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Impact assessment of climatic changing pattern on lakes water quality of Kumaun region

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Introduction

Lake ecosystem are made up of the physical, chemical and biological properties contained within water bodies. Lakes are superb habitats for the study of ecosystem dynamics. Lakes are important ecosystems because humans depend on it for many services such as drinking water, waste removal, fisheries, agricultural irrigation, industrial activity and recreation. A lake and its watershed are often considered to be a single ecosystem (Likens, 1985).

The Kumaun Himalaya lies in the lesser Himalayas zone from 28°43'55" to 30°49'12" N latitude and from 78°44'30" to 80°5'E longitude with a total area of 21,035km^2. It provides an epitome of geological architecture of the whole Himalayan region. Hence, Kumaun is one of the most representative sector of the great mountain system and is blessed with enhanced beauty and varied natural water resources. Nature has bountifully supplied the Kumaun region with a large number of lakes and rivers with an average annual discharge exceeding 2.0 million m^3. Himalayan lakes in the mid 20th century raised concern about the consequences of cultural eutrophication for example Nainital, Bhimtal, Naukuchiatal, Sattal, etc.

Lakes in the Kumaon region have undergone ecological changes during the last few decades that have affected water quality, increasing heavy metal content and algal productivity (Chakrapani 2002; Das, 2005; Choudhary *et al.,* 2009). Deterioration of the water quality of Kumaun lakes because of the intense cultural activities in their catchment areas has been recognized recently (Das and Pandey, 1978). In lakes water quality has been highly transformed due to anthropocene.

Impacts of climate change on water quality of lakes

Climate change is recognized as a threat on biological productivity of lakes. Climatic variation affects the hydrological characteristics of lakes. The hydrological and physico-chemical characteristics of lakes are

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changing due to climatic variations *i.e.* increasing pattern of air and water temperature, rate of evaporation, precipitation, humidity and solar intensity. Impacts of global warming on lakes include an extended growing period at high latitudes, intensified stratification and nutrient loss from surface waters, decreased hypolimnetic oxygen (below the thermocline) in deep, stratified lakes, and expansion in range for many invasive aquatic weeds (Bates *et al.* 2008).

Lakes are very vulnerable to climate change. In the lake ecosystem, the impact of climate changes on biological productivity and distributional pattern of aquatic biodiversity has recently been the focus of interest. The diversity of biotic components in the lake ecosystem serves as a reliable index of biological productivity and its trophic status. The temperature structure of lake water mass is one of the major factors modifying the hydro-biological, chemical, sedimentation and physical processes occurring in lakes. Direct effects of climate change on lakes includes changes in temperature, water level, pH, concentration of dissolved gases (dissolved oxygen, free carbon dioxide etc). Elevated temperatures would decrease oxygen solubility and increase the rates of microbial oxygen demand, both leading to a decrease in dissolved oxygen available for biotic communities in different trophic level of lake ecosystem. Climate changes are increasingly recognized as important regulatory factors to assess the primary productivity in relation to changing pattern of biotic communities (phytoplankton, zooplankton, benthos and fish species) in the lake ecosystem. Therefore, the thermal stratification of lake affects the solubility of gases, availability of nutrients and ultimately the biological productivity of lake ecosystem.

Climate change driven physical fluctuations exert strong impacts on aquatic ecosystems because climate is modifying the abiotic and biotic environment. Phytoplankton forms a highly diverse group of aquatic microorganisms and contributes as vital source of energy through primary producers, serves as a direct source of food to the other biotic organisms. Phytoplankton are the initial or primary biological component from which the energy is transferred to higher organisms through food chain (Boyd, 1982; Rajesh *et al.*, 2002) and the abundance and species composition of phytoplankton in an aquatic ecosystem are regulated by many physico-chemical factors such as pH, light, temperature, salinity, turbidity and nutrients (Buzzi, 1999; Veeresha Kumar and Hosmani, 2006).

Climate directly affects light, turbulence and water temperature of lakes and influences the phytoplankton productivity because of changes in these factors, indirect effects are of climate change on lakes are grazing because if zooplankton biomass is enhanced in warmer water this will lead to a reduction in the phytoplankton biomass. The most significant climatic effects on phytoplankton species composition will very likely be mediated through changes in thermal stratification patterns such as the extent of the growing season and vertical mixing processes

(Schindler *et al.*, 1996; Rodriguez *et al.*, 2001; Diehl *et al.*, 2002; Smol *et al.*, 2005). Deepest lakes are most sensitive to climate warming on a long period of time due to their greater heat storage capacity and will consequently show the highest winter temperature (GEOrage et al., 2007).

Temperature

Temperature is one of the most important physical factors influencing the aquatic life. It is the basic environmental factor that effects chemical and biological reaction in water and maintain the optimum aquatic biodiversity (Boyd, 1982).Temperatures in lake ecosystems are closely coupled to air temperature (Meisner *et al.*,1988; Boyd and Tucker,1998) .Thus, it is obvious that an increase in air temperature is expected to be followed by similar increase in water temperature. Water temperature, a regular factor for various physicochemical as well as biological activities in lake ecosystems fluctuated markedly with the variations in air temperature (Sharma and Kumar, 2002).Temperature directly affects plant metabolism, which consists of both photosynthetic and respiratory activity, while metabolic rates of primary producers are primarily limited by photosynthesis (Dewar *et al.*, 1999). Thus, increases in water temperature due to climate change will result in increased oxygen demand and can also increase the productivity of lake by increasing algal growth, bacterial metabolism and nutrient cycling rates (Ficke *et al.*, 2005). The high water temperature in summer season was recorded in Kumaun lakes because of low water level, high air temperature and clean atmosphere Sharma *et al.*, (2000).

pH

The reduced rate of photosynthetic activities reduces the assimilation of carbon dioxide and bicarbonates which are ultimately responsible for increase in pH, the low oxygen values coincided with high temperature during the summer month (Kamble *et al.*, 2009). Higher pH values of Kumaun lakes water during summer could be ascribed to increased photo synthetic assimilation of dissolved inorganic carbon by planktons (Goldman, 1972).An increase in water temperature has also an impact on Kumaun lakes chemical processes with increases in pH and greater in lake alkalinity generation (Psenner and Schmidt, 1992).

Dissolved Oxygen

Dissolved oxygen is the most crucial ecological factor for sustain the healthy lake ecosystem and survival of fishes. Dissolved oxygen is an important measure of purity for all waters and the productivity of aquatic systems (Wetzel, 1983). The reduction of DO might be due to organic load through the municipal, domestic sewage and nutrients loads during throughout the year. The limiting factors affecting the DO content are mainly temperature, photosynthesis, respiration and decomposition processes. Warmer temperature during summer increases the rates of photosynthesis and decomposition, when all plants die at the end of the growing season, their decomposition results in heavy oxygen consumption. DO were found lower trends in summer because higher rate of decomposition

of organic matter and limited flow of water, leading to consumption of oxygen from water (Jameel, 1998). Dissolved oxygen is most significant factor for growth of nutrients, water quality assessment and important regulator of metabolic processes of organisms and community as a whole in Lake Ecosystem (Hutchinson, 1967). Dissolved oxygen is governed by photosynthetic activity and aeration rate (Gautam *et al.,* 1993). A minimum acceptable level is considered to be 5 mg/l dissolved oxygen in lake water (Ellis *et al.,* 1946).

Biological Oxygen Demand

BOD means an essential requirement of oxygen by all biotic organisms for their metabolic activities in aquatic system. Biological oxygen demand increases as the bio degradable organic content increases with large numbers of consumers occurred in lakes. In last twenty years, BOD showed increased in summer season by presence of phosphates, nitrites and nitrates in Kumaun lake water through domestic liquid wastes entering through the inlet of lake (Malik and Shikha, 2014). The highest value of BOD was observed in summer season due to high temperature favors microbial activity while the lowest during the winter season (Tidame and Shinde 2012; Sachidanandamurthy and Yajurvedi, 2006).

Chemical Oxygen Demand

COD is the measure of oxygen consumed during the oxidation of organic matter. High level COD indicated presence of all forms of organic matter, both bio degradable and non bio degradable contributed the degree of pollution in lake water. The higher values of COD in summer indicated water pollution due to oxidisable organic matter in lake water, Rasool *et al.,* (2003).

Electrical Conductivity

Total concentration of soluble salts in water is represents the Electrical conductivity. Conductivity has been used as an important parameter in deciding whether water resources are suitable for irrigation purpose. Conductivity values showed seasonal variations. High mineralization of organic matter occurs in bottom water of lake in summer season so EC value was recorded less in winter and high in summer.

Nitrate and Phosphate

Nitrate content in natural waters is likely to vary due to input of nutrient concentration of domestic as well as municipal liquid waste. The increase could be correlated with a decline in phytoplankton biomass in the lake during winter season. As phytoplankton deplete, the utilization or uptake of NO_3-N is also reduced.

Phosphate is one of the limiting factors for lake productivity, because of geochemical shortage of phosphate in drainage basins. Low phosphate may be attributed to locking up of phosphate in dense phytoplankton and macrophytic vegetation (Wani *et al.,* 1990). During plankton multiplication automatically phosphate concentration is decreased (Moss *et al.,* 1989).

Nitrate and phosphate concentrations may vary with the depth in lake due to deeper and shallow zones as per their bioaccumulation in detritus cycles. At the surface of the lake,

where sun light stimulates algae growth, total nutrient concentrations may be higher than those deeper in the lake. These high total concentrations reflect the increased concentration of organic matter, because the organisms are utilizing most of the nutrients that are produced, available nutrient concentrations may be low. Since decomposition of organic matter formation of available nutrients from total nutrients occurs to a larger extent near the bottom of a lake, available nutrient concentrations may be higher at depth. The main source of nitrate is the runoff and decomposition of organic matter. The higher inflow of water and consequent land drainage causes high value of nitrate (Thilanga *et al.,* 2005). The higher concentration of nitrates is indication of level of micronutrients in water bodies and has ability to support plant growth. Higher concentration of nitrate favored growth of phytoplankton.

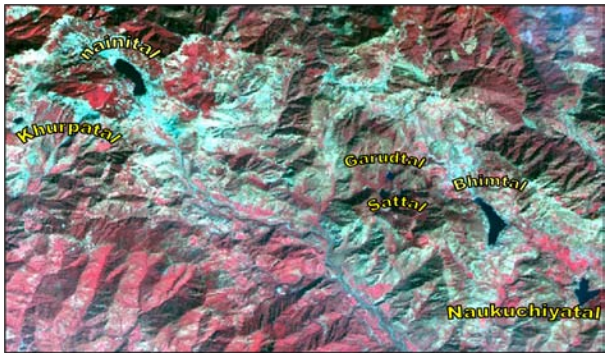

Fig. 1: A satellite view of lakes of Uttarakhand

Phosphate content in a lake may be due to release of phosphate from bottom sediments and organic load of the water contributing in growth of the phytoplankton and weeds in the lake (Dhembare, 2011). Phosphate showed increasing tendencies in hypolimnion, they were not clearly distinguishable among the depths. Its highest values were observed in the summer due to loss of water as a result of rising temperature and concentration of pollutant present in lake water.

Conclusion

The present observations revealed that the relationship of climate changing patterns among different atmospheric attributes contributed significantly to alter water quality and biological characteristics of lakes. Climate change impacts on water quality of Kumaun lakes have showed that a degradation trend of water quality leading to increase of at risk situations with regard to potential health impacts, mainly during extreme meteorological events. Increasing water temperature enhanced production and decomposition intensity, thus leading to oxygen depletion, particularly at night and during algal blooms. The long term effects of changing pattern of climatic conditions contributed as a change or shift phytoplankton species composition and their biomass. The present ecological and nutrient dynamics in Kumaun lakes has showed that trophic status is changing towards eutrophication under subtropical condition.

Mitigation Strategies

Various remedial measures proposed for the conservation of Kumaun lakes:

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. Ecofriendly industrial units should be promoted, municipal

or domestic waste water and sewage should be treated by bioremediation technology before drain into lake. Many anthropogenic activities

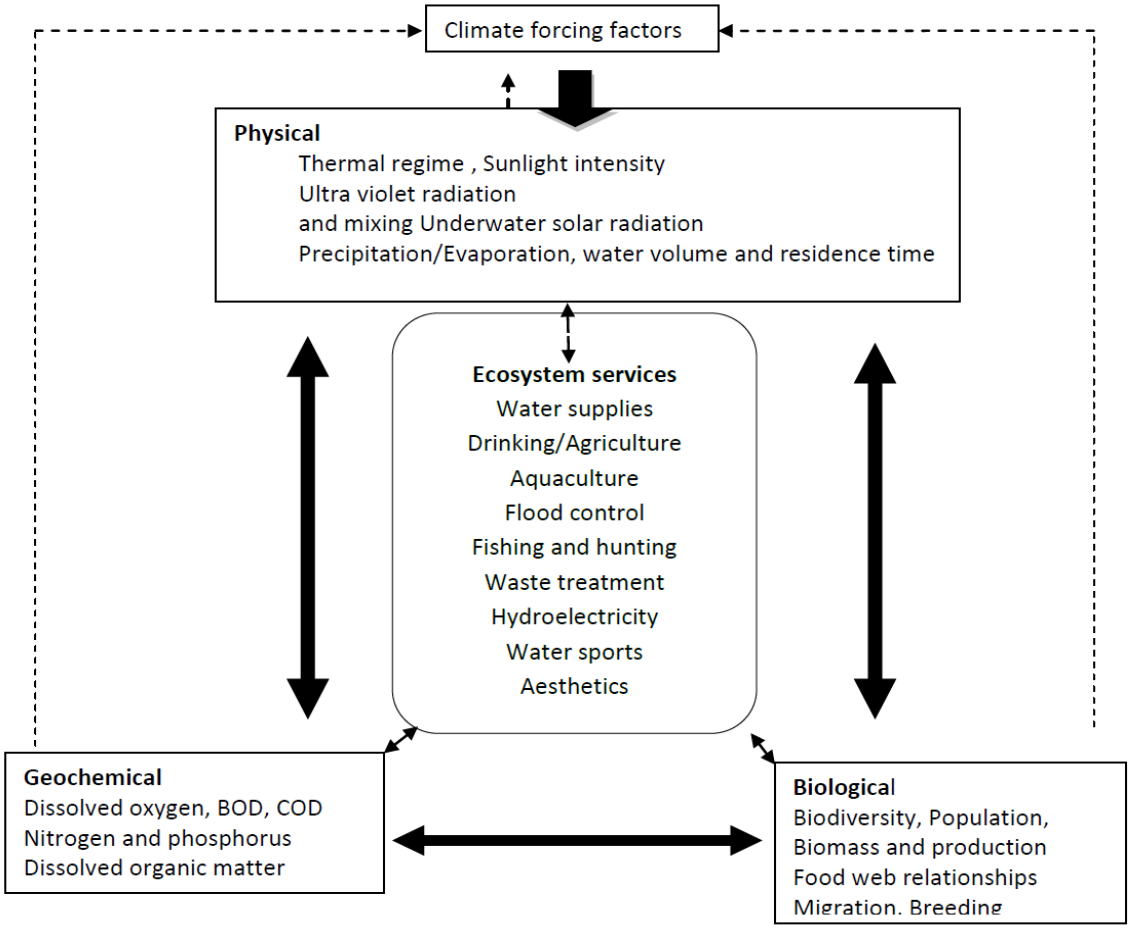

Fig.2: Inter-change relationships among climate forcing variables and different components of lake ecosystems.

like tourism in catchment basin of lake should be monitored continuously to restoration of lake ecosystem. There is a huge need for water quality monitoring and predictive tools as models and decision support systems mainly with the aim of health risk assessment and remediation and adaptation actions. All these preventive measures would be contributed significantly to reduce the sedimentation and siltation load in the lakes and water quality of lakes will be hygienic, pathogen free for drinking purpose by inhabitants of Kumaun region.

Fig. 3: A view of Nainital lake

Fig. 4: A view of Bhimtal lake

Fig. 5: A view of Naukuchiatal lake

Fig. 6: A view of Sattal lake

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