RESEARCH ARTICLE

PHYSICO-CHEMICAL CHARACTERISTICS OF FIVE HIMALAYAN LAKES FROM KUMAUN REGION IN UTTARAKHAND, INDIA.

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Manuscript Info	*Abstract*
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The present study was undertaken to assess the physico-chemical parameters of five Himalayan lakes from Kumaun region of Uttarakhand state of India. The study becomes important as all these lakes are natural and located on the high altitude in Nainital District (29.38°N 79.45°E). The water samples collected from different lakes were analyzed for its physico-chemical parameters. Study concluded that the overall temperature of lakes under study varies from (22 to 25°C), pH (7.7 to 8.8), DO (7.2 to 7.9 mg/l), COD (30 to 100 mg/l), BOD (18 to 40 mg/l), alkalinity (60 to 224 mg/l), total hardness (60 to 300 mg/l), Ca (12 to 52 mg/l), Mg (7.2 to 40 mg/l), chloride (8.5 to 17.0 mg/l), phosphate (0.1 to 0 mg/l) and sodium (2.2 to 10.3 mg/l). The variation in these parameters indicates that the lakes with high human activities in the catchment are affecting the surface runoff to the lake. Now it has become a challenge, to preserve these natural sources, and same time look for the immediate sustainable options for the growing population, as these lakes have been moderately polluted due to increasing human interference.

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Introduction:-

Lake and their surrounding are unique assets and valuable ecosystems of society and nature, these are of social, cultural, and aesthetic value (Kumar et al., 2008). Lakes in mountainous terrain are considered an extreme environment because they are small and sensitive ecosystems with rapid flushing rates (Vreca and Muri, 2006). In Uttarakhand, Kumaon Himalayan lakes occupy a significant position, and are major tourist attraction owing to their geographical situation, evolve an integral component of the natural beauty and have been investigated for various physicochemical parameters by several authors in the recent past (Das and Upadhyaya, 1979; Sharma and Pant, 1984; Patiani and Das, 1979; Kara et al., 2004). The hills which have always been a source of inspiration for sages, philosophers, writers, scientists and many others for generations, unfortunately are witnessing a deterioration of valuable water potential mainly due to human activities. The Nainital district lakes normally fall in Lesser Himalaya zone (Fig 1), mainly comprised of few renowned lakes such as Nainital, Bhimtal Naukuchiatal, Sattal and Khurpatal which are also popular tourist destinations. The catchment area around them has been rapidly urbanized in recent years and as a result, various environmental problems have been reported. Deterioration of sediment and water quality in the lake is said to be related to domestic sewage and untreated wastewater from nearby hotels, which has led to eutrophication, fish kill, persistent anoxia and heavy metal pollution (Das, 2005;

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Choudhary, 2008., Choudhary et al., 2009). According to Singh et al., (2002) open sewers disposing large quantities of sewage in the lakes are causing a detrimental effect on the lake water quality. Also 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). Hence there is need for determination of various physical, chemical parameters of lake waters, in order to evaluate water quality for controlling the pollution. By such effort we can promote better living condition around the reservoirs to save it from eutrophication. In effort to conserve these resources present study was conducted on five lakes of Kumaun Himalaya for the assessment of physicochemical analysis.

