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Assessment of Lake Water Quality by using Trophic State Index Indicators Parameters for Ecological Lake Restoration- a Case Study of Naukuchiatal, Kumoun Region, Uttrakhand , India

Naresh Gopal Shrivastava**
Ex- Additional General Manager
Pollution Control Research Institute, BHEL, Ranipur, Haridwar 249403 (Uttrakahand), India

ABSTRACT: Lakes, water reservoirs and streams are the most valuable source of drinking water for the country. However, the lakes and reservoirs have special characteristics, which make them vulnerable to pollution and degradation. . In addition, eutrophication is a fundamental index that has been affecting the ecological evaluation of water quality. The input of organic contaminants from different sources may result in the alteration of water quality. In order to ensure the water quality, it is important to have a complete inventory of the lakes/reservoirs/wetlands and their status. Till date number of incentivization of Lakes, Reservoirs & wetland have been done by the number of agencies, but the information is lacking on Water Quality of Lakes, Reservoirs & Wetlands with reference to eutrophication status of these inland water bodies in India. Due to the unavailability of the scientific database on Lake Water Quality, a proper conservation plan cannot be prepared. This study has been undertaken for the incentivization of Lake Water Quality with reference to Eutrophication Status of Naukuchiatals, located at Longitude $29^0$19".19.2" N Latitude E $79^0$35'.6.72"E and Altitude: 1350 m. and prepared of a conservation plan for restoration of Naukuchiatal. The four water chemistry parameters to determine the water body's trophic state: total chlorophyll, total phosphorus, total nitrogen, and Transparency (water clarity). These four parameters serve as indicators of a water body's biological productivity — its ability to support life. Biological productivity is not measured directly hence word indicator is applied. However, it can be estimated. Read on to find out how each parameter relates to the biological productivity of your water body and to its trophic state. The study will help in the identification of hot spots and polluted water bodies in India, which will help in the rational planning of Pollution Control Strategies. Results revealed that the concentration of important parameters that mainly govern the catchment area characteristics was found above to the threshold level of eutrophication. By perusing the results of Trophic Index results of trophic state index indicate that Naukuchiatal is in a higher stage of Mesotrophic due to high nutrients loading through uncontrolled disposal of domestic waste from the catchment area

KEYWORDS: Naukuchiatal, Trophic state index, Eutrophication, Lake Restoration.

I. INTRODUCTION

Being a valuable natural resource, lakes have always been of great importance to mankind. From the past, these are providing water for domestic use. Since long, lake water is getting used for industrial purposes also as for irrigation. Lake is additionally one among the means of transport and has always attracted the eye of the citizenry for recreation. A number of the saline lakes are useful sources of some important minerals also. In short, a lake may be a kind of catalyst within the development of the town, region, and therefore the country as an entire. But, unfortunately, the recognition of lakes often results in its deterioration. The increased input of commercial and domestic waste and sediments and therefore the human activities not only hamper the capacity of the lake but also cause a rise within the productivity of the lake resulting in the biological and chemical changes leading to hazards just like the death of fish, obnoxious odor, and unsightly conditions. Water is one of the foremost abundant substances on earth. It covers approximately 71% of the globe's surface with the majority held by oceans. It's estimated that 97% of the whole quantity of water is within the oceans and only 3% is fresh water. However, only a little portion of the freshwater is out there to humans, animals, and plants. Most of the three freshwater supplies are held frozen in polar ice caps. The freshwater in lakes, rivers, and groundwater is 0.3% of the whole freshwater source of the planet which uses for drinking (10%), industry (21%), and agriculture (69%). Lakes, water reservoirs, and streams are the foremost valuable source of beverage for the earth's population. The livelihood of the citizenry and a couple of other living components depends upon natural lakes for beverage and agriculture & industrial activities. However, the lakes and reservoirs have special characteristics,

