E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2018; 6(1): 177-187

www.fisheriesjournal.com
Received: 11-11-2017
Accepted: 12-12-2017

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Assessment of surface water quality of sacred lake Badhani Tal, India

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Abstract
The current study was carried out to investigate the water quality of Badhani Tal. The samples were collected for a period of one year during January, 2015 to December, 2015. A total of 16 physico-chemical parameters were assessed to develop the water quality index. It is the first report on any aspect of Badhani Tal. The mean values of pH ranged from 6.9 to 7.8; water temperature fluctuated from 16.1 to 25.12 ^{0}C; dissolved oxygen varied from 8.2 to 9.8 mg.l^{-1}; free CO_2 varied from 1.23 to 2.13 mg.l^{-1}; total dissolved solids varied from 110 to 188 mg.l^{-1}; calcium from 11.22 to 28.86 mg.l^{-1} and magnesium from 1.45 to 5.82 mg.l^{-1}. The Water Quality Index was recorded as 37.66. Most of the values of physico-chemical parameters are within the prescribed limits of WHO/BIS recommended for the water used for drinking purpose. The calculated value of WQI based on the weight values of these physico-chemical parameters revealed the 'excellent' water quality of the lake. The government officials have to make policies and take necessary action for its conservation and management.

Keywords: Badhani Tal, Garhwal Himalaya, India, water quality index, physico-chemical characteristics, sacred lake

1. Introduction
Water is so much important for the survival of life on the planet 'Earth'. It is one of the most precious resources of nature to the living organisms on this planet [1]. Water plays an important role in the existence of life and numerous economic sectors such as agriculture, aquaculture, electricity generation, industries and other important activities [2].

The human population has been increasing day by day which exerts an extensive pressure on the ecosystem and the resources. The increasing level of urbanization, industrialization, the modernization of agriculture, the increase in traffic contribute to global pollution, which requires accurate monitoring and related information about the water quality of the available water resources [3]. Water quality is used to assess the health of water body and the purpose for which it has been used. The assessment of water quality includes various physical, chemical and biological characteristics and to compare these characteristics with the standards recommended for drinking water by several organizations such as WHO, BIS, CPCB, ICMR [4].

It has been widely known that water contain a large numbers of chemical elements [5]. Physical characteristics like the temperature of water, turbidity, transparency, total dissolved solids are also known to operate in Lake Ecosystem [6]. The study of physico-chemical characteristics could help in understanding the structure and function of any aquatic ecosystem in relation to its inhabitants. Lakes are considered as the ecological barometers of the health of a region as they are playing an important role to regulate the micro-climate of any region [7], thereby influencing the life of the people adjacent to it. The environmental conditions of any lake system depend upon the nature of that lake and its exposure to various environmental factors [8]. Hence, the surface water quality not only depends on natural phenomenon (precipitation inputs, erosion) but also on anthropogenic actions (urban, industrial and agricultural activities) [9].

Surface water pollution of lakes with toxic chemicals and eutrophication are of great environmental concern worldwide. Global availability of freshwater for human consumption is very low [10]. Water covers about 70% of the earth, but a large amount of water is saline and remains in the ocean and sea with a high salt concentration of 3.5%. Less than 3% of water is fresh and out of this water, approximately 2% is in the ice caps, glaciers and groundwater.

The remaining amount of water which is less than 1% is available for the use to humankind which is very less in quantity [11].

The explosion in the population growth and their activities made surface water pollution a great problem and decreased the availability of drinking water. The lakes located in the Himalaya are the most important source of drinking water available for the local inhabitants, trekkers, sages and wild animals [12]. Hence, it is necessary to assess the quality of water of such lakes regularly so that the people of Himalaya get drinking water of good quality.

A Water Quality Index (WQI) value is useful in understanding the general status of water quality of any water body. This index method can be applied to assess the water quality of both the surface and ground water quality [13-15]. The aim of WQI is to find out a single value to assess the water quality of a water body by calculating and assessing its physico-chemical parameters. This WQI value interpret the status of water quality and its suitability for various purposes such as drinking, irrigation, fishing, sanitation, etc [16].

Though some work has been done on different aspects of the lakes. This include the work of [17] on Manyas lake of Turkey; [18] on lakes of western Himalaya; [19] on groundwater of Greater Noida sub basin and [3] on water quality index assessment of Koudiat Medouar Reservoir, Algeria. But no work has been done so far on any aspect of Badhani Tal. Hence, the present work was carried out to assess the water quality of Badhani Tal by analyzing physico-chemical parameters and estimating the water quality index. The basic data on the water quality of this lake is having a great important for its conservation and management.

2. Materials and Methods

2.1 Study area

Badhani Tal is located at Badhani village of Rudraprayag district of Uttarakhand at an altitude of 2,310 m. above sea level. It lies between latitude $30^0$29’52” N and longitude $78^0$55’23” E (Fig. 1). This lake is easily approachable throughout the year as it is only 200 m far from the road. This lake is somewhat oval in shape with a length of about 23 meter and width of 15 meter. It is around 3 m in depth which covers an area of about 350 m^2. The lake has both an inlet and outlet for water. The source of water for this lake is the melting of snow at the Triyuginarayana and other nearby mountain peaks and the rain water during the monsoon season. The lacustrine ecosystem of Badhani Tal is an important natural resource and particularly valued for its aesthetic and recreational value. The dominating species of trees which provide an enchanting view to the visitors and nature lovers are *Quericus leucotricophora, Q. semicarpifolia, Q. floribunda, Rhododendron arboretum, Myrica esculenta, Lyonia ovalifolia, Taxus baccata* at the top canopy, while the ground vegetation is dominated with *Rubus ellpticus, Berbaris aristata, B. aisatica, B. lyceum* and other important medicinal herbs.

