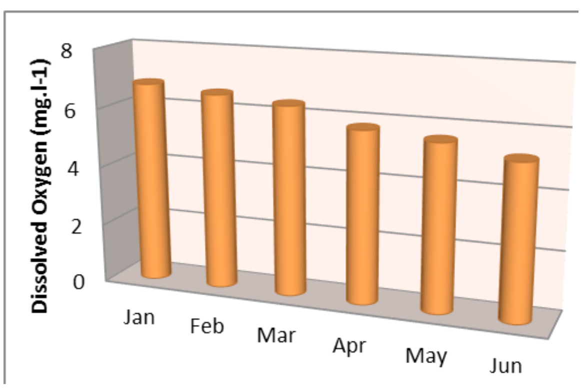

Figure 6: Variation in Dissolved oxygen.

Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) of the lake water of Beni Tal ranged from 1.0 mg/l in the month of January to 2.6 mg/l in the month of March (Figure 7). It is the amount of oxygen consumed by the microbes during the incubation period. The permissible limit of BOD in drinking water as per WHO standards is 2.0 mg/l. Thus, the BOD of Beni Tal water is under the prescribed limit.

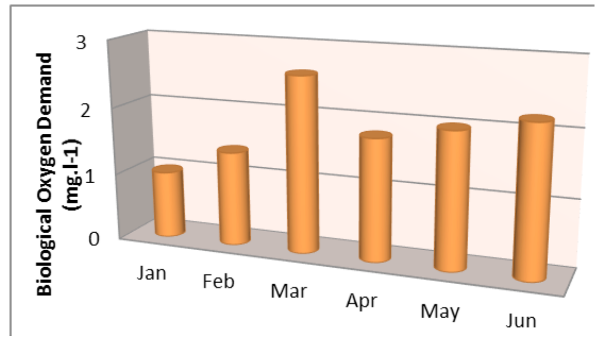

Figure 7: Variation in Biochemical oxygen demand.

Conductivity

Conductivity is the measurement of cations which greatly affects the taste of water. It is an indirect measure of total dissolved solids. Minimum conductivity (116.0 µS/cm) was recorded in the month of January and maximum conductivity (224.5 µS/cm) was recorded in the month of June (Figure 8). The permissible limit of electrical conductivity for drinking water as per WHO standards was less than 250µS/cm. Similar results on conductivity were observed by Bhat et al. [22].

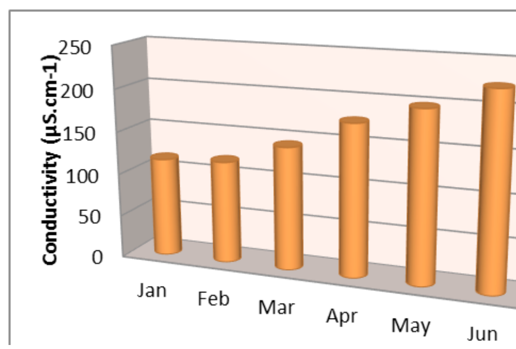

Figure 8: Variation in Conductivity.

Total Dissolved Solids

Total dissolved solids (TDS) refer to the minerals, salts, metals, ions and organic matter dissolved in the water. The minimum value (69.8 mg/l) of TDS was recorded in the month of January and maximum value (182 mg/l) in the month of June (Figure 9). The recorded range was much less than the permissible limit of 600 mg/l for drinking water as per WHO standards. Similar results were observed by Bhat et al. [22] and Singh et al. [23].

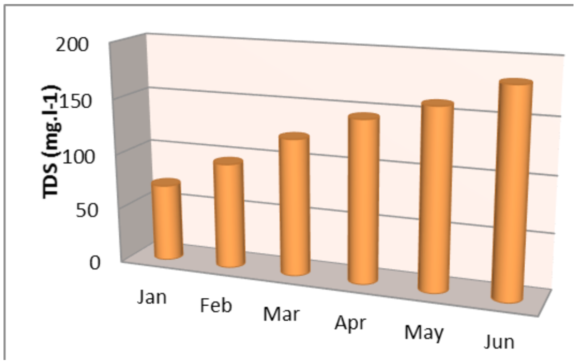

Figure 9: Variation in Total Dissolved Solids.

Chlorides

The concentration of chlorides dissolved in the surface water mainly occurs naturally from the surroundings. The concentration of chlorides ranged between 4.16 mg/l and 5.40 mg/l (Figure 10), which is much less than the permissible limit of 250 mg/l for drinking water as per WHO and BIS standards. The similar range of fluctuations (4.25±0.03mg/l to 7.44±0.33 mg/l) in the concentrations of chlorides was found in different basins of Dal Lake of Kashmir Himalaya by Lone et al. [24].