Study Area:-

Hilly region of Nainital district houses numerous lakes of big and small sizes. Some of the large lakes of the districts are, Nainital, Bhimtal, Naukuchiatal, Sattal, Khurpatal, Lokhamtal, Harishtal and Malwatal. This study is carried out on five major popular lakes Nainital, Bhimtal, Naukuchiatal Sattal, and Khurpatal. District Nainital is located approximately between 80º 14' and 78º 80' East longitude and 29º 00' and 29º 05' North latitude. Geography of Nainital district encompasses both towering mountains as well as plains. Two geographical zones divide the district namely Hilly and Bhabar. All lakes are small to medium in size with the Bhimtal lake as the largest one, covering 72 ha area. Lake Naukuchiatal is the deepest, with a maximum of 40.8 m depth. All these lakes of Kumaun are at short distance from each other with a diversity of lithology and population in their catchment areas. Few of the lakes are fed by streams, and most of them are land locked. The lake region of Bhimtal, Naukuchiatal and Sattal are unique for its biodiversity since it falls in the blend zone of Paleastic and Indo-Malayan zoo-geography. It was also reported that all these are fresh water, tectonic lakes formed during the Holocene period (Valdiya, 1988). The location map of different lakes which belongs to Nainital Districts used in the present study are shown in Fig.1.
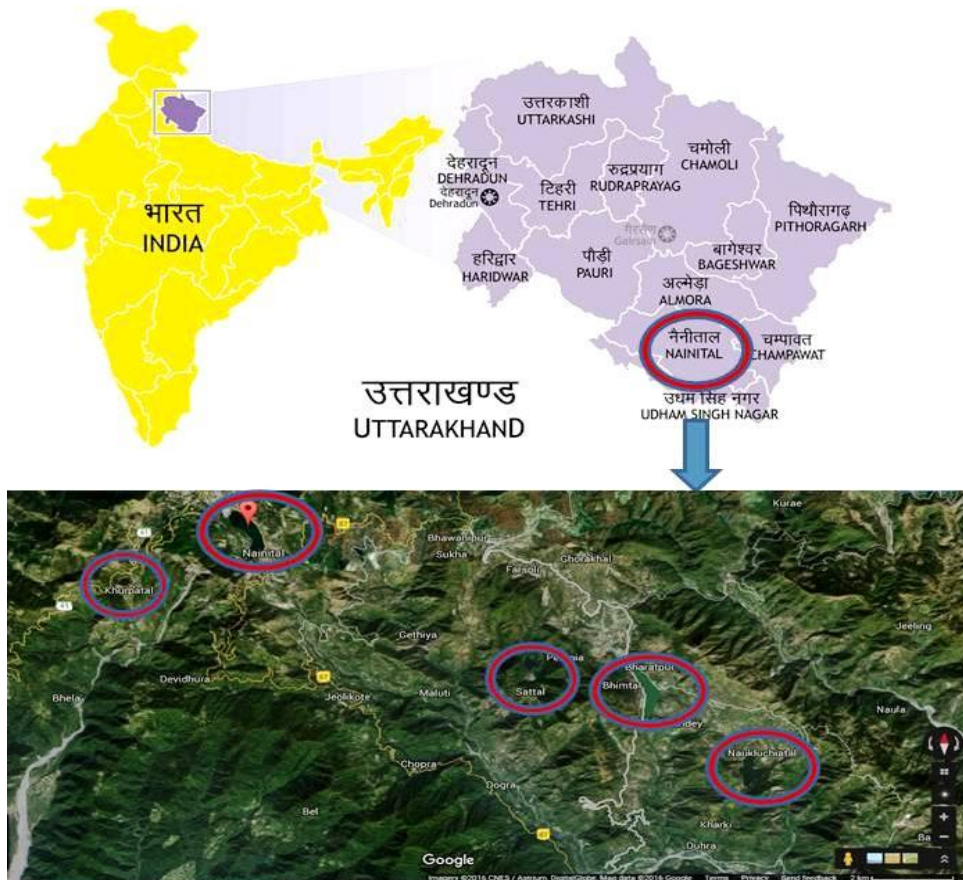

Fig 1:- Location map of different lakes belongs to Nainital Districts used in the present study

Material and Methods:-

The water samples were collected from five selected lakes i.e. (a) Naukuchiatal, (b) Bhimtal, (c) Sattal, (d) Nainital and (e) Khurpatal (as shown in Fig. 2). The water samples were collected randomly from five different locations for each lake in 1 litre of polyethylene sterilized bottles. These samples were stored in an insulated ice-cooled container and delivered to the laboratory on the same day. The samples collected from five different points, were mixed together to prepare an integrated samples per lake. The physiochemical parameters of the collected samples were carried out simultaneously.

Fig 2:- Lake photos from where sampling was performed for the present study.
(a) Naukuchiatal (b) Bhimtal (c) Sattal (d) Nainital and (e) Khurpatal

The physical and chemical parameters for all the samples were analyzed in the season of monsoon (i.e. July-August). The physiochemical parameters including temperature, pH, electrical conductivity, turbidity, total dissolved solid, total alkalinity, total hardness, calcium, magnesium, dissolved oxygen, biochemical oxygen demand, chloride, sodium, nitrate and phosphate, were analyzed. We adopted standard guidelines of water sampling and physico-chemical parameters evaluation (APHA, 2005).

