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Comparative water quality assessment of Central Himalayan Lake: Nainital

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Abstract
The Nainital Lake, situated in the central Himalayas of India, is an important water body and a major tourist spot. This study aims to identify factors or processes that determine the water quality of the lake. For this purpose, different data of different years were compared with the data of present study. In order to assess the state of the lake's water quality, the samples were compared with the standard water quality values. Turbidity, electrical conductivity, total alkalinity, and heavy metal (lead, iron, and copper) concentration were found to be above the desirable limit of the prescribed national and international standards in all four seasons at both Mallital and Tallital. Reasons affecting the water quality were found to be natural (thermal stratification and lead-bearing rocks) and anthropogenic (domestic sewage, runoff, and illegal construction activities in the vicinity of lake). Various lake restoration alternatives/interventions have been suggested that can lead to an improvement in the lake's water quality, such as afforestation and phytoremediation.

Keywords: water quality assessment, Nainital Lake

Introduction
Lake and their surroundings are unique assets and valuable ecosystems of society and nature; these are of social, cultural and aesthetic value (Kumar *et al*., 2008) [7]. Lakes in mountainous terrain are considered an extreme environment because they are small and sensitive ecosystems with rapid flushing rates (Vreca and Muri, 2006) [21]. Nainital city is one of the major tourist attractions in the northern part of India. The lake provides water to 40,000 local inhabitants (Purushothaman, *et al*., 2012) [13] and thousands of tourists visiting it every year (Gupta *et al*., 2012) who use the water for different purposes like drinking and for recreational activities (Misra *et al*., 1993, Porohit and Singh, 1981) [8, 11]. Increasing local population, logarithmic increase in the tourist flux in Nainital, and the concomitant mushrooming of a large number of hotels in the catchment area have severely affected the water resources and biodiversity of this watershed (Jain *et al*., 2007, Shah *et al*., 2009) [4, 15]. According to Singh *et al*. 2002, open sewers disposing large quantities of sewage in the lake are definitely causing a detrimental effect on the lake water quality. Other anthropogenic activities such as illegal construction, litter, domestic discharge, and recreational use of lake water are major concerns for sedimentation and eutrophication of the lake water (Purushothaman, *et al*., 2012) [13].
Nainital Lake has been extensively studied over several decades for structure and tectonic (Valdiya 1980, 1988) [19, 20], sediment accumulation (Das *et al*. 1994) [2], water balance (Kumar *et al*. 1999), paleoclimatic conditions (Kotila *et al*. 2000) [5], water sediment chemistry (Chakrapani 2002) [1], eutrophication (Pant *et al*. 1980) [10], phytoplankton community (Sharma *et al*. 1982), water pollution (Pant *et al*. 1981) [9], benthic micro-invertebrates (Gupta and Pant 1990) [3], inshore macro-zoobenthic community (Gupta and Pant 1986) and morphology and morphometry (Rawat 1987). However, a comprehensive study on the water quality after bank filtration has been lacking. Therefore, a study was undertaken with an objective of evaluating bank filtration as a treatment step for drinking water production.

Material and Methods

Study area

Nainital is located at 29.38°N 79.45°E near the Main Boundary Thrust (MBT) that separates the Siwaliks from the lesser Himalaya. The slopes of the nearby mountains are most populated, with an elevation ranging from 1,940–2,100 m (6,360–6,890 ft) and encompassing hills (7 in numbers) rise from 2139 to 2619m above the sea level. The highest point nearby is Naina Peak or China Peak, with an elevation of 2,619 m (8,593 ft). in summers the temperature of Nainital reaches 27 °C (81 °F); and in winters the minimum temperature of Nainital reaches −3 °C (27 °F). The basic pattern of climate is governed by the monsoon. The summer precipitation (June end to September end) brought by the monsoon accounts for 75% to 80% of the annual rainfall, which generally ranges between 200cm and 250cm. The Nainital Hill forms a synclinorium, which is cut diagonally into two parts by a fault called the Naini Fault. The catchment area is surrounded by the lithology of the Krol Formation (Precambrian) consisting mainly of carbonate rocks, such as limestone, dolomite, gypsum, calcareous slates, ferruginous shales, greywackes, etc. (Chakrapani 2002) [1]. The north-western part is made exclusively of argillaceous limestone and marlites, whereas the south-western part comprises dolomite with limestone and black carbonaceous slates (Valdiya 1988) [20]. It is believed that the subrecent rotational movements were responsible for the blockade of the Balia River, in its upper reaches, resulting in the formation of Lake Naini. The drainage pattern of the lake catchment is controlled by both geology and structure with the very few streams in the western part and the several parallel to sub parallel streams in the east following the faults and joints (Valdiya 1988) [20]. The flora grown in the region are *Quercusleucotrichophora, Aesculusindica, Juglansregia, Populusciliata, Fraxinusmiscrantha, Platanusorientalis, Rubuslasiocarpus, Rhododendron arboreum, Cedrusdeodara, Salix acmophylla* and *Pinusroxburghii*. The fauna includes *Presbytisschistaceous, Invus rhesus, Urssustibetans, Martesflavigula, Hysrixleucura, SusIndicus.*

Methodology adopted

The review of various research papers, thesis and articles based on Nanital lake were reviewed from Kumaun University, in Google search engine articles were searched with the board point as Nainital lake and water quality of the lake, some other points that were searched on Google were water quality and pollution impact on lake water. The data for the present study was generated from secondary sources which are related to development works of the lake. Major secondary data was collected from LDA (Lake Development Authority), PWD (Public Work Department) and Nagar Palika, Nainital. The recharge areas of the lake and their current status are presented in table 1.