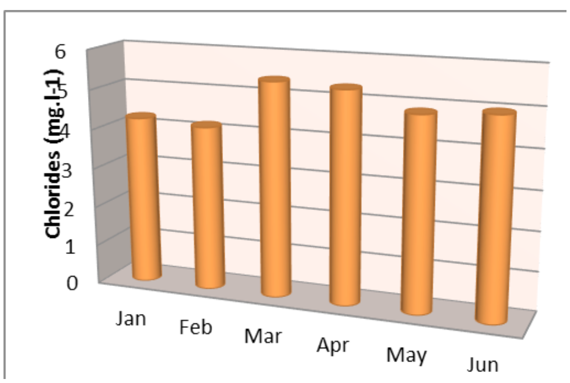

Figure 10: Variation in Chlorides.

Total Alkalinity

The total alkalinity was recorded minimum (27.0 mg/l) in the month of May and maximum (72.3 mg/l) in the month of January (Figure 11). The permissible limit of total alkalinity for drinking water is 200mg/l as per WHO and BIS standards. The similar results were recorded by Naik et al. [25].

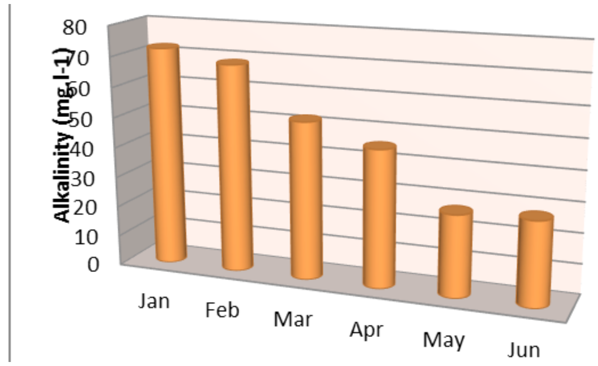

Figure 11: Variation in Total Alkalinity.

Hardness

The value of total hardness is the amount of salts dissolved in the water. It is mostly due to the presence of Calcium and Magnesium ions. The use of water can be decided by the concentration of hardness present in the water whether it is used for drinking purpose, irrigation purpose or industrial purpose. The rocks surrounding the water body is largely the source of hardness. The value of hardness in the water body during the study period ranged between 42.0 mg/l to 77.0 mg/l (Figure 12), which is much less than the permissible limit of hardness in the drinking water (200 mg/l) as per WHO and BIS standards.

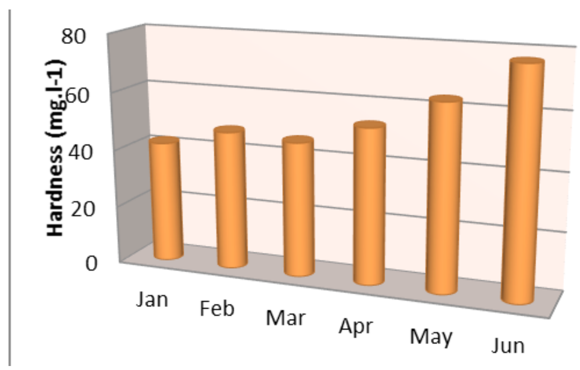

Figure 12: Variation in Hardness.

Calcium and Magnesium

The concentration of calcium ranged from 9.21 mg/l to 20.39 mg/l (Figure 13) whereas, the concentration of Magnesium was recorded minimum (4.13 mg/l) in the month of January and maximum (6.92 mg/l) (Figure 14) in the month of May. Both the concentrations of Calcium and Magnesium are much less than the permissible limit of Calcium (75 mg/l) and Magnesium (30 mg/l) for drinking water as per WHO and BIS standards.

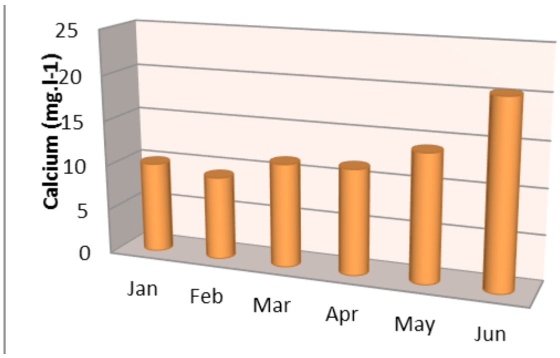

Figure 13: Variation in Calcium.