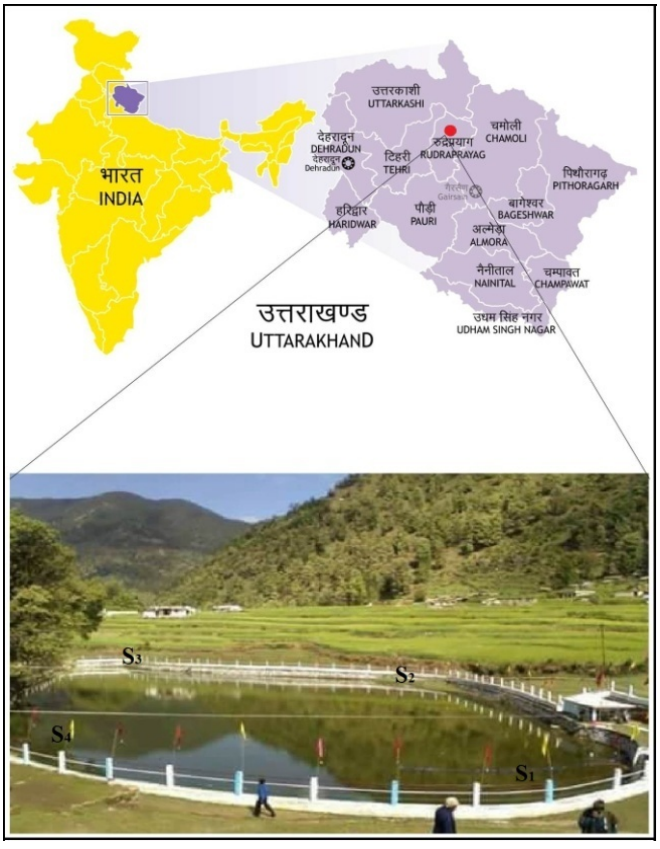

Fig. 1: Study area of the present study

2.2 Water sampling

The lake water was collected as sample for a period of January, 2015 to December, 2015. The samples of water were collected from four different sites (S_1, S_2, S_3 and S_4) of the lake (Fig. 1) from surface water dipping the sterilized sample bottles 10 cm below water surface in the lake during 8:00 to 10:00 hrs. This lake has both the inlet (S_3) and outlet (S_1) for water. Some of the physico-chemical parameters required for

water quality analysis like pH, air temperature, water temperature, free carbon dioxide and dissolved oxygen were measured at each sampling site of the lake. For the analysis of left over 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 [20] and APHA [21]. 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 ^{0}C to +300 ^{0}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 after incubating the samples at 20^{0}C for five days. Conductivity and total dissolved solids (TDS) were measured by using the Toshcon Bench Top Multiparameter analyzer (Model No. TPC-17). Free CO_2, total alkalinity, total hardness, calcium, chlorides and Magnesium were measured by following the protocols available in APHA [21]. Nitrates, sulphates and phosphates 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 all the sites were also calculated. Pearson's correlation coefficients between various physico-chemical parameters were also computed.

2.3 Statistical treatment of data

Statistical treatment (mean; standard deviation) of the physico-chemical parameters of water was conducted. The relationships (correlation coefficient) between the parameters were also calculated.

2.4 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, fifteen water quality parameters were selected. Values used for each parameter were the mean value of the three 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 [22]. The calculation and formulation of the WQI involved the following steps [23]:

First step: Each of the fifteen parameters has been assigned a weight (AWi) ranging from 1 to 4 depending on the collective expert opinions taken from different previous studies [23-26]. 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.

Table 1: Assigned weight values of water quality parameters adopted from the literature [23-26]

Parameters	Sampling sites				Mean value
	S_1	S_2	S_3	S_4	
pH	4	4	3	3	3.5
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	2	2	2.5
TDS (mg/l)	3	3	2	3	2.75
Chlorides (mg/l)	2	2	2	3	2.25
Total alkalinity (mg/l)	2	2	2	2	2.0
Total hardness (mg/l)	3	3	3	3	3.0
Calcium (mg/l)	3	3	2	2	2.5
Magnesium (mg/l)	3	3	3	3	3.0
Nitrates (mg/l)	4	4	4	4	4.0
Sulphates (mg/l)	4	4	4	4	4.0

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.

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

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	3.5	0.093333
DO (mg/l)	5.0	6.0	4.0	0.106667
B.O.D. (mg/l)	N.A	2.0	4.0	0.106667
Conductivity(µS/cm)	250	N.A	2.5	0.066667
TDS (mg/l)	600	500	2.75	0.073333
Chlorides (mg/l)	250	250	2.25	0.060000
Total alkalinity (mg/l)	200	200	2.0	0.053333
Total hardness (mg/l)	200	200	3.0	0.080000
Calcium (mg/l)	75	75	2.5	0.066667
Magnesium (mg/l)	30	30	3.0	0.080000
Nitrates (mg/l)	45	45	4.0	0.106667
Sulphates (mg/l)	200	200	4.0	0.106667
Total			37.5	1.0

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 [27].