Table 1: Recharge areas of Nainital Lake in 1936 & their current status

S.No.	Recharge area	Total area ($m^{2)}$	Current Status
1	Sukhatal	33369	reduced to 25%
2	Oak Park	13220	reduced to 35%
3	Sleepy Hollow	10872	reduced to 35%
4	Near Dalhausi villa	4597	reduced to15%
5	Sherwood	4790	reduced to 50%

(**Source:** Shah, *et al*., 2009)

Result and discussion

The different physicochemical parameters of the lake water are discussed below and compared with WHO/BIS/ICMR standards, and the results of the study were also compared with results taken over the period of time from 2004 to 2011 presented in table 2. The lake water appears to be alkaline in nature in present study and in other samples that were taken from 2003, except in 2008-09 where the nature of water is slightly neutral in nature, Purohit and Singh 1985 [12] too reported high pH in the lake in their study. Increase in photosynthetic activity of submerged and suspended algal population in aquatic ecosystem may be the reason for this increase in pH value (Sharma 2014) [16]. Total alkalinity recorded in the Nainital Lake water ranges between 206mg/L in 2003-04 to 299mg/L in 2006-07. The maximum concentration of alkalinity is recorded during rainy years. During wet season, surface runoff brings organic matter and, with decomposition of this organic matter, carbon dioxide is released resulting in the addition of carbonate and bicar bonate, which also increases the alkalinity value. Dissolved oxygen (DO) is the indication of general health of a water body. D O recorded in the water of the Nainital Lakeranges between 4.08 mg/L in 2005 -06 and 10.08 in 2008-09 mg/L. Higher amount of DO can be explained by the fact the during active photosynthesis more oxygen gets dissolved in the lake (Singhal *et al*., 1986, Sreenivasan *et al*., 1997) [17]. Biochemical oxygen demand (BOD) is a key parameter and it indicates the organic load in aquatic ecosystem. BOD value in the Nainital Lake ranges between 21 mg/L to 6.8 mg/L. Presence of clay, silt, organic matter, phytoplankton, and other microscopic organisms causes turbidity in lake water. Presence of high turbidity indicates the presence of large a mount of suspended solids. Turbidity in Nainital Lake was recorded in ranges between 6NTU to 10.3NTU.

This high turbidity can be attributed to particulate addition through surface runoff from the surrounding hills. Also, an increase in population and cultural activities leading tomassive deforestation and waste generation in the catchment of Nainital Lake in turn leading to an increased concentration of suspended solids can also affect the turbidity in the Nainital Lake. The mean turbidity values obtained for Nainital Lake were in conformance with the values as reported in literature (Purohit and Singh, 1985) [12]. Total hardness recorded in the water of Nainital Lake for present investigation ranges between 292mg/L to 377mg/L respectively. High temperature, evaporation of water, weathering of rocks, and addition of calcium and magnesium salts by means of plants and living organism were found to be contributing factors for the hardness of the lake water.

The water quality studies carried out by the National Institute of Hydrology during 1999–2001 on physico-chemical parameters (pH, temperature profile, Secchi's transparency, dissolved, BOD, COD and nutrients), biological profile (density of population, biomass and species diversity of phyto, zooplankton and macrobenthos) and bacteriological characteristics have led to the conclusion that long-term limnological changes have occurred in the lake. Excess of nutrients inflow have contributed to the eutrophic conditions and the internal recycling of nutrients from sediments during water circulation has resulted in luxurious growth of phytoplankton. The lake is thus anoxic and has reduced dhypolimnion, winter circulation, large phytoplankton and relatively lower animal population.

Table 2: Water quality of Nainital Lakes as reflected by physico-chemical parameters of water during 2003-04 to 2010-11 and present study

Parameter	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	Present study	Normal Desirable value
pH	8.1	8.1	8.4	8.2	8.27	7.13	8.25	8.0	8.5	6.5-8.5
Transparency (m)	1.19	1.22	1.21	1.16	2.70	2.3	1.9	1.72	1.9	>5
Turbidity (NTU)	10.3	7.0	6.0	6.2	7.91	6.4	9.5	8.25	7.6	5
Alkalinity (mg/l)	206	262	276	299	245			232	278	<200
Hardness (mg/l)	292	342	377	361	310				321	<300
Salinity (ppm)	0.26	0.269	0.26							<0.5
DO (mg/l)	4.63	4.517	4.08	5.46	7.8	10.08	9.00	8.55	8.06	5-12 (Surface W)
BOD (mg/l)	21	18.03	15.2	12.3	10.3	8.36	8>	6.8	7.7	<6
NO3-N (mg/l)	0.27	0.267	0.48	0.51	0.7	0.37	0.85	0.55	0.34	<0.30 Total of all the three forms of N
NH4-N (mg/l)	1.2	2.109	0.83	0.64	1.2					-
NO2-N (mg/l)	0.09	0.059	0.068	0.031	0.29				0.0788	<10
PO4-P (mg/l)	0.97	0.116	0.132	0.138	0.290	0.27	0.35	0.30	0.0348	<0.3

*Source: LDA Nainital

Conclusion

Sewage treatments: The household water should be treated properly so that they become environmentally safe and with effective sewage treatment.

Afforestration: That will help in control of erosion in to the lake thus controlling the turbidity of the lake.

Phytoremediation: Growing common aquatic plants like bulrush, water hyacinth, duckweed, *hydrilla*, and lotus in the catchment area and inside the Nainital Lake will help in the removal of heavy metals from the surface runoff and lake water.

Routine cleaning: Lakes and wells meant for human use should be routinely cleaned and treated, so that it remains fit for human use.

Public Awareness: Common public should be aware about the effect of water pollution.

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