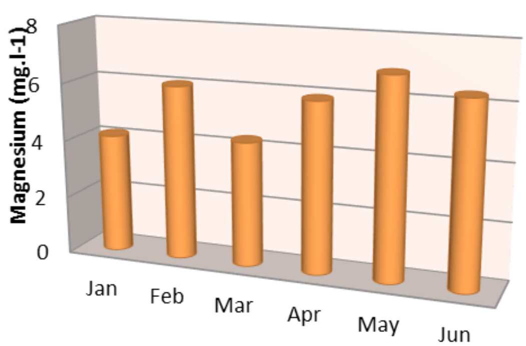

Figure 14: Variation in Magnesium.

Sulphates and Nitrates

The concentration of sulphates in the water samples of Beni Tal ranged from 2.83 mg/l to 5.48 mg/l (Figure 15), whereas, the concentration of nitrates in the water samples was recorded minimum (0.23 mg/l) in the months of January and maximum (3.63 mg/l) in the month of June (Figure 16). The concentrations of sulphates, phosphates and nitrates were recorded much less than the permissible limit of WHO and BIS standards for drinking water which 200 mg/l for sulphates and 45 mg/l for nitrates.

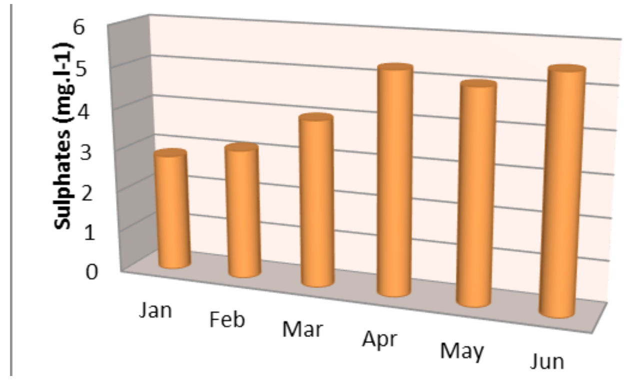

Figure 15: Variation in Sulphates.

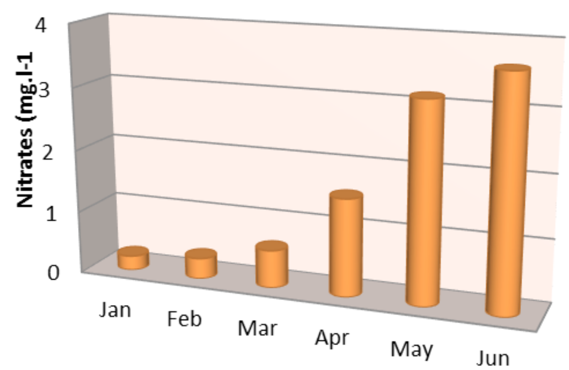

Figure 16: Variation in Nitrates.

Turbidity

Turbidity represents the clarity of the water. The measurement of turbidity in the water sample of a water body is a key test to assess the quality. Turbidity and the intensity of scattered light are directly proportional to each other. It also meant that as the turbidity of water increases, the amount of sunlight penetrates the water decreases. The concentration of turbidity was recorded minimum (6.90 NTU) in the month of January and maximum (10.84 NTU) in the month of June during the rainy month (Figure 17). The permissible limit of turbidity in the drinking water is up to 0.5 NTU as per WHO standards and 1.0 NTU as per BIS standards.

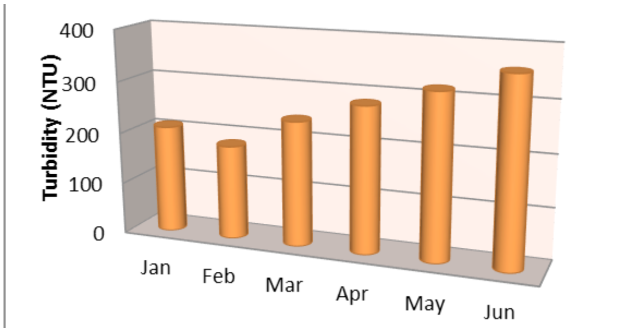

Figure 17: Variation in Turbidity.