Result and Discussion:-

A comparative study of the lakes (Tables 1 and Fig. 3) reveals that the physico-chemical characteristics of these lakes vary from each other due to their ecological variations and primarily due to different lithology in the individual catchments and magnitude of anthropogenic inputs. Various water quality parameters of lakes have been discussed below.

Temperature:- The temperature plays an important role for controlling the physico-chemical and biological parameters of water and considered as one among the most important factors in the aquatic environment particularly for freshwater (Singh and Mathur, 2005). The highest lake temperature in summer was recorded was around 27°C which is due to high solar radiation, low water level, clear atmosphere and high atmosphere temperature (Dagaonkar and Saksena, 1992). The lowest temperature was reported during winter season was around 09°C due to cold low ambient temperature and shorter photoperiod (Bohra and Bhargava, 1977). In our study the on-spot recorded temperatures of lakes varies from (22 to 25°C), which was in harmonization to the earlier reported temperature.

pH:- pH is a term used universally to express the intensity of acid or alkaline condition of a solution. The pH values of water samples of five lakes varied between 7.7 to 8.8 as shown in the Table 1. Maximum pH was recorded in Bhimtal Lake whereas minimum was observed in Naukuchiyatal Lake. Water of all the five lakes, is more or less alkaline in nature (pH was always above 7). The higher pH of Bhimtal, Naukuchiyatal and Sattal Lakes indicates higher photosynthesis, making water under saturated in CO_2 due to the assimilation of CO_2 which is faster than its replenishment from the atmosphere, Das (2005). High pH (8.8) of lake water is also associated with the high decomposition activities of biotic and abiotic factors (Chaudhary et al., 2004).

Total Hardness (TH):- Calcium and magnesium, the two most dominant cations play a major role in determining the hardness of the water. Hardness of water sample (Table 1) showed values in the range of 60 to 300mg/lit. TH values cross the WHO limit of 100 mg/l (or ppm) in Nainital and Naukuchiatal Lake. Sharma (2014) also found that 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 these lake water. Regular addition of large quantities of sewage and detergent into lakes from the nearby hotels and residential localities also contribute to the hardness of water. Water with less than 75 mg/l (or ppm) of $CaCO_3$ is considered soft and above 75 mg/l (or ppm) of CaCO3 as hard (Bohra and Bhargava 1977). It may affect the potability of water and indicating that water of these two lakes is fairly hard. However, it may not be harmful from human/ animals health point of view.

Total dissolved Solid (TDS):- In natural water bodies, dissolved solids consist of inorganic salts, small amount of organic matter and dissolved materials. In present study maximum TDS of 400 mg/lit was recorded of Nainital lake, and minimum TDS of 175mg/lit was recorded of lake Khurpatal. Nainital being the busiest tourist destination with increased human interference lead   to the addition of sewage waste and surface runoff from the surrounding region. Also the contamination of domestic waste water, garbage etc in the natural surface water body increases the amount of TDS. It is an important parameter in drinking water quality standard and it may cause gastro intestinal irritation with more than 500mg/l. Whereas, Khurpatal is lesser explored lake with less human interference is clearly indicative of lesser TDS values. Results of increased TDS show conformance with the previous study by Sharma (2014).

Total Suspended Solids (TSS):- Most suspended solids are made up of inorganic materials. Suspended solids which contain much organic matter may cause decomposition and consequently the water body may be devoid of dissolved oxygen. In general the TSS is used to evaluate the strength of domestic waste waters and efficiency of treatment units. A high TSS value of Bhimtal Lake is attributed to low treatment facilities, which is better employed at Nainital lake.

Alkalinity:- The   highest amount of alkalinity in present study can be seen in Nainital Lake (224 mg/l), followed by Naukuchiatal lake. This can be due to the addition of large amount of sewage waste and organic pollutant to the lake, which may in turn influence photosynthesis process in lake, and result in death of lake Flora and Fauna. Total alkalinity is due to salts of weak acids and bicarbonates (Mahadev et al., 2010). The degradation of plants, living organism and organic waste might also be one of the reasons for increase in a carbonate and bicarbonate, resulting an increase in alkalinity value (Verma et al., 2011).

