

## Study on bathymetric and sediment characteristics of Bhimtal Lake in Kumaun Region

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### Abstract

Bhimtal is a mesotrophic lake and the sediments acted as a sink or trap of nutrients in the bottom of lake. The water quality and volume of Bhimtal Lake has showed a degrading trend due to very rapid settlement, constructions and encroachment on lake catchment basin or hills by human habitation beyond its carrying capacity. The bathymetric mapping of the lake showed that the maximum depth of Bhimtal Lake was recorded only 20.9m on south-west from the middle island point. The sedimentation rate in three zones of Bhimtal Lake ranged from 0.27 to 1.05mm/year. The rates of sediments showed higher trend in the mallital zone compared with

central zone and tallital zone. The mallital zone has received high sedimentation load because of extensive road and house building construction activities on the slopes in catchment areas along with perimeter of Bhimtal Lake. The lake is also decreasing in water area, depth level, water quality and its biotic resources because of offsite and onsite impacts of soil sedimentation due to invasive land use pattern, degraded forest zones and changed agriculture pattern in lake catchment area.

### Introduction

The Nainital region is known as “West-moor land of Kumaun” contained several perennial and seasonal lakes. The Kumaun lakes are being used as a source of water for drinking, irrigation, pisciculture and recreation. Due to many anthropogenic activities or poor management and conservation practices, the inflow of eroded material and other contaminants from the catchment slopes has

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accelerated the sedimentation and siltation rate in lakes (Zutshi, 1985; Kumar *et al.*, 1999). Eutrophication process occur in lakes very fast because of many anthropogenic activities like changes in land use pattern, increased industrialization, urbanization and climatic variations, these are the main factors contributed significantly to effect the chemistry of lake water and sediments is a cumulative reflection of catchment geology, weathering and sediment erosion process as well as anthropogenic inputs. The spatial distribution of nutrients and organic loads accumulate in lake sediments reflect as degradation or decline in quality of lake water and aquatic ecosystems (Li *et al.*, 1995; Wang *et al.*, 2004). Sediment is carried into the lake by streams, rivers as well as its transformation depends upon hills slope, vegetation cover and geology of the lake catchment basin. Since many lakes are sinking of agricultural runoff, municipal and industrial waste water discharges, they become enriched with nutrients, sediments and associated heavy metals (Koussouris and Diapoulis, 1989; Skoulikidis *et al.* 1988). Due to drastic rise in developments in the lake surroundings and very low dispersion and high mobilization rates, the lake water quality decreasing throughout the world has become a direct threat to many life forms (Koussouris *et al.* 1987; Nag and Das, 1993; Sujatha *et al.* 2001). Many research scientists have been studied morphological, hydrological and sediment load with their accumulation pattern in different Himalayan and Kumaun lakes as Trisal (1987), Gopal and Zutshi (1998), Chakrapani (2002) and Das (2005).

Bhimtal Lake is situated in the lesser Himalaya region of Uttarakhand in Indian subcontinent. The water quality of Bhimtal lake has been showing degrading trend due to fast changing land use pattern in its catchment basin since two decades after developing Uttarakhand as a new state. The lake is receiving high sedimentation and nutrient load from its catchment basin resulted reduction lake water volume and started eutrophication processes. Therefore, preliminary studies were made to estimate the bathymetric position, deposition of inorganic or organic load from municipal sewage and sedimentation in different zones of Bhimtal Lake at Kumaun region.

### Materials and Method

Bhimtal Lake is situated between 29°21' N latitude and 79°24' E longitude at 1332 m above of sea level in the Kumaun region. Bhimtal Lake is the largest lake among all Kumaun lakes having approximately 85.26 ha area and located at a distance of 22 km from Nainital. An island used as a fish aquarium towards the outlet, gives it a distinction among all the Kumaun lakes. The lake serves as a vital source of drinking water supply for the population of Bhimtal town and provide water supply for agricultural practices towards Naukuchiatal lower areas. The Bhimtal lake is divided into three zones as per its physiogeographical position. The north-east part of the lake is known as mallital zone, while the south-west part is termed as tallital and central zone is middle part, consisting an island and sluice gate as outlet of lake. The inlet of the lake is in the form a small channel the jhingari Nullah emptying at mallital.

The Morphometric analysis of Bhimtal lake was analysed by GPS (GARMIN GPSMAP model no. 76CSx) for analyzing the altitude and longitude of different sampling points and bathymetric parameters were determined by various ground truth surveys and by using various types of gauges like rod, tape, wire or point gauge for measuring the distance to the water surface and depth with the help of moving boat. The Meteorological data were measured on spot during sampling period and compared with directorate of cold water fisheries, Bhimtal.

The sediment samples were collected from bottom surface of different sampling points at Bhimtal lake by using Eckmans dredge samplers and put into wide mouthed plastic containers. The present study was conducted during the period 2012 to 2013. The sediment samples were collected on monthly basis from different depth of bottom sediments. The organic matter of the sediment samples were measured by igniting the samples at 550 and 950°C, respectively in a muffle furnace (Rippey *et al.* 1982; Kaiserli *et al.* 2002).

## Result and Discussion

Bhimtal is situated at a comparatively lower altitude than Nainital. The pattern of seasons in and around Bhimtal Lake showed quite similar trends and fluctuated as in Nainital region. The minimum water temperature was observed in winters 10.36°C and maximum water temperature observed in summer season was 24.52°C. The air temperature showed an increasing trend from the month March to June reaching to the maximum 31.42°C and the lowest air temperature in December 11.13°C.

The lowest relative humidity was observed 10% and highest 99%. The annual rainfall was recorded 1378.2 mm in 2012-2013. The Climatically, Bhimtal lake is subtropical and warm monomictic lake. The shoe shaped lake has a catchment area 11.70km<sup>2</sup>. It is 1915.5m long and 486.5m wide and has a maximum depth of 20.9m. The climate of Bhimtal and its surrounding areas is relatively warmer. Rainfall increased then the previous year. Such erratic rainfall adversely affected the water quality of lake, while the wettest months of the year were recorded as June, July and August (Table 1 & 2).

Parameters	Observations
Altitude (m)	1332
Longitude	79°34'E
Latitude	29°21'N
Length(m)	1915.5
Width(m)	486.5
Mean Depth(m)	17.9
Surface area (ha)	85.26
Catchment area (Km <sup>2</sup> )	11.70
Shoreline (m)	4025
Volume of water (m <sup>3</sup> )	4064.9

**Table 1:** Morphometric characteristics of Bhimtal Lake

Parameters	Observations
Annual Rainfall(mm)	1378.2
Max. air temperature(°C)	31.42°C
Min. air temperature(°C)	11.13°C
Max. Water temperature (°C)	27.52°C
Min. Water temperature (°C)	10.36°C
Min Relative humidity (%)	10
Max. Relative humidity (%)	99

**Table 2:** Meteorological characteristics of Bhimtal Lake

The bathymetric maps were prepared on the basis of depth contour of Bhimtal Lake. Depth wise distribution of Lake Basin area and percentage of this area are given in Table 3.

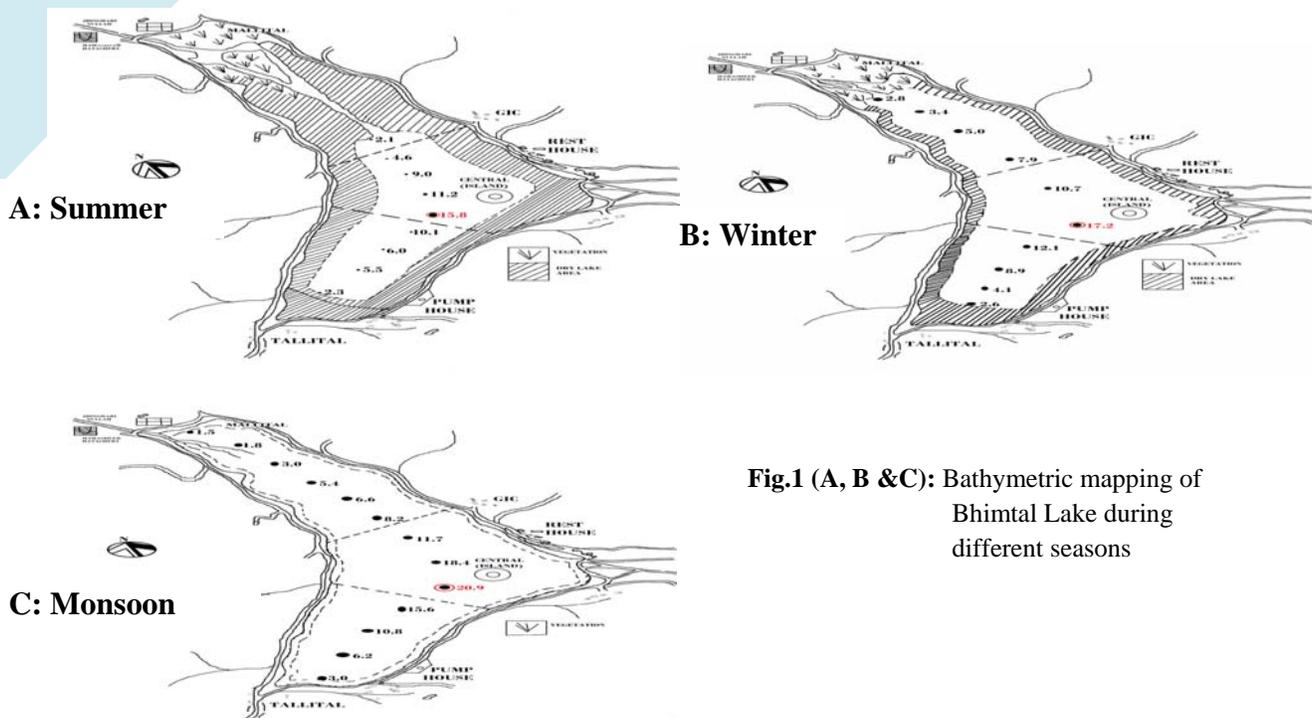
Depth(m)	Lake Basin Area (ha)					
	Summer		Winter		Monsoon	
	Area	%	Area	%	Area	%
0-2.5	1.6	1.87	3.2	3.75	5.90	6.92
2.6-5.0	5.6	6.57	6.8	7.97	8.20	9.62
5.1-7.5	8.29	9.72	11.5	13.49	12.50	14.66
7.6-10.0	10.35	12.14	13.0	15.25	14.10	16.54
10.1-12.5	14.90	17.47	14.8	17.36	18.40	21.58
12.6-15.0	8.50	9.97	12.1	14.19	14.60	17.12
15.1-17.5	2.30	2.69	6.0	7.04	18.50	21.70
17.6-20.0	-	-	-	-	7.20	8.44
Island	0.91	1.07	0.91	1.07	0.91	1.07
Swamp	10.2	11.96	4.85	5.69	-	-
Dry land area	22.4	26.27	11.84	13.89	-	-

**Table 3:** Percentage of Lake Basin area in relation of depth level of Bhimtal Lake

Bhimtal Lake showed the maximum depth 20.9m was observed in monsoon season was marked on middle line drawn between central and tallital zone. During summer season the major part of mallital zone got dried due to siltation and sandy soil and in central zone depth showed a declined trend by the maximum lake water drained out through the outlet for agricultural purposes and maximum depth was recorded 15.83m in summer. In winter season the maximum depth was recorded 17.2m. The average depth of central zone remained between 15.8m to 17.2m while the maximum depth 20m was towards the south west part. A ratio between mean depth and maximum depth made the basin a trough shaped towards tallital and saucer shaped towards mallital. The 35.84% of total lake basin was found converted in to swamps or a wetland from March to May. There was evidence to show that the depth of Bhimtal lake reduced due to rock silt erosion from surrounding hills terrain and other catchment areas during the rainy season. There was sufficient siltation at the bottom especially during monsoon season. The islands, swamp

and dry land part in and around the lake has a total area about 20.0% of the total basin area of the lake (**Table 3 and Fig. 1, 2 & 3**).

Bhimtal lake receives lot of inorganic and organic pollutants from different sources like construction activities, tourism development and domestic discharge etc. However, the indiscriminate construction activities e.g. industrial units, hotels & resorts and residential flats & houses occurred mainly in mallital industrial areas, tallital areas and other hilly terrains of catchment basin of Bhimtal lake. Geologically, Bhimtal is comprised of metabasites associated with shallow water quartzites, grits, conglomerates, phyllites and rocks of zeolite and greenschist facies. Sediments results from weathering of rocks in the catchment area. Much of the variation resulting from weathering may be expressed in the system  $Al_2O_3-CaO-Na_2O-K_2O$ , where CaO represents calcium in the silicate fraction only. Silica ( $SiO_2$ ) is the dominant oxide in the lake. In Nainital lake,  $SiO_2$  is less (42%) compared with Bhimtal lake (51.2%). The origin of lake and their geological characteristics described in details by Chakrapani (2002).



**Fig.1 (A, B &C):** Bathymetric mapping of Bhimtal Lake during different seasons



**Fig.2:** Maximum water drained out for agricultural activities in summer season



**Fig.3:** Sedimentation and vegetation on Mallital zone of lake during summer season.

The organic content is determined in the sediment cores to understand the contribution of organic matter in the lake through the municipal waste and other anthropogenic activities. The high rate of sediments and organic matter were determined in mallital zone. The sedimentation rate varied between 0.68-1.05mm and organic matter 6.7-10.4% in summer season, because major part of the township is situated on mallital zone and the human population of the town ship showed an increasing trend due to industrialization at mallital valley (**Table 4**). The many anthropogenic factors were created as high demand on lake water for house hold activities and industrial purposes. A jhingari drain was carried municipal wastes, sewage and other liquid waste waters and drained as an inlet in mallital zone of Bhimtal lake. In central zone of lake, sediments rates varied between 0.36-0.49mm and organic matter 5.4%-8.7%. The

tallital zone have less sediments and organic matters in comparison of other two zones as the sediment was recorded in this zone is 0.27-0.31mm and organic matter 3.4%-4.9%. The spatial distribution of sediment in a lake depend on the water inflow velocity, gravitational forces, depth, bottom topography, vegetation cover of catchment basin. The sediment comprises silty material with practically less amount of humus in tallital zone. The sedimentation rate and organic matter in Bhimtal lake is less than Nainital lake. The rate of sedimentation has been recorded in decreasing order from the near shore to the far shore in Nainital lake (Kumar *et al.*, 1999). The process of sedimentation and its deposition rate in different lakes of Himalayan region were described by Kusumagar *et al.* (1989) Das *et al.* (1994) and Rai *et al.* (2007).

Lake zone	Sedimentation rate (mm year <sup>-1</sup> )	Organic matter (%)
Mallital zone	0.68-1.05	6.7-10.4
Central zone	0.36-0.49	5.4-8.7
Tallital zone	0.27-0.31	3.4-4.9

**Table 4:** Sedimentation rate in Bhimtal lake water

The major oxides chemistry delineates the lithology of the catchment area as observed, indicating short distance transport and poor mixing of the detritus. Bhimtal have low percentage of organic matter in comparison of Nainital. Bhimtal is a mesotrophic lake and the sediments acted as a sink or trap of nutrients for the most part of the year. Various remedial

measures proposed for the conservation of lake includes intensive afforestation programme should be implemented on the eroded hill terrains of the catchment area, commercial urbanization activities like flats, cottages should be restricted on hilly terrains, Eco friendly industrial units should be promoted, municipal or domestic waste water & sewage

should be treated by bioremediation technology before drain into lake and other anthropogenic activities in catchment basin of lake should be monitored continuously to restoration of lake ecosystem. All these preventive measures would be contributed significantly to reduce the sedimentation and siltation load in the lake and water quality of lake will be hygienic, pathogen free for drinking purpose by inhabitants of Bhimtal area.

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