Statistical Treatment of Data

The correlation coefficients of air temperature was found positive in relation with water temperature (r=0.992) and with turbidity (r=0.912) (P<0.1). The correlation coefficients of dissolved oxygen in relation with conductivity (r= -0.995), total dissolved solids (r= -0.977), total hardness (r= -0.946), nitrates (r= -0.962), sulphates (r= -0.956) and turbidity (r= -0.963) was found significant negative relationship; but it was positive relationship with alkalinity (r= 0.954) (P<0.1). The correlation coefficient of conductivity showed positive relation with total dissolved solids (r= 0.973), total hardness (r= 0.945), calcium (r= 0.901), nitrates (r= 0.973), sulphates (r= 0.946) and turbidity (r= 0.959); but showed negative relationship with alkalinity (r= -0.968) where (P<0.1). Total dissolved solids showed a positive correlation with total hardness (r= 0.904), nitrates (r= 0.921) and sulphates (r= 0.963); but showed negative correlation with alkalinity (r= -0.970) (P<0.1). The correlation coefficient of alkalinity showed a negative correlation with nitrates (r= -0.950); sulphates (r= -0.929) and turbidity (r= -0.902) with significance level (P<0.1). Total hardness also showed positive correlations with Calcium (r=0.951) and nitrates (r=0.964) with significance level of P<0.1. Nitrates showed a strong positive correlation with turbidity (r=0.936); whereas the sulphates also showed a positive correlation with turbidity (r=0.931) (P<0.1) (Table 4).

	AT	WT	pH	DO	BOD	Cond	TDS	Cl^-	Alkal	TH	Ca	Mg^{2+}	NO_3^-	SO_4^-	Turb
AT	1														
WT (°C)	**0.992**	1													
pH	-0.39	-0.319	1												
DO	-0.775	-0.741	0.721	1											
BOD	0.026	-0.016	-0.873	-0.542	1										
Cond	0.779	0.746	-0.754	**-0.995**	0.564	1									
TDS	0.647	0.603	-0.821	**-0.977**	0.699	**0.973**	1								
Cl^-	0.285	0.253	-0.829	-0.525	0.835	0.538	0.638	1							
Alkal	-0.681	-0.623	0.872	**0.954**	-0.666	**-0.968**	**-0.97**	-0.599	1						
TH	0.683	0.667	-0.572	**-0.946**	0.45	**0.945**	**0.904**	0.293	-0.881	1					
Ca	0.648	0.658	-0.566	-0.88	0.502	**0.901**	0.841	0.358	-0.818	**0.951**	1				
Mg^{2+}	0.509	0.442	-0.372	-0.74	0.168	0.694	0.706	0.041	-0.692	0.738	0.493	1			
NO_3^-	0.768	0.73	-0.685	**-0.962**	0.455	**0.973**	**0.921**	0.358	**-0.95**	**0.964**	0.898	0.753	1		
SO_4^-	0.75	0.708	-0.798	**-0.956**	0.621	**0.946**	**0.963**	0.716	**-0.929**	0.813	0.749	0.651	0.86	1	
Turb	**0.912**	0.881	-0.636	**-0.963**	0.354	**0.959**	0.897	0.455	**-0.902**	0.88	0.807	0.715	**0.936**	**0.931**	1

Table 4: Statistical correlation (correlation coefficients) computed between the physico-chemical parameters of water of Beni Tal.

Water Quality Index (WQI)

The Water Quality Index (WQI) was used to accumulate diverse parameters and their dimensions in a single value, that displaying the water quality of Beni Tal. It was observed from all the computed data for all the required water quality parameters that the value is 98.49. Therefore, the water of Beni Tal can be categorized into "Good" during the sampling period (January, 2016 to June, 2016). Detailed statistics for all the water quality examined during the assessment are shown in Table 3, while the correlation coefficients between the parameters are shown in Table 4. In order to reach better view on the water quality of Beni Tal water, selected results from the physico-chemical parameters are presented in Table 3.

Conclusion

Water quality index is a quick and unique method for the evaluation and management of water quality of a water body. Most of the physico-chemical variables of water of Beni Tal were within the range of drinking water recommended by WHO and BIS. However, few parameters were beyond the permissible limits. The value of Water Quality Index (WQI) (98.49) computed after accumulating diverse physico-chemical parameters of the lake water confirms the good quality of the water of Beni Tal. Water of Beni Tal is used by tourists, trekkers, local inhabitants, sages and wildlife for drinking purposes. Therefore, keeping in view the sustainable maintenance of water quality and its religious importance, the conservation and management of the Beni Tal should be taken up on priority basis.