Dissolved oxygen (DO):- Dissolved oxygen is one of the important parameter in water quality assessment. It reflects the biological and physical process prevailing in the water. Its presence is essential to maintain the higher form of biological life in the water body. Water without adequate DO may be considered waste water. Various biodegradable pollutants from domestic and industrial sources stimulate the growth of microorganisms, which consume the DO of the water. The main source of dissolved oxygen in water are diffusion of oxygen from air which mainly depend on temperature, salinity, total dissolved salt and water movements (Bohra and Bhargava, 1977). In

the present study, although not much difference in DO was measured but Nainital lake was found to have the highest DO of 7.9 mg/l, closely followed by identical value (7.8 mg/l) in Khurpatal and Naukuchiatal Lakes respectively. It was also reported earlier that DO value is related to anthropogenic activity, which is least in Sattal and highest in Nainital (Das et al., 1995).

Chemical Oxygen Demand (COD):- COD is a measure of the oxygen required for the oxidation of all the substance present in water, included those are not biologically decomposable. COD is a reliable parameter for judging the extent of pollution in water. The COD of water increases with increasing concentration of organic matter. And in the present study Nainital lake was found to have almost double COD as compared to other lakes (Fig. 1).

Biochemical Oxygen Demand (BOD):- High value of BOD in each layer indicated the magnitude of pollution in lake. The higher value of BOD in Sattal lake followed by Naukuchiyatal lake might be due to input of organic wastes and enhanced bacterial activity in lakes. The reason of high BOD might also be due to presence of several microbes in water bodies.

Ca and Mg:- Sirsath et al., (2006) reported that calcium and magnesium are the principal cation that imparts hardness. Calcium is an important nutrient for aquatic, organism. The amount of calcium in lakes ranges between 12-52 mg/lit. The minimum amount of Calcium was recorded in lake Sattal, and maximum calcium was recorded in lake Nainital. Above study also shows that Nainital lake water is most hard in nature. The desirable value of calcium as per BIS (1991) is 75ppm, which shows that water of Nainital lake is within a desirable limit. Likewise, Venkatasubramani and Meenambal, (2007) reported that magnesium is often associated with calcium in all kinds of waters, but its concentration remains generally lower than the calcium. Magnesium was found in the range of 7.2-40.8 mg/lit highest was found in lake Nainital and lowest was found in lake Sattal. Magnesium is essential for chlorophyll growth and act as a limiting factor for the growth of phytoplankton (Swarnalatha and Narasingrao, 1998).

Cl:- Chloride (Cl⁻) concentration is the most useful parameter for evaluating atmospheric input to the lakes. Chloride ions are essential for plants and animals. They are stored in plants and animal bodies as sodium chloride (NaCl). The highest amount of chloride recorded was 17.0mg/l of Nainital lake followed by next most popular lake Bhimtal (11.3mg/l). The probable reason for the presence of Chloride can be the water runoff from households and hotels which was disinfected to serve for drinking purpose in these tourist places.