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 [23-26].

3. Results and Discussion

3.1 Physico-chemical characteristics of water

The values of all the physico-chemical parameters were obtained from the analysis of water samples of Badhani Tal collected from four different sites of the lake throughout the year during January, 2015 to December, 2015. The reported 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).

Table 3: Monthly variations in mean values of physico-chemical parameters of Badhani Tal, Uttarakhand from January 2015 to December 2015 (Mean value of all sites, minimum, maximum and Mean ±SD)

Parameters/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Min.	Max.	Mean±SD
AT (^{0}C)	19.2	20.4	23.0	24.6	26.2	26.5	26.0	26.2	25.0	20.2	19.5	18.6	18.6	26.5	22.95±3.15
WT (^{0}C)	16.1	17.3	18.2	20.0	21.5	23.4	25.12	24.0	23.5	18.5	17.0	16.5	16.1	25.12	20.09±3.27
pH	6.9	7.2	7.5	7.4	7.6	7.4	7.8	7	7.4	7.5	7.6	7.8	6.9	7.8	7.43±0.28
DO (mg/l)	9.8	9.6	9.4	8.8	8.6	8.2	8.2	8.6	8.8	9.2	9.4	9.2	8.2	9.8	8.98±0.53
BOD (mg/l)	1.4	1.8	2.0	2.2	2.4	2.6	2.4	2.4	2.0	1.8	1.6	1.4	1.4	2.6	2.0±0.41
Cond (µS/cm)	228	232	222	241	251	242	265	272	268	250	235	230	222	272	244.67±16.66
TDS(mg/l)	117	123	164	176	188	162	170	168	150	145	123	110	110	188	149.67±25.86
Free Co_2 (mg/l)	1.23	1.35	1.49	1.57	1.63	1.71	1.98	2.13	1.82	1.74	1.71	1.29	1.23	2.13	1.64±0.27
Cl^- (mg/l)	4.26	4.16	5.4	5.32	4.86	4.98	5.68	5.68	4.86	4.86	4.48	4.48	4.16	5.68	4.92±0.52
Alkal (mg/l)	120	147	135	130	132	137	150	145	120	120	110	98	98	150	128.67±15.65
Hard (mg/l)	40	44	44	48	52	72	84	80	76	58	50	44	40	84	57±16.53
Ca (mg/l)	12.02	11.22	13.63	13.63	16.03	22.45	24.05	28.86	25.65	19.24	16.03	12.83	11.22	28.86	17.97±5.95
Mg^{2+} (mg/l)	2.42	3.88	2.42	3.41	2.91	3.89	5.82	1.93	2.9	2.42	2.42	2.91	1.45	5.82	2.95±1.14
NO_3^- (mg/l)	0.279	0.289	0.296	0.322	0.335	0.379	0.402	0.422	0.4	0.312	0.303	0.285	0.279	0.422	0.345±0.05
PO_4^- (mg/l)	0.05	0.05	0.053	0.046	0.043	0.056	0.062	0.06	0.052	0.05	0.05	0.048	0.043	0.062	0.052±0.01
SO_4^- (mg/l)	1.535	1.763	2.107	2.484	2.701	2.949	3.231	3.087	2.643	2.316	2.013	1.876	1.535	3.231	2.392±0.55

3.1.1 Air and water temperature

The difference in the mean values of air and water temperature at the lake was quite high. The air temperature was recorded minimum (18.6^{0}C) in the month of December and maximum (26.5^{0}C) in the month of June (Fig. 2), with an average air temperature of 22.95^{0}C during the study period. Similarly as air temperature, the variation in the value of water temperature was also quite high. It was recorded minimum (16.1^{0}C) in the month of January and maximum (21.12^{0}C) in the month of July (Fig. 3). Similar observation were recorded by Khuhawar *et al.* [28] for Baghsar Lake of Azad Kashmir; Manjare *et al*. [29] for Tamdalge Tank of Kolhapur District, Maharashtra; Magarde *et al*. [30] for Upper lake of Bhopal; Abir [31] for Rudrasagar Wetland in Tripura. The water and air temperature are directly proportional to each other. Increase in the air temperature causes an increase in the water temperature.

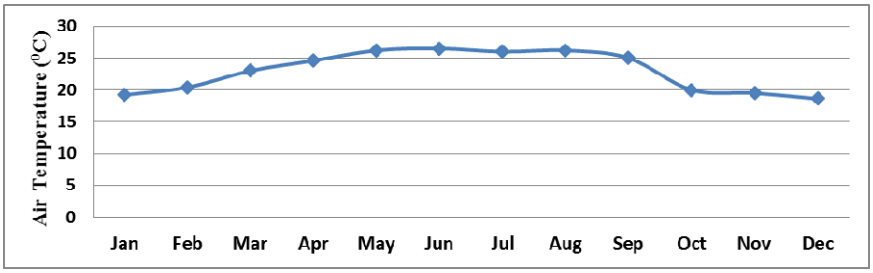

Fig 2: Variation in Air Temperature in the present study

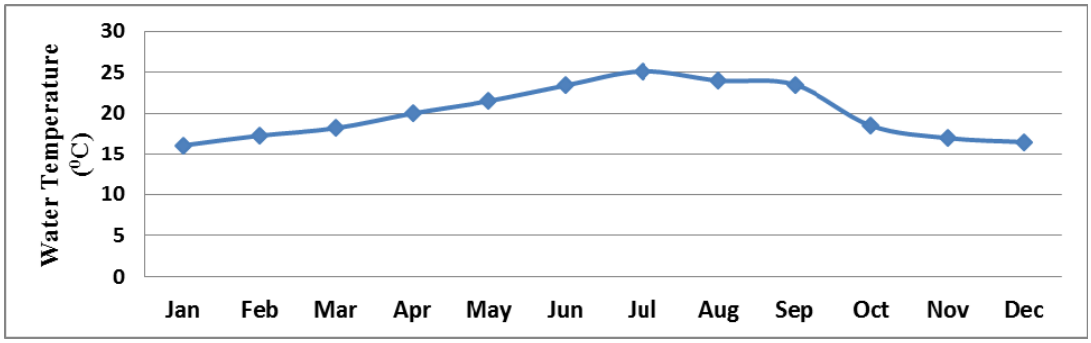

Fig 3: Variation in Water Temperature in the present study

3.1.2 pH

The pH or hydrogen ion concentration is considered as one of the most important factors that resembles the level of pollution in the water. During the entire study, the water of the lake was found slightly acidic to slightly alkaline in nature. It was ranged from 6.9 to 7.8 (Fig. 4). The average pH of the lake water during the study period was recorded as 7.43. The permissible range of pH for drinking water was specified as 6.5 to 8.5 as per WHO and BIS standards. The similar results on pH were observed by Khuhawar *et al*. [28] for Baghsar Lake of Azad Kashmir; Abir [31] for Rudrasagar Wetland in Tripura.

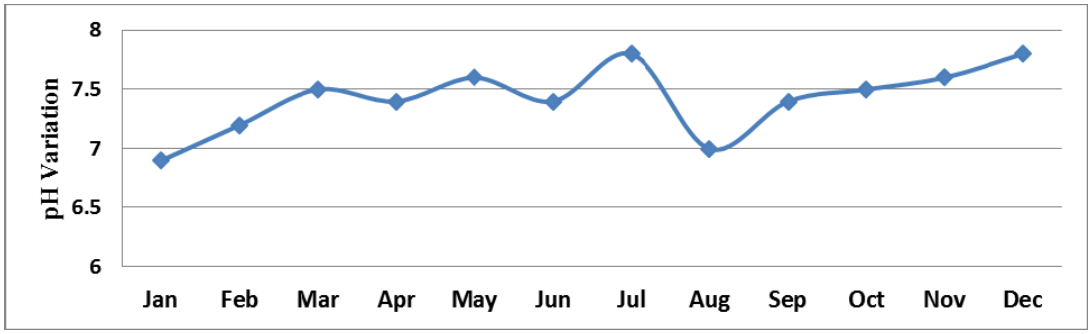

Fig 4: Variation in pH in the present study

3.1.3 Dissolved oxygen

It has been considered that dissolved oxygen is the most important characteristic of water for assessing its health whether it is fit for human consumption or not. It is considered as a direct indicator for assessing the 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 is the temperature, lower is the dissolved oxygen in the water body. The concentration of dissolved oxygen was recorded minimum (8.2 mg/l) in the month of June and July and maximum (9.8 mg/l) in the month of January (Fig. 5). 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 magnitude level of eutrophication [32]. Similar observation was recorded by Bhat and Pandit [33] from Wular Lake, a Ramsar site in Kashmir; Singh and Sharma, [34] for Baldi in Garhwal Himalaya.

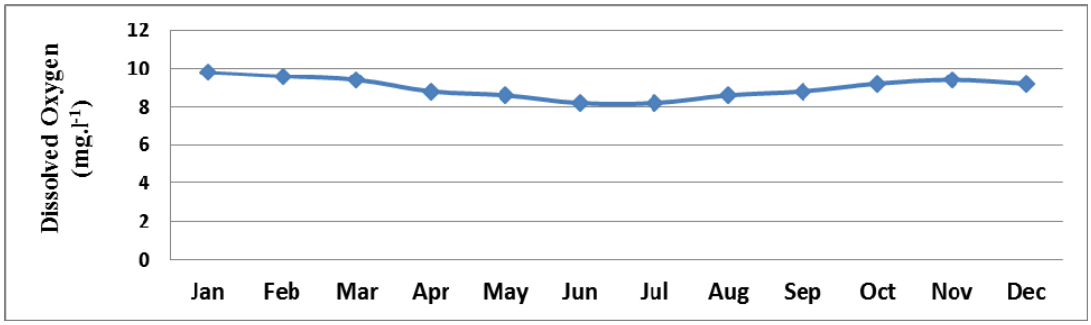

Fig 5: Variation in Dissolved oxygen in the present study

3.1.4 Biochemical oxygen demand

The concentration of biochemical oxygen demand (BOD) of the lake water of Badhani Tal ranged from 1.4 mg/l in the month of December and January to 2.6 mg/l in the month of June (Fig. 6). 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.

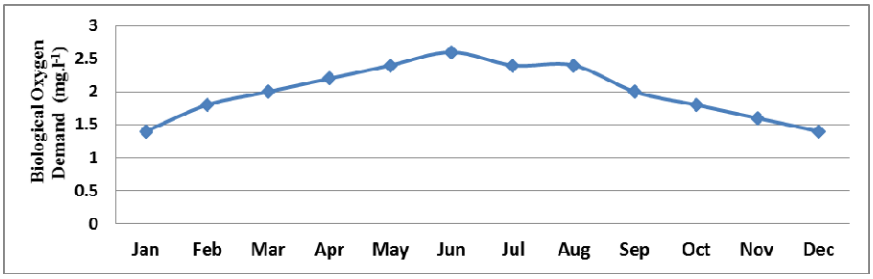

Fig 6: Variation in Biochemical oxygen demand in the present study

3.1.5 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 (222 µS/cm) was recorded in the month of March and maximum conductivity (272 µS/cm) was recorded in the month of August (Fig. 7). 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.* [35] in Pengong Lake in Ladakh region.

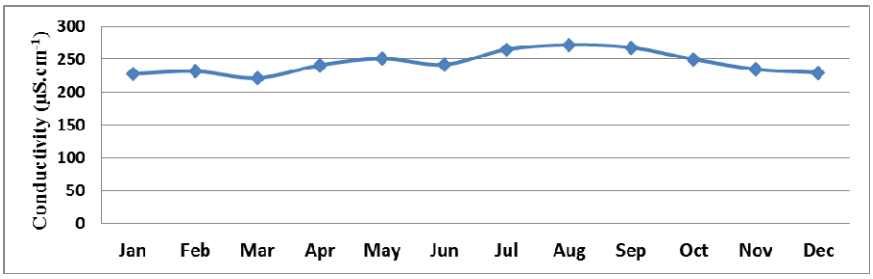

Fig 7: Variation in Conductivity in the present study

3.1.6 Total dissolved solids

Total dissolved solids (TDS) refer to the minerals, salts, metals, ions and organic matter dissolved in the water. The minimum value (110 mg/l) of TDS was recorded in the month of December and maximum value (188 mg/l) in the month of May (Fig. 8). 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.* [35] in Pengong Lake in Ladakh region and Singh *et al.* [36] for Deepak Tal of Lahaul-Spiti in Himachal Pradesh.

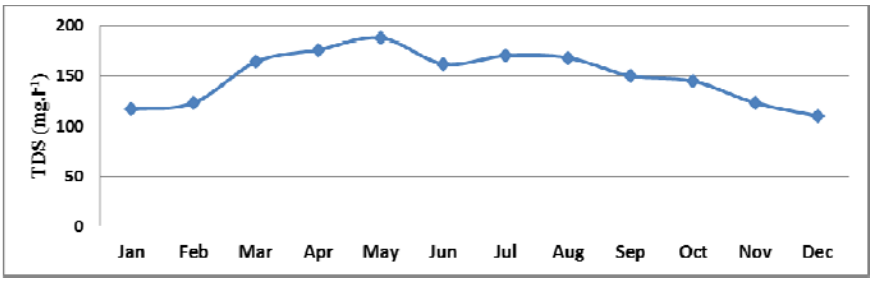

Fig 8: Variation in Total Dissolved Solids in the present study

3.1.7 Free CO_2

It is also considered as one of the important water quality parameters to assess the quality of water of a water body. It is measured always at the site. Higher is the free CO_2, higher is the pollution level in the water body. The minimum concentration (1.23 mg/l) of free CO_2 was recorded in the month of January and maximum (2.13 mg/l) was recorded in the month of August (Fig. 9). The concentration of free CO_2 was much less than the permissible limit of WHO for drinking water which is 250 mg/l [22].

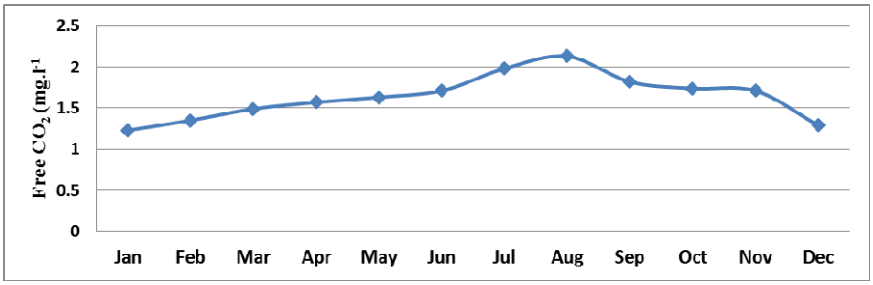

Fig 9: Variation in Free CO_2 in the present study

3.1.8 Chlorides

The concentration of chlorides dissolved in the surface water mainly occurs naturally from the surroundings. Chloride is a good conservative element which is used for the assurance of water quality. The concentration of chlorides ranged between 4.16 mg/l to 5.68 mg/l (Fig. 10), which is much lesser than the permissible limit of 250 mg/l for drinking water as per WHO and BIS standards [22].

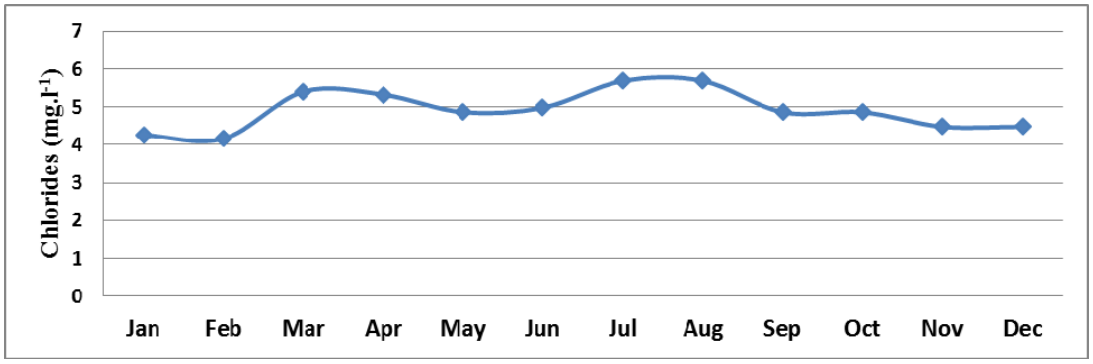

Fig 10: Variation in Chlorides in the present study

3.1.9 Total alkalinity

The total alkalinity was recorded minimum (98 mg/l) in the month of December and maximum (150 mg/l) in the month of July (Fig. 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*. [37] on high mountain lake, Kailash Lake of Jammu and Kashmir.

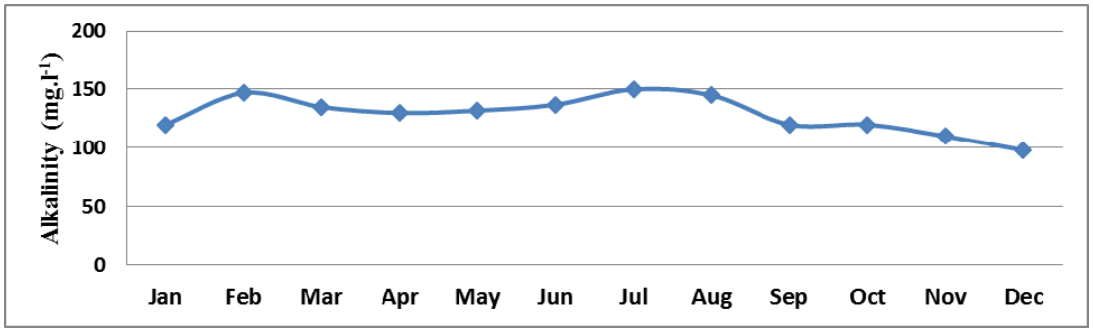

Fig 11: Variation in Alkalinity in the present study

3.1.10 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 40 mg/l to 84 mg/l (Fig. 12), which is much less than the permissible limit of hardness in the drinking water (200 mg/l) as per WHO and BIS standards [22].

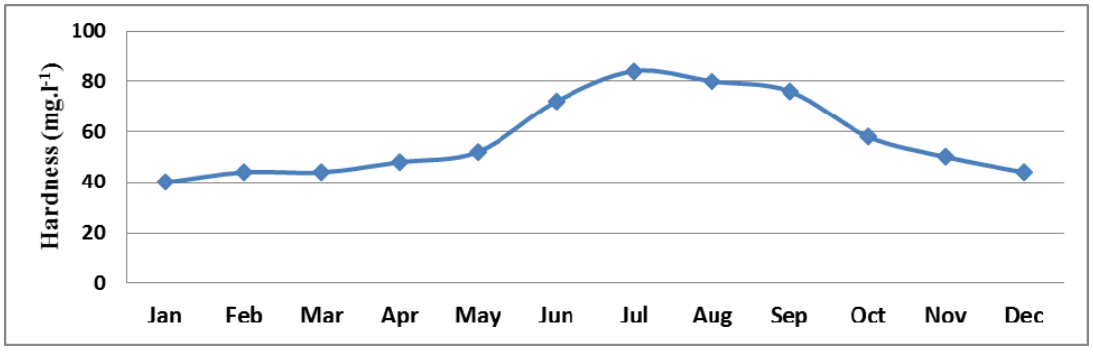

Fig 12: Variation in Hardness in the present study

3.1.11 Calcium and magnesium

The concentration of calcium was recorded minimum (11.22 mg/l) in the month of February and maximum (28.86 mg/l) in the month of August (Fig. 13), whereas the concentration of magnesium ranged between 1.45 mg/l to 5.82 mg/l (Fig. 14). 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 [22].

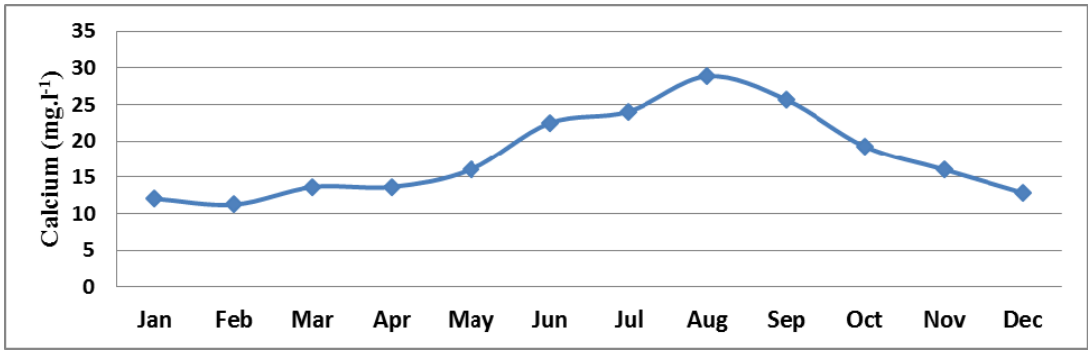

Fig 13: Variation in Calcium in the present study

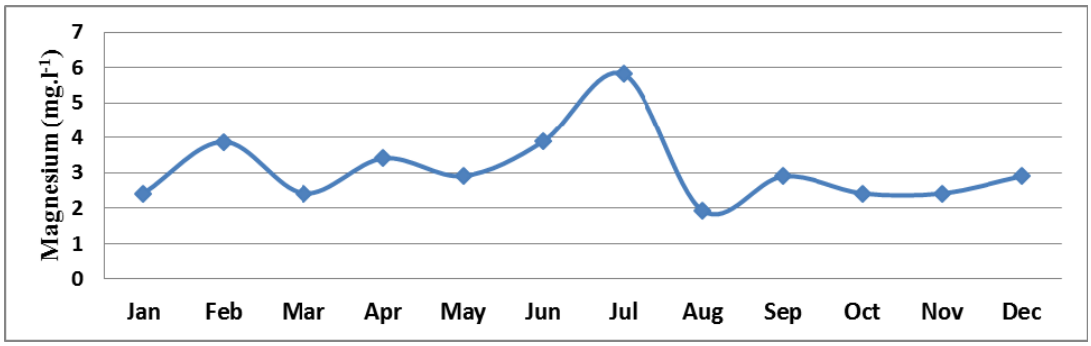

Fig 14: Variation in Magnesium in the present study

3.1.12 Nitrates, Phosphates and Sulphates

The concentration of nitrates in the water samples was recorded minimum (0.279 mg/l) in the months of January maximum (0.422 mg/l) in the month of August (Fig. 15). The concentration of phosphates was recorded within a range of 0.043 mg/l to 0.062 mg/l (Fig. 16). However, the concentration of sulphates in the water samples of Badhani Tal ranged between 1.535 mg/l to 3.231 mg/l (Fig. 17). The concentration 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 [22].

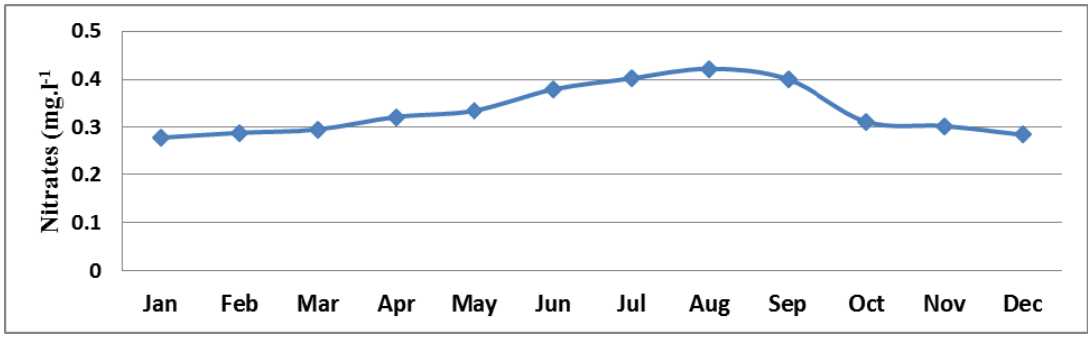

Fig 15: Variation in Nitrates in the present study

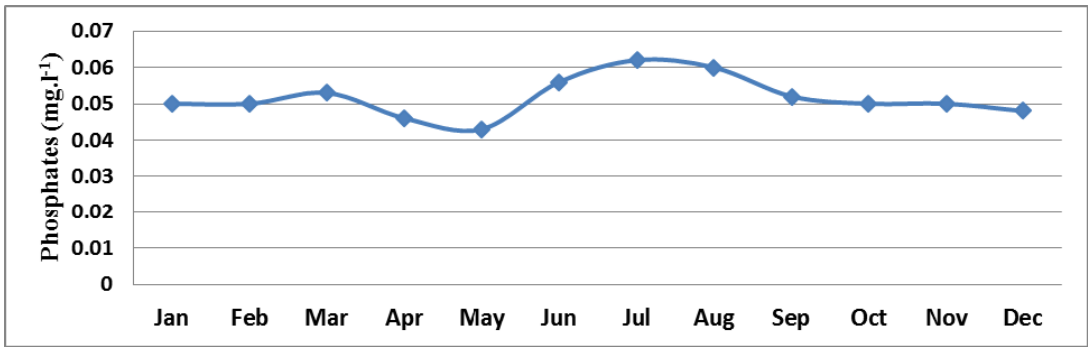

Fig 16: Variation in Phosphates in the present study

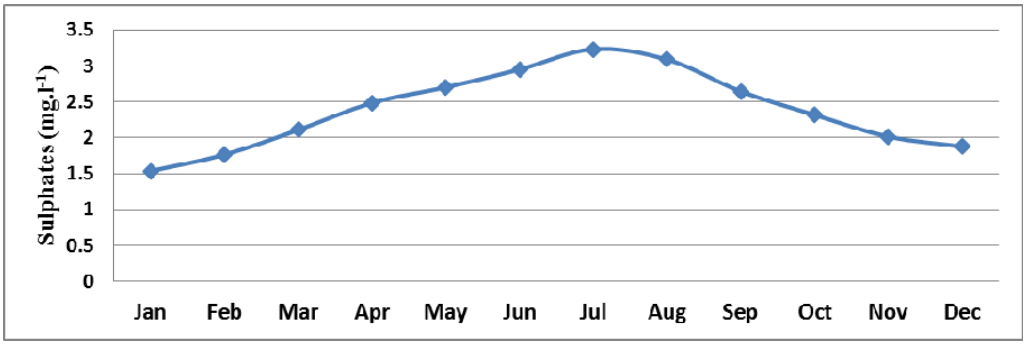

Fig 17: Variation in Sulphates in the present study

3.2 Statistical treatment of data

The correlation coefficients of air temperature in relation with water temperature (r=0.918), biochemical oxygen demand (r= 0.959), total dissolved solids (r= 0.897) and sulphates (r= 0.900) in the study has shown a significant positive relationship, where (P<0.001). The correlation coefficients of water temperature in relation with hardness (r= 0.925), nitrates (r=0.964) and sulphates (r= 0.963) in the study has shown a significant positive relationship but it shows a negative relationship with dissolved oxygen (r= -0.913) (P<0.001). The correlation coefficients of dissolved oxygen have negative relation with biochemical oxygen demand (r= -0.874) and sulphates (r= -0.953) (P<0.001). The correlation coefficient of biochemical oxygen demand showed positive relation with total dissolved solids (r= 0.892) and sulphates (r= 0.897), where (P<0.001). Conductivity showed a positive correlation with free CO_2 (r= 0.873), hardness (r= 0.887), calcium (r= 0.896) and nitrates (r= 0.901) (P<0.001). The correlation coefficient of free CO_2 showed a positive correlation with hardness (r= 0.893); calcium (r= 0.916), nitrates (r= 0.886) and sulphates (r= 0.872), where (P<0.001). Hardness also showed the positive correlations with calcium (r= 0.963); nitrates (r= 0.967) and sulphates (r= 0.888) where (P<0.001). Calcium also showed a positive correlation with nitrates (r= 0.953) (P<0.001). Nitrates showed a strong positive correlation with sulphates (r=0.916) (P<0.001) (Table 4).

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

	A.T.	W.T.	pH	DO	BOD	Cond	TDS	Free Co_2	Cl^-	Alkal	Hard	Ca	Mg^{2+}	NO_3^-	PO_4^-	SO_4^-
AT	1															
WT	0.918	1														
pH	0.026	0.087	1													
DO	-0.870	-0.913	-0.328	1												
BOD	0.959	0.869	0.064	-0.874	1											
Cond	0.659	0.848	-0.004	-0.694	0.579	1										
TDS	0.897	0.729	0.124	-0.732	0.892	0.508	1									
Free Co_2	0.679	0.828	0.085	-0.714	0.673	0.873	0.585	1								
Cl^-	0.745	0.727	0.156	-0.687	0.728	0.557	0.790	0.732	1							
Alkal	0.647	0.581	-0.268	-0.427	0.721	0.357	0.592	0.428	0.527	1						
Hard	0.712	0.925	0.075	-0.804	0.675	0.887	0.474	0.893	0.639	0.449	1					
Ca	0.666	0.866	-0.040	-0.717	0.612	0.896	0.446	0.916	0.622	0.341	0.963	1				
Mg^{2+}	0.341	0.437	0.419	-0.505	0.394	0.192	0.218	0.146	0.222	0.484	0.379	0.117	1			
NO_3^-	0.825	0.964	-0.022	-0.832	0.757	0.901	0.588	0.886	0.684	0.492	0.967	0.953	0.293	1		
PO_4^-	0.391	0.601	-0.095	-0.442	0.407	0.479	0.161	0.638	0.581	0.535	0.759	0.706	0.373	0.677	1	
SO_4^-	0.900	0.963	0.211	-0.953	0.897	0.814	0.788	0.872	0.803	0.536	0.888	0.838	0.400	0.916	0.563	1

3.3 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 Badhani Tal. WQI indicates the water quality and also assured its usage, whether it is fit for human consumption or not. It was observed from all the computed data for all the required water quality parameters that the value is 37.66. However, Sharma and Kumar [26] recorded 28.504 (WQI) for the glacier-fed Lake Satopanth. Therefore the water of Badhani Tal can be categorized into "Excellent" during the sampling period. 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 Badhani Tal, selected results from the physico-chemical parameters are presented in Table 3.

4. Conclusion

From the results of present study, it can be concluded that the entire physico-chemical parameters lie within the range of permissible limit recommended for drinking water quality by the various agencies such as WHO, BIS, ICMR. The value (37.66) of Water Quality Index (WQI) computed after accumulating diverse physico-chemical characteristics of the lake water also confirms the above assessment of the water quality. This lake is religiously significant and sacred and has a great value for the local communities, trekkers, sages, wild animals. This maiden study on the assessment of water quality of Badhani Tal can be a good reference for further study on Himalayan Lakes

5. Acknowledgements

The author (Rahul Kumar) is thankfully acknowledged University Grants Commission, New Delhi and H.N.B.

Garhwal University (A Central University) for providing him University fellowship.

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