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References

1. Papatheodorou G, Demopoulou G, Lambrakis N (2006) A long-term study of temporal hydrochemical data in a shallow lake using multivariate statistical techniques. Ecol Model 193: 759-776.
2. Singh S, Hussian A (2016) Water quality index development for groundwater quality assessment of Greater Noida sub-basin, Uttar Pradesh, India. Cogent Engineering 3: 1177155.
3. Alam M, Pathak JK (2010) Rapid assessment of water quality index of Ramganga River, Western Uttar Pradesh (India) using a computer programme. Nat Sci 8: 1-8.
4. Seth R, Mohan M, Singh P, Singh R, Dobhal R, et al. (2014) Water quality evaluation of Himalayan Rivers of Kumaun region, Uttarakhand, India. Appl Water Sci. 6: 137-147.
5. Yadav KK, Gupta N, Kumar V, Sharma S, Arya S (2015) Water quality assessment of Pahuj River using water quality index at Unnao Balaji, M.P., India. International Journal of Basic Science and Applied Research 19: 241-250.
6. Alobaidy AHMJ, Abid HS, Maulood BK (2010) Application of water quality index for assessment of Dokan lake ecosystem, Kurdistan region, Iraq. Journal of Water Resource and Protection 2: 792-798.
7. Sharma RC, Kumar R (2017) Water quality assessment of sacred glacial Lake Satopanth of Garhwal Himalaya, India. Applied Water Science 7: 4757-4764.
8. Shuchun Y, Bin X, Deyang K (2010) Chronology and nutrients change in recent sediment of Taihu Lake, lower Changjiang River Basin, East China. Chin Geogr Sci 20: 202-208.
9. Ravikumar P, Mehmood MA, Somashekar RK (2013) Water quality index to determine the surface water quality of Sankey tank and Mallathalli lake, Bangalore urban district, Karnataka, India. Applied Water Science 3: 247-261.
10. Ramesh N, Krishnaiah S (2014) Assessment of physico-chemical parameters of Bellandur Lake, Bangalore, India. International Journal of Innovative Research in Science, Engineering and Technology 3: 10402-10407.
11. Lala MGN, Mushtaq F, Pandey AC (2015) Assessment of pollution level in a Himalayan Lake, Kashmir, using geomatics approach. International Journal of Environmental Analytical Chemistry 95: 1001-1013
12. Joshi P, Joshi P, Ruwari NP, Pande V (2016) Physico-chemical characteristics of five Himalayan lakes from Kumaun region in Uttarakhand, India. International Journal of Advanced Research 4: 1190-1196.
13. Bouslah S, Djemili L, Houichi L (2017) Water quality index assessment of Koudiat Medouar Reservoir, northeast Algeria using weighted arithmetic index method. Journal of Water and Land Development. 35: 221-228.
14. Prakash S (1993) Structure and petrochemistry of the rocks between Simili and Dewalikhal area, Chamoli district, Garhwal Himalaya. Uttar Pradesh, India.
15. Wetzel RG, Likens GE (1991) Limnological Analysis, 2nd Ed. Springer-Verlag, New York. Inc: 1-391.
16. APHA (1998) Standard Methods for the Estimation of Water and Waste water. American public Health Association. American Waste Water Association and Water Pollution Control Federation. 20th Edition, Washington D.C.
17. World Health Organization (WHO) (2004) Guidelines for Drinking-Water Quality. 3rd Edition, World Health Organization (WHO), Geneva.
18. Ramakrishnaiah CR, Sadashivaiah C, Ranganna G (2009) Assessment of water quality index for the ground water in Tumkur Taluk. E-Journal of Chemistry 6: 523-530.
19. Sharma RC, Sharma N, Kumar R (2016) Physico-chemical and microbiological water quality of Bhimgoda wetland of Garhwal Himalaya, India. Journal of Research and Development 16: 96-103.
20. Mashatq B, Raina R, Yaseen T, Wanganeo A, Yousuf AR (2013) Variations in the physico-chemical properties of Dal Lake, Srinagar, Kashmir. African Journal of Environmental Science and Technology 7: 624-633.
21. Bhat SA, Pandit AK (2014) Surface water quality assessment of Wular lake, a Ramsar site in Kashmir Himalaya, using discriminant analysis and WQI. Journal of Ecosystems.

22. Bhat FA, Yousuf AR, Aftab A, Arshid Mahdi JMD, Balkhi MH (2011) Ecology and biodiversity in Pangong Tso (lake) and its inlet stream in Ladakh, India. International Journal of Biodiversity and Conservation 3: 501-511.

23. Singh Y, Khattar JIS, Singh DP, Rahi P, Gulati A (2014) Limnology and cyanobacterial diversity of high altitude lakes of Lahaul-Spiti in Himachal Pradesh, India. Journal of Biosciences 39: 643-657.

24. Lone JF, Rasool A, Unnisa SA (2017) Assessment of physico-chemical parameters of water in Kashmir region with reference to Dal Lake. Journal of Environmental and Analytical Toxicology 7: 1-4.

25. Naik AA, Wanganeo A, Ishaq A, Bhat NA (2012) Summer limnology of a high mountain lake Kailash lake Bhaderwah, Jammu and Kahmir. International Journal of Environmental Sciences 3: 931-939.