Silicates & Phosphate:- Nutrients such as phosphate, nitrate, and ammonium support luxuriant phytoplankton and algal growth (Sharma et al., 1982; Ali et al., 1999). Silicates and Phosphates concentration were found to be highest in Nainital Lake. The high PO_4^{3-} contents in Nainital Lake and the increasing trend with time, together with enhancement of other nutrients (NH_3^-N) and (NO_2^-N) have led to the eutrophic condition of this lake, Das (2005). Previous studies also suggest that recent fish kills are a consequence of long-term anoxia and presence of toxic pollutants in the lake (Ali et al., 1999; Singh et al., 2001; Nagdali and Gupta 2002).
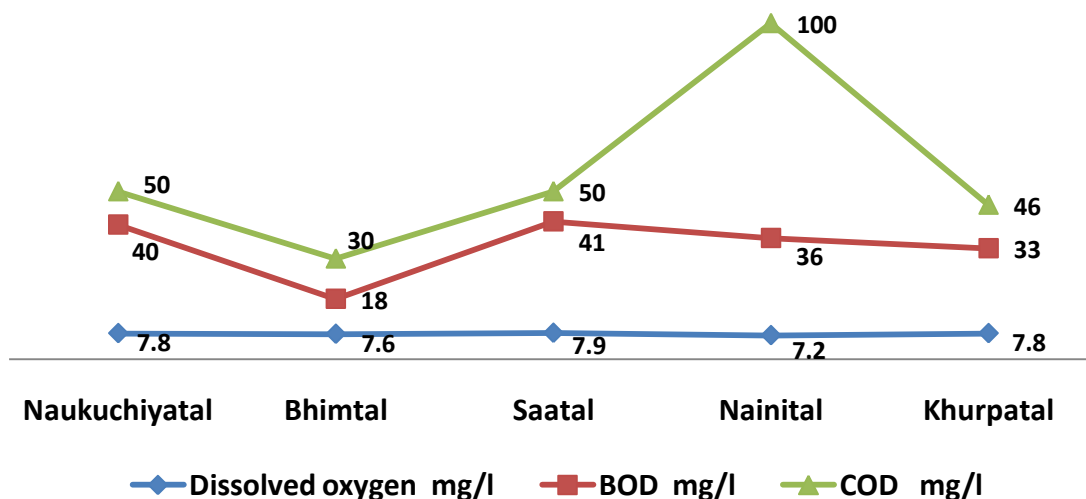
Conclusion:-

The present study suggests that total hardness, total dissolved solids, total alkalinity, COD, Ca and Mg levels were found to be above the desirable limit of BIS/WHO standard in Nainital and Bhimtal lakes. As Naukuchiyatal, Khurpatal and Sattal Lakes, are sparsely populated, still maintain their pristine state. Above results successfully provided evidence in support of the fact that the ideal geographic Lake setting of Nainital attracts many tourists (~300,000 - 400,000 people annually) during summer (April - August). The population is spread over a small area of 8-10 km². Surroundings of Nainital and Bhimtal Lake are also much urbanized in comparison to other lakes which increased the construction of buildings and roads, and human population has also doubled since the 1950's. Deterioration of sediment and water quality in the lakes is said to be related to domestic sewage and untreated wastewater from nearby hotels, which has led to eutrophication, fish kill, persistent anoxia and heavy metal pollution. Thus, various lake restoration alternatives should be suggested that can lead to the improvement in the lake's water quality, such as sustainable waste water and garbage discharge management, aeration, afforestation, phytoremediation, etc.

Table 1:- Table showing several Physico-chemical parameters of five different Himalayas lakes from Kumaun region.

SAMPLE DATE 28.6.15						
S.No	PARAMETER	Naukuchiyatal	Bhimtal	Sattal	Nainital	Khurpatal
1.	pH	7.7	8.8	8.1	7.9	8.0
2.	Temperature	24	25	22	25	22
3.	Total hardness mg/l	110	90	60	300	60
4.	Total dissolved solid mg/l	200	196	184	400	172
5.	TSS mg/l	24.6	40.5	22.4	33.6	20.4
6.	Total alkalinity mg/l	110	84	60	224	73
7.	Dissolved oxygen mg/l	7.8	7.6	7.2	7.9	7.8
8.	COD mg/l	50	30	50	100	46
9.	BOD mg/l	40	18	41	36	33
10.	Ca as Caco3 mg/l	68	42	30	130	38
11.	Mg as Caco3 mg/l	42	48	30	170	40
12.	Ca as Ca mg/l	27.2	16.8	12	52	18
13.	Mg as Mg mg/l	10.1	11.5	7.2	40.8	8.0
14.	Silica mg/l (dissolved)	0.98	2.01	1.73	6.55	2.0
15.	PO_4 mg/l	0.1	0.2	NIL	0.3	NIL
16.	SO_4 mg/l	3	6	1	115	3
17.	Chloride mg/l	9.9	11.4	8.5	17.0	8.5
18.	Sodium mg/l	4.2	5.3	2.2	10.3	4.0

NOTE- SAMPLE COLLECTION & ANALYSIS AS PER BIS NORMS.

Fig. 3:- Comparative Analysis of Lake Water in terms of DO, BOD & COD.

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