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Study of water quality by physicochemical analysis of a Himalayan lake of Uttarakhand, India

Bonika Pant*, Vibha Lohani, Malobica Das Trakroo and Hema Tewari

College of Fisheries, G. B. Pant University of Agriculture & Technology, Pantnagar 263145 U.S. Nagar, Uttarakhand, India

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ABSTRACT

Water exists in many forms and is one of the most abundant compounds. Lakes are very important lentic freshwater ecosystems, where the water quality is governed by many environmental and seasonal attributes. Lake Bhimtal in the Kumaun region is the largest lake of Uttarakhand. Three sites according to the anthropogenic interference were selected and the study of physiochemical parameters of the surface water was performed for a year (Jan-Dec, 2014). The range of physical properties i.e. water temperature, transparency, electric conductivity and turbidity during the study period was 11.5 to 27.5 °C, 235-332 cm, 170-185.5 µS/cm and 21-38.9 NTU respectively. Chemical parameters like pH, dissolved oxygen, free CO_2, total alkalinity, nitrate and phosphate levels were found to be in the range of 7.4-8.7, 6.9-9 mg/L, 0-18.7 mg/L, 75-95 mg/L, 0.3-0.5 mg N L^{-1} and 0.01-0.03 mg P L^{-1} during the investigation period. The results indicate that the water is fit for recreational and domestic use but the human activities must be regulated near the lake to ensure long term utilization and preserving beauty of this lake.

Key words : *Lentic, Freshwater, Anthropogenic, Physical, Chemical*

Introduction

Water is a basic need for most of the animals and a prime natural resource. Lakes have been defined as a body of standing water, occupying a basin or lacking continuity with sea (Forel, 1892). Lakes of all sizes provide us fisheries, drinking water, scenic splendour, power generation, increase in property values and act as excellent systems for ecological studies. Lakes are an important element of the natural environment that defines both landscape and its ecological functioning. During the last few decades lakes all over the world have become the focus of environmental investigation as they exhibit enormous diversity based on the genesis, geographical location, hydrological regimes and substrate factors. water quality constitutes of various abiotic and biotic factors associated with the ecosystem. The maintenance of a healthy ecosystem is dependent on the physico-chemical properties of the water and biological diversity. Abiotic and biotic factors of an ecosystem are interdependent and the fluctuation of abiotic ones frequently affects the biotic factors changing their quantity and biodiversity. Physical characteristics like temperature, light intensity, transparency, pressure, conductivity and water current whereas chemical properties like levels of dissolved oxygen, free carbon dioxide, pH, alkalinity, hardness, phosphate, nitrate levels etc of the lake water highly govern the aquatic life and determine the trophic status of the water body. Abiotic factors are usually the governing forces of the environment and influence the well being, distribution of organisms and functioning of the ecosystem.

***Corresponding Author's e-mail:** hereami09@gmail.com

The shoe shaped lake Bhimtal (29°202353N, 79°332333E) is a very unique and beautiful lake of Uttarakhand which is the largest lake of Kumaon region. Bhimtal Lake situated at 1370 m above msl not only forms major drainage reservoir of the place but is also the source of water for domestic and irrigation purposes. Bhimtal Lake can be said to have temperate climate in winter and semitropical weather in summer season. These properties attract a large number of tourists and hydrologists in the area which leads to heavy anthropological activities keeping this in focus, the quality aspects of water of lake Bhimtal were analysed in order to assess the condition of the lake.

Materials and Methods

Sampling sites

A study was conducted for a period of one year (Jan-Dec, 2014) in the Lake Bhimtal and three sampling stations -S_1, S_2, S_3, were selected based on human intervention Site S_1 in the lake is the Boat Stand which has a wide area with a small market and a few restaurants thus with maximum anthropologic activities, while site S_3 is the spot in the middle of the lake (25 m from site S_1) parallel to the island with minimum human disturbance and site S_2 is between S_1 and S_3, around 12m from site S_1.

Sample Collection

Surface water samples were collected in clean glass stoppered sampling bottles from all the three sites (S_1, S_2 and S_3). Sampling for water quality analysis was done in sterile plastic bottles carefully cleaned and rinsed thoroughly with distilled water (APHA, 2005). Some of the limnological parameters were analysed on the spot while samples for few water quality parameters were brought to the laboratory under ideal conditions.

Sample Analysis

Under physico-chemical analysis of lake water major parameters i.e., temperature, pH, specific conductivity, secchi transparency, dissolved oxygen, free CO_2, alkalinity, PO_4-P and NO_3-N were estimated. Surface water temperature was recorded with the help of a mercury thermometer, water transparency was measured by standard Secchi disc and turbidity was analysed using Turbidity meter (2100 PT HACH). Biogen pH-temperature-conductivity meter was used to determine the conductivity in mhos and pH.

Result and Discussion

Water temperature

The range of water temperature during the study period was 11.5 to 27.5 °C (Fig. 1). The lowest water temperature was recorded in the month of January i.e., 11.9, 11.5, 11.8°C at sites S_1, S_2 and S_3 respectively, while the highest temperature was recorded in the month of June i.e.27.5, 27.1, 27.3°C respectively at S_1, S_2 and S_3 stations. The average water temperatures at three sampling sites were 19.9±5.44, 19.2±5.58, 19.4±5.69 °C respectively. The site S_1 with maximum human interference and pollution showed maximum temperature, followed by S_3 and S_2 . A rising trend of water temperature can be seen from January to the month of July which is followed by decreasing values up to December 2014. The maximum value of 27.5 °C was recorded at site S_1 in June and minimum value of 11.5°C was recorded at site S_2 in January. During summer, the temperature of lake surface water increases due to sunlight (Hairston Jr and Fussmann 2002). Similar results were also concluded by Basualto *et al.* (2006) and Medudhula *et al.* (2012).

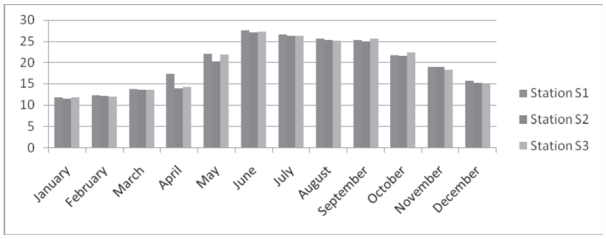

Fig. 1. Monthly variations of Water Temperature (°C) during the study period in Lake Bhimtal

The surface water temperature of Lake Bhimtal was found to be positively correlated with water turbidity significantly (Pradhan *et al.*, 2003 and Mansoor Ahmad *et al.*, 2014), electrical conductivity, free CO_2, phosphate, nitrate, and a significant negative correlation was observed with pH, total alkalinity and dissolved oxygen (Table 1).

Water transparency

The values of transparency ranged between 235-332 cm at the three sites throughout the investigation period with an average value of 272.75±30.36,

274.83±30.72 and 278.75±32.04 cm at site S_1, S_2 and S_3 respectively (Fig. 2). The observation show that the site S_1 has the least transparency as it is marginal with maximum human activity and with heavy load of allocthonous materials. The maximum transparency was at site S_3 which is almost at the centre of the lake with maximum light penetration and least affected by contaminants entering the lake. The highest transparency was recorded during November (300, 300 and 310 cm at S_1, S_2 and S_3) and the visibility was very poor during July and August (rainy season)with transparency in the range of 235-257 cm at all the stations. Lower transparency during rainy season may be due to result of washing of allocthonous sediment particles entering from catchment area and suspended particles of the lake (Mustapha and Omotosho, 2005 and Adenji, 1982).

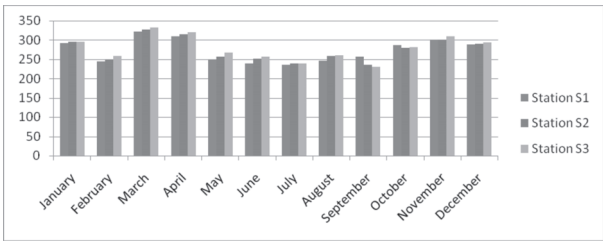

Fig. 2. Monthly variations of Transparency (cm) during the study period in Lake Bhimtal

The transparency of Lake Bhimtal was significantly positively correlated with total alkalinity, and dissolved oxygen. A significant negative correlation was observed with pH, water turbidity, nitrate, electrical conductivity and phosphate (Table 1).

Electrial Conductivity (EC)

Kumar and Sinha (2010) suggested that the underground drinking water quality of study area can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas. The lowest electrical conductivity was recorded in the month of January i.e.170, 170 and 170.5 µS cm^{-1} at site S_1, S_2 and S_3 respectively (Fig. 3). The highest conductivity was recorded in the month of August i.e. 185.5, 184.9, 184.5 µS cm^{-1}, at S_1, S_2 and S_3 stations respectively. According to Sinha *et al.*, (2013) the presence of higher concentration of dissolved salts in the water is indicated by higher EC values. The maximum average value was recorded at site S_1 (177.84 µS $cm^{-1)}$ and minimum value, at site S_3 (175.75 µS$cm^{-1)}$ and

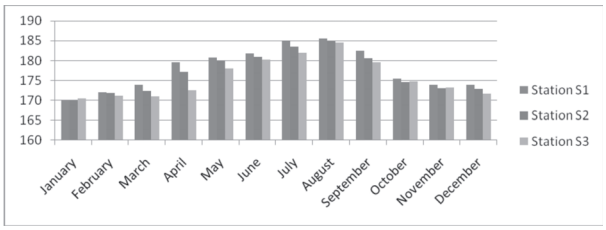

Fig. 3. Monthly variations of Electrical Conducivity (µS/cm) during the study period in Lake Bhimtal

S_2 recorded an average value of 176.79 µS cm^{-1}.

Electrical conductivity had a significant positive correlation with parameters such as temperature, turbidity, nitrate and phosphate, while significant negative correlation of EC was found with dissolved oxygen, pH and total alkalinity. Arul Antony *et al.*, (2008) also observed positive correlation of conductivity with turbidity and pH while negative correlation with dissolved oxygen (Table 1).

Water turbidity

Turbidity is important because it can influence biological communities such as submerged aquatic vegetation and algae as it affects their ability to photosynthesize. The values of turbidity in Bhimtal lake ranged between 21-38.9 NTU throughout the study period (Fig. 4). The highest values of water turbidity were noticed during the month of August and the values were 38.9, 38.7 and 38.8 NTU at station S1, S_2 and S_3 respectively. Sinha *et al.* (2013) stated that high turbidity may be due to human activities, decrease in water level and presence of suspended particulate matter. The lowest values were recorded during January at all the three stations S1, S_2 and S_3 which are 21.2, 20.5 and 20.3 NTU respectively. The results are supported by Dagaonkar and Saksena (1992) and Garg *et al.* (2006) who also reported high turbidity during rainy season.

During winter and summer season settlement of silt, clay results in low turbidity and in rainy season

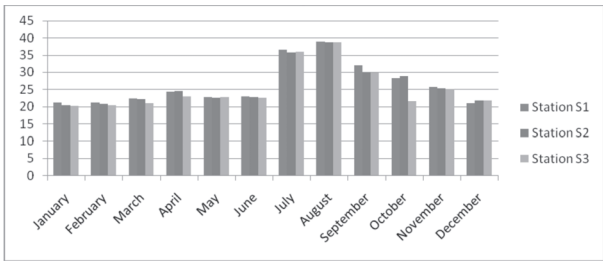

Fig. 4. Monthly variations of Turbidity (NTU) during the study period in Lake Bhimtal

clay, silt and other suspended particles contribute to the turbidity values. The average values were 26.44±6.20, 26.18±5.98 and 25.27±6.22 NTU throughout the study period at stations S_1, S_2 and S_3 respectively.

Turbidity is significantly positively correlated with temperature, turbidity, nitrate, phosphate and free CO_2 whereas significantly negative correlated with pH, total alkalinity, transparency and dissolved oxygen (Table 1). The results are strengthened by the findings of Arul Antony *et al.*, (2008).

pH

The pH of water is an important water quality parameter because pH is a major factor in most chemical and biological reactions. The range of pH in the lake Bhimtal during the study period was 7.4-8.7. Similar results were concluded by Ramachandra and Solanki (2007) who stated that pH of natural water usually lies in the range of 4.4 to 8.5 (Fig.5). The highest value of pH recorded in the investigation period was in the month of August in station S1, S2 and S3 i.e. 8.3, 8.5 and 8.7 respectively while lowest in the month of December i.e. 7.7, 7.4 and 7.5 in S1, S2 and S3. The result indicated that the pH of lake is neutral to slightly alkaline. During several studies it was found that the pH of lake ecosystem generally neutral to slightly alkaline. It has been suggested that the high pH is normally associated with a high photosynthetic activity in water (Wani and Subla, 1990).

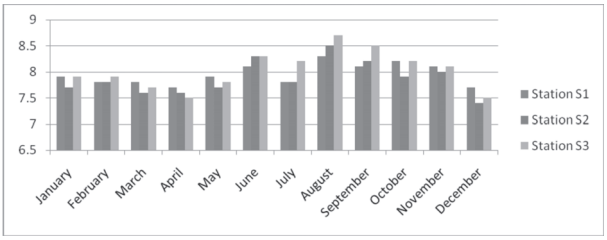

Fig. 5. Monthly variations of pH during the study period in Lake Bhimtal

pH of Lake Bhimtal was found to be significantly positive correlated with free CO_2 and phosphate while a significantly negative correlation was observed with total alkalinity, dissolved oxygen and nitrate (Table 1). Patela and Vaghani (2015) also observed a negative correlation between pH and dissolved oxygen. Shrivastava & Joshi (2008) was also noticed negative correlation of pH with dissolved

Table 1. Correlation between physico-chemical parameters of water during the study period in Lake Bhimtal
*Shows significant correlation at 5 % level

Parameters	Temperature	Transparency	Conductivity	Turbidity	pH	DO	CO_2	Alkalinity	Nitrate	Phosphate
Temperature	1									
Transparency	-0.6763*	1								
Conductivity	0.9010*	-0.6722*	1							
Turbidity	0.6969*	-0.4941	0.8030*	1						
pH	0.73363*	-0.5593*	0.6313*	0.6536*	1					
DO	-0.7895*	0.5917*	-0.8123*	-0.596*	-0.4785	1				
CO_2	0.4925	-0.3571	0.4551	0.6096*	0.7088*	-0.528*	1			
Alkalinity	-0.5184*	0.7844*	-0.6340*	-0.684*	-0.7259*	0.3308	-0.6667	1		
Nitrate	0.8408*	-0.6644*	0.9401*	0.8865*	0.6905*	-0.553*	0.6292*	-0.719*	1	
Phosphate	0.6523*	-0.5868*	0.6360*	0.4963	0.5658*	-0.647*	0.6628*	-0.678*	-0.559*	1

oxygen, while positive correlation with phosphate and nitrate.

Dissolved oxygen

The average values at the three sites of lake Bimtal were 7.2±0.93, 7.4±0.90 and 7.5±0.97 mg/l respectively (Fig. 6). Typically, the solubility of dissolved oxygen in natural surface waters ranges from 15 mg/L to 8 mg/L at 0°C to 25°C . The highest value of DO was found in the month of January and the values were 8.7, 8.5, 8.9 mg/L. The lowest DO was observed in the months of June and September with a lowest of 6.2 mg/l at station S_1. Basualto *et al.* (2006) also concluded the similar results in Lake Budi (IX Region, Chile). Dissolved oxygen level of the lake water is positively correlated with transparency at a significant level and significantly negative correlated with temperature, conductivity, turbidity, free CO_2, nitrate and phosphate levels (Table 1). A negative correlation between dissolved oxygen and phosphate was observed by Mansoor Ahmad *et al.* (2014).

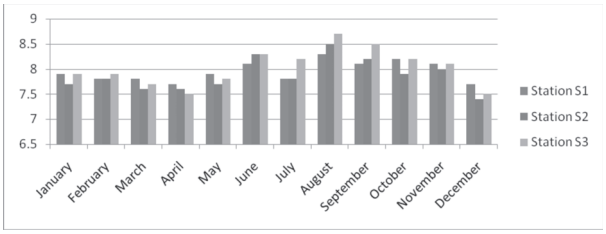

Fig. 6. Monthly variations of Dissolved Oxygen (mg l^{-1}) during the study period in Lake Bhimtal

Free CO_2

At Lake Bhimtal the highest value of free CO_2 was recorded in September, where the values at station S_1 , S_2 and S_3 were 18.7, 18 and 18.5 mg/l respectively . The free CO_2 was nil during most of the year (January-July) due to optimum temperature, high rates of photosynthesis and decomposition of organic matter.

The statistical analysis showed that there is positive significant correlation with temperature, turbidity, nitrate levels, phosphate levels (Joshi *et al.*, 2009) whereas dissolved oxygen (Lianthuamluaia *et al.*, 2013), total alkalinity and are significantly negative correlated.

Total Alkalinity

It is the quantative capacity of water which indicates the presence of strong and weak bases such as bicarbonates, carbonates and hydroxides in the water body (Karikari, 2013). The highest total alkalinity was recorded at site S_1, S_2 and S_3 as 95, 95 and 96 mg/L in the month of March and the lowest values were recorded in the month of September as 60, 70 and 75 mg/L at the three sites respectively (Fig.8). The average values of alkalinity at the station S_1, S_2 and S_3 were 84.41±9.89, 82.79±10.34 and 84.16±9.31 mg/L. The alkalinity of all water samples were in the range of 120 to 170 mg/L in various Lakes of Bangalore, Karnataka studied by Sinha *et al.* (2013).

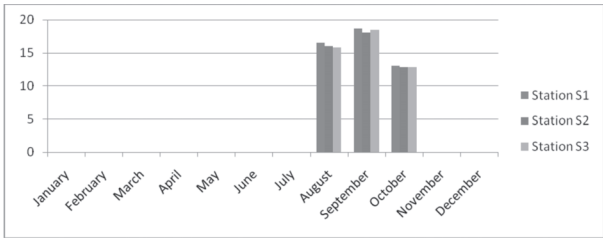

Fig. 7. Monthly variations of Free CO_2 (mg L^{-1}) during the study period in Lake Bhimtal

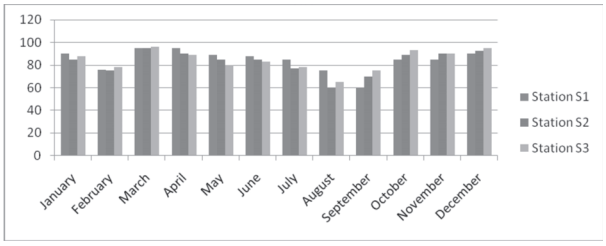

Fig. 8. Monthly variations of Total Alkalinity (mg L^{-1}) during the study period in Lake Bhimtal

Significantly positive correlation of total alkalinity is found with pH, transparency and significantly negative correlated with temperature, conductivity, turbidity, free CO_2, nitrate and phosphate levels (Table 1). Similar observations were found by Mansoor Ahmad *et al.* (2014).

Nitrate-Nitrogen

Nitrate nitrogen is an indicator of past pollution in the process if stabilisation. The highest value were observed in the monsoon season while lowest value in the post monsoon season in all the three stations The average values of nitrate concentration at site S1, S2 and S3 were 0.40 ±0.07, 0.38 ±0.07 and 0.38 ± 0.06 mg/L respectively. Medudhula *et al*., (2012) reported that in Manair reservoir situated in Andhra Pradesh, nitrate fluctuated between 0.02 to 0.03mg/

l. The present study shows decrease in the concentration of nitrate in post monsoon which may be due to utilization of nitrogen by phytoplankton and periphyton. The value was highest in monsoon probably due to the effect of huge amounts of drainage water discharged into Lake. The Nitrate content increase during monsoon was also noted by Salaskar and Yeragi (1997).

Nitrate was found to be significantly negatively correlated with temperature, pH, conductivity and turbidity. Nitrate was negatively correlated with pH and turbidity (Sharma and Chhipa, 2013). According to Verma and Verma (2014) nitrate has positive correlation with transparency and dissolved oxygen. During the study by Medudhula *et al.*, (2012) of Manair Reservoir situated in Andhra Pradesh, nitrate fluctuated between 0.02 to 0.03 mg/L.

Phosphate-phosphorus

Phosphorus is essential for the growth of organisms and generally limits the primary productivity in water. The values of phosphate-phosphorus was highest in the month of June and the values were 0.034, 0.036, 0.035 mg/L in the stations S_1, S_2 and S_3. The lowest values were reported in December and the values were 0.015, 0.012, 0.015 mg/L in the stations S_1, S_2 and S_3. Some what similar results were reported by Medudhula *et al.* (2012), in Manair reservoir situated in Andhra Pradesh and the phosphate concentration ranged from 0.015 to 0.0575 mg/L in different seasons.This finding is in agreement with those of Udaipur lakes as reported by Ranu (2001) and Chisty (2002).

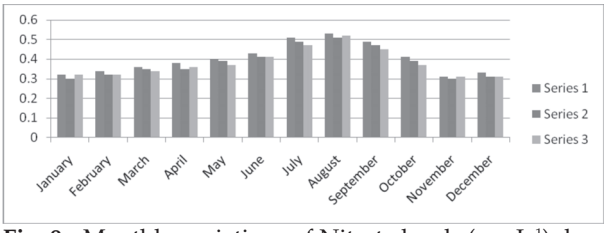

Fig. 9. Monthly variations of Nitrate levels (mg L^{-1}) during the study period in Lake Bhimtal

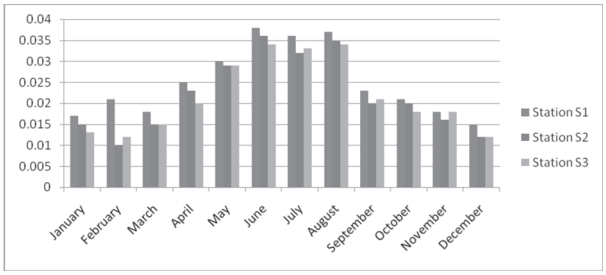

Fig 10. Monthly variations of Phosphate levels (mg L^{-1}) during the study period in Lake Bhimtal

A positive significant correlation of phosphate was found with water temperature, pH, conductivity, free CO_2 and turbidity whereas transparency, dissolved oxygen, total alkalinity, nitrate levels are negative correlated significantly. Verma and Verma (2014) in their study found a significant positive correlation of phosphate with water temperature and pH while dissolved oxygen and nitrate were negatively correlated.

Conclusion

On the basis of fair examination of physical and chemical parameters the lake can be categorised as mesotrophic. Mesotrophic lakes have been defined as having nutrient levels of 0.3-0.65 mg N l^{-1} and 0.01-0.03 mg P l^{-1}, (UK Biodiversity Steering Group, 1998) which matches with the findings of the present study. Mesotrophic lakes have been defined as having nutrient levels of 0.3-0.65 mg N l^{-1} and 0.01-0.03 mg P l^{-1}, (UK Biodiversity Steering Group, 1998) which matches with the findings of the present study.

The physico-chemical parameters at the three sites (S_1, S_2 and S_3) were not significantly different, except for nitrate and phosphate concentrations as these two parameters are generally influenced by the amount of allocthonous materials entering the lake. The higher concentration at site S_1 supports this fact. Excessive tourism load and anthropogenic disturbances can push the lake to eutrophic condition, hindering its uses in recreational, domestic and agricultural activities. Limnological analysis of water of Lake Bhimtal has indicated a continuous change in its trophic state, which correlates temporally with an increase in anthropogenic activities.

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