Which make them vulnerable to pollution and degradation. The input of organic contaminants from different sources may end within the alteration of water quality. Till the Ramsar Conventions, there is no specific definition for Lakes in India. Because water bodies described as – natural, manmade, and ephemeral including wetlands. Many of them are euphemistically called Lakes more by convention and a desire to be grandiose rather than by the appliance of an accepted definition. The opposite way around, many lakes are categorized as wetlands. India has many manmade water bodies located in typical of the tropics. The Reservoirs, Ponds, and Tanks are manmade (artificial) water bodies though it's a commonplace. While it's difficult thus far the natural lakes, most of the manmade water bodies like Ponds and Tanks are historical. The huge reservoirs are all of the recent origins. Most without any exception have impacted environmental degradation. Only the degree of degradation differs. The degradation itself could also be a result of a scarcity of public awareness. Things are changing but slowly. This is often thanks to the shortage of availability of environmental databases on these lakes & reservoirs in India. Environmental activism and legal interventions have put the sustainability of lakes and reservoirs within the vanguard of environmental issues. The foremost environmental issue related to lakes and reservoir is Eutrophication. Through. Introduction of nutrients from agricultural run-off and untreated industrial and concrete discharges cause Eutrophication of lakes and reservoirs which also enhanced degradation process. Accelerated eutrophication of lakes and reservoirs, experienced during this century in most parts of the earth represents a big degradation of water quality. Impairment of water quality because of eutrophication can cause health-related problems and end in economic losses. Many problems originate from the event of activities. Agricultural growth, including the event of irrigation and drainage systems and thus the excessive use of fertilizers and pesticides, cleaning of forests, and thus the development of factories. Human settlements in lake and reservoir watersheds often cause eutrophication of the lakes and reservoirs.

Proper planning and management of the associated watershed are required for control of eutrophication or restoration of eutrophic lakes and reservoirs generally, man-made factors increased eutrophication through the elimination or reduction of nutrient supplies from different sources, like municipal and industrial wastewater, agricultural wastes and fertilizers, etc. However, in most cases, it's impossible to eliminate all sources of nutrients. Therefore, it is vital to understand the connection which exists between the nutrient supplies and thus the degree of eutrophication. this data is vital to develop sound management strategies to manage the eutrophication of lakes or reservoirs at minimum costs. To date, efforts were made during a scattered manner and not during a scientific manner on Water Quality of Lakes, Reservoirs, and Wetlands in India. The available data has not been compiled/available which may help different government agencies to make a conservation plan for these water bodies. Very limited action plans are available and executed which are being delayed. This might be due to the non-availability of the Limnological conditions of these water bodies. Organic pollution and nutrient enrichment are one among the foremost significant and widespread water quality issues. Thanks to demographic pressure and rapid urbanization around the water bodies, eutrophication has become a standard problem in freshwater ecosystems. A gradual increase in water eutrophication is the biggest problem of the governments and therefore the public in recent years.

This because of the reason that the mechanisms of water eutrophication are not fully understood, but excessive nutrient loading into the surface water system is considered to be one among the main factors (Fang et al 2004, Tong et al 2003). Many freshwater lakes undergo eutrophication with the increasing input of nutrients (Zang 2008). Certain chemicals, like nitrogen, phosphorus play the most role in distorting aquatic ecosystems by increasing productivity. In most of the lakes, the severe eutrophication, degeneration of ecosystems, and deterioration of water quality have resulted in uncontrolled nutrient inputs to water bodies and their proximity to agriculture and use in aquaculture (Chen et.al 2003). within the recent past, in several parts of the planet including India, there have been several studies conducted on the physic-chemical and biological characterization of lotic and lentic ecosystems by different authors viz. Parikh and Mankodi (2012), Patil Shilpa G et al (2012), Seyed Ahmad Reza Hashem et al (2012), Hashemzadeh, and Venkataramana (2012), Safari et al (2012), Kumar Manoj and Padhy Pratap Kumar (2013) and Pathakand Mankodi (2013). aside from surface water bodies, Physico-chemical and microbiological characterization of subsurface water were reported by several authors Parihar S.S. et. Al (2012), Nirmala B (2012). In line with the wise use of resources, Lake Gahar Basin was assessed as a possible site for focused ecotourism by Gholipoor Mehranoosh (2012). Surface water quality during a region is essentially determined both by natural processes and by anthropogenic inputs. The anthropogenic discharges constitute a continuing polluting source, whereas surface runoff may be a seasonal phenomenon, largely suffering from climate within the basin Singh et, al. (2004). Vega (1998). Land erosion within the lake catchment not only affects the physical and chemical properties of soils but also enriched the lake water with nutrients Upadhyay et al (2012). For any urban water body, the expansion of the habitation around the lake vicinity without a correct sewerage system further exaggerates organic and nutrient loading within the lake. Inline thereupon hydrochemical changes also are found in lakes thanks to the immersion of idols and non-secular offerings which are common

in India Dhote and Dixit (2011). Thus, point and non-point sources both are liable for the degradation of the water quality of the limnetic environment. In this paper, we've considered the Naukuchiatal of Naukuchiatal as a test suit. The Naukuchiatal is found in Naukuchiatal within the Kumaon region of Uttrakhand, India, and is that the only source of water for the town. Economic also as recreational activities of the town also are heavily hooked into the supply of water within the lake, which is received organic and nutrients load through various points and non-point sources. Therefore, this study is administered to realize the subsequent targets: i. Assessment of organic pollution and concentration of plant nutrients in Naukuchiatal, ii. Assessment of Trophic index to work out the extent of organic pollution in Naukuchiatal, iii. to work out the trophic level of Naukuchiatal by using the Trophic State Index (TSI).

II. MATERIAL AND METHODS

The Study Site: within the present study, the Naukuchiatal which is geographically located at Longitude $29^0$19".19.2" N Latitude E $79^0$35'.6.72"E, Altitude: 1350 m respectively of Naukuchiatal (Uttrakhand) is considered as a test suit. The Naukuchiatal is one among the oldest and largest impoundments and a serious beverage source for the town of Naukuchiatal and Haldwani city. The study area experiences between subtropical to temperate climates on high elevation (more than 2000m). The yearly average temperature in summers ranges from 10.6O C to 26.7O C and in winters it remains between 2.8O C to 15.6O C. Rainfall begins earlier within the month of June and continues up to the top of September. Nainital records heavy rainfall in these months mainly due to the local rain. During winter, rains create a substantial fall in temperature. Snowfall is that the heaviest in January or in early February. Frost is additionally experienced within the winter season. The summer season remains between April to June is pleasant, The lake Naukuchiatal is a closed water system. It is surrounded by hills and has a catchment area of 17.21 km2 with an average annual rainfall of approximately 2424 mm (Figure 1). The lake has an irregular shape with nine corners and V shaped basin. It is situated at Longitude $29^0$19".19.2" N Latitude E $79^0$35'.6.72"E, Altitude: 1350 m above mean sea level, with a surface area of 0.306 km2 (30.6 ha) at an elevation of 1314m and volume of 8.13 million cu.m. The Lake has 950.9 m length and 691.8 m breadth and a maximum depth of about 40.8 m. It receives water from springs and through canal in different parts of the year.in Table-1.

Figure 1: A View of Naukuchiatal

Catchment Area (Watershed): The genesis of the Naukuchiatal is intimately related to Naukuchiatal, which is 30m above Naukuchiatal. The lake has a 950.9m length, 691.8m breadth and a maximum depth of about 40.8m. It has a total length of shoreline is 3600 m. The lake receives water as surface runoff and also as underground recharge through springs and seepage zones. The shoreline is mostly rocky with scree and rock boulders. The lake water is pumped for drinking. The hills are fairly thickly vegetated except the higher peaks, which are devoid of vegetal cover. The slope around the lake is about 15-20° becoming steep in the adjoining ranges. The Naukuchiatal Subproject area is situated in the lesser Himalayas or Shivalik zone. The Subproject area has sub temperate climate with hilly terrain. The altitude of the area is between 1200 to 1900m above Mean Sea Level. This region comprises of several fresh water lakes including Naukuchiatal. Table 1.

Table-1

Salient Features of the Study Site

SN	Features	Naukuchiatal
	Longitude	$29^0$19”.19.2” N
	Latitudes	E $79^0$35’.6.72”E
	Catchment area	17.21 km2 (1,721.2 hac)
	Submergence area at FTL	0.306 km2 (30.6 ha)
	Storage capacity	8.13 million cu.m
	Maximum Depth	40.3 m
	Maximum Water level (R.L)	06 m
	Main water uses	Potable water supply
	Source of water	Rain water/Springs

The shoreline is gently inclined being very steep after 12 m depth. The side towards Kamaltal (north western) is relatively gentle with fallen blocks of volcanic and quartzite. The interstitial spaces of these blocks are occupied by mud. The central part of the lake near the intercept line of maximum width and length is about 40.8 m. As such this is the deepest lake of the region. The Bathymetric map of the lake is embedded as Figure 2. The Elevation Area storage details of the lake are given in Table 2.

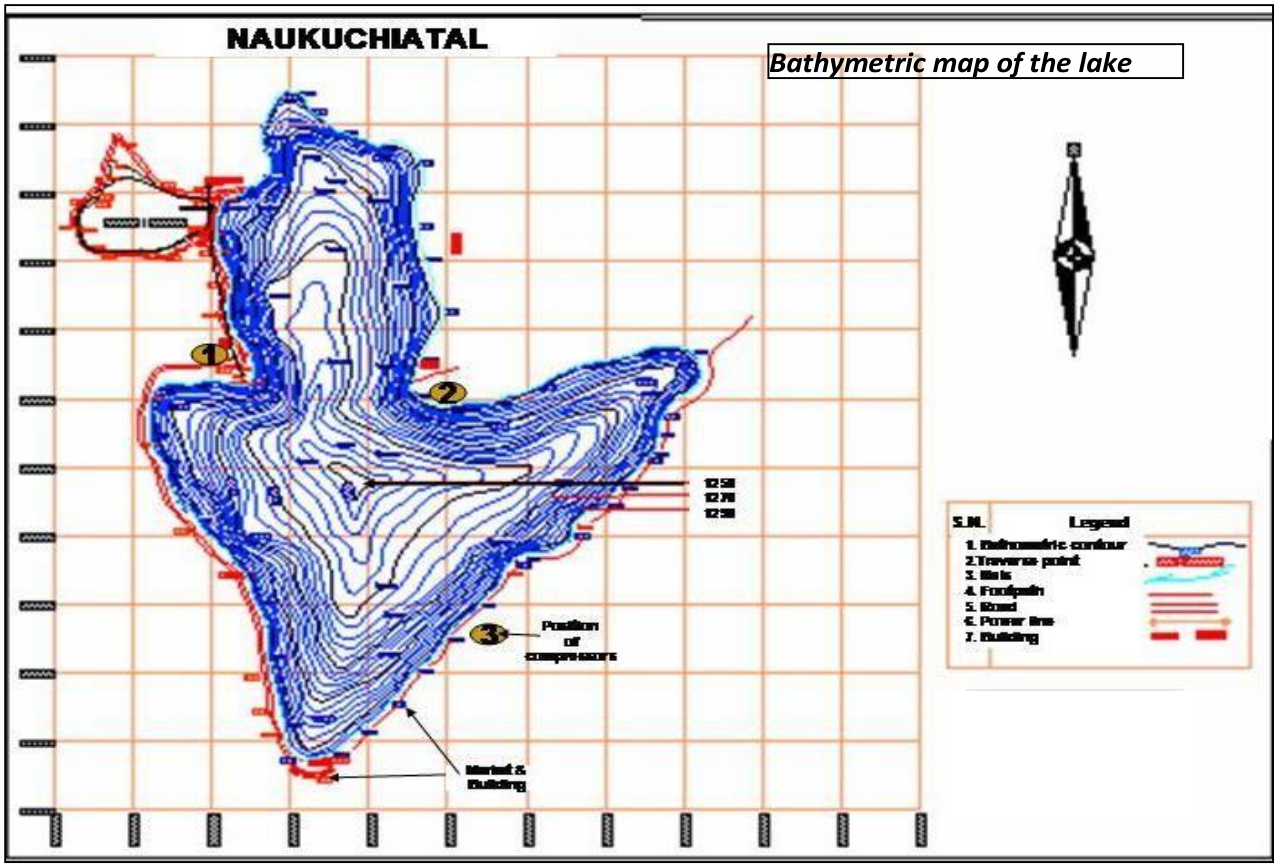

Figure 2: Bathymetric Map of Naukuchiatal

Table 2: Elevation – Area- Storage Curve at Naukuchiatal

Elevation (m)	Water surface area (sqm)	Storage (MCM)
1270	0.001071	0.001071
1276	0.022967	0.073 185
1280	0.068255	0.255629
1286	0.130237	0.851104
1290	0.163217	1.438013
1296	0.193290	2.507534
1300	0.231387	3.356888
1302	0.243066	3.831341
1304	0.255799	4.330206
1306	0.268770	4.854775
1308	0.282047	5.405592
1310	0.295086	5.982725
1312	0.305745	6.583556
1314	0.306000	7.195301
1315	0.307100	7.501301
1317	0.309200	8.1133

Source: Irrigation Department, Nainital District

The methodologies were adopted:

Used following questionnaire for collection of basic information about lake. This questionnaire was sent to authorized concerned agencies in the State and collected during ground level monitoring by the project team:
QUESTIONNAIR ON BASIC INFORMATION ON LAKES

GENARAL	
Name of the Water Body	:
Locations (Describe: name nearest town, District & State)	:
Geographical Coordinates (Latitude/Longitude/Altitude)	:
Lake Type	: Natural lake / Lagoon / Manmade(Reservoir)
Area , (Hectare) Full Water Level)	
Maximum Depth , m (Full Water Level)	
HYDROLOGY	
Source of Water (inflow)	: Rainfall / Runoff / River / Drain / W/W Drain
Outflow, if any described	
Water level changes (annual) meters	
Does the lake dry out completely?	: Every Year / Occasionally / Rarely
CATCHEMENT (WATERSHED)	
Area, (km2)	: Nature : ◘ Hilly (if so slope in degree) ◘ Plan ◘ Coastal
Land Use (%)	: Urban Agriculture Forest Mining Grazing Fallow
Population (Total)	: ◘ Human / ◘ Animal
If urban Catchments (Has sewerage been provided)?	: ◘ Yes / ◘ No / Portion of Population (%)
Sewerage Treatment	: ◘ No. ◘ STP ◘ Oxidation Pond ◘ Septic Tank Vol. (MLD)
Solid Waste disposal in Lake (if any) (including religious offering)	:

Described any prominent/ special features	:
WATER QUALITY & POLLUTION STATUS	
Source	: ◘ Domestic / ◘ Industrial / ◘ Storm water / ◘ Agric. Runoff /
	◘ In-Lake Human Activity / ◘ Cattle Wading / ◘ Other (Specify)
Level	: ◘ Very High / ◘ Moderately High / ◘ Medium / ◘ Low/◘ Negligible
Water Quality	:……pH/……DO(mg/l)/……PO4((µg/l) /……NO3((µg/l)…….Chlorophyll (µg/l)
Pollution Status	: ◘ Olgiotrophic / ◘ Mesotrophic / ◘ Eutrophic / ◘ Toxic pollution
BIODIVERSITY (give specific number if known	
Aquatic Plants	: ◘ Submerged / ◘ Emergent / ◘ Free Floating / ◘ Algae
Aquatic Animals	: ◘ Zooplankton / ◘ Benthic / ◘ Mollusks / ◘ Fish : ◘ Amphibian / ◘ Reptiles / ◘ Birds / ◘ Mammals
Name important/rare/endemic/exotic species	:
FUNCTION AND VALUES	
Water used for (Give estimated % amount)	: ◘ Drinking Water supply / ◘ Irrigation / ◘ Hydropower / ◘ Fisheries ◘ Transport / ◘ Recreation / ◘ Religious
Use of Biological Resources	: ◘ Reeds & Grass for Thatch or fodder / ◘ Plant Cultivation for food / ◘ Prawn / ◘ Fisheries
Functions of the Lake	: : ◘ Groundwater Recharge / ◘ Flood mitigation / ◘ Tourism Local/National/International/ ◘ Supports Biodiversity ◘ Influence of Microclimate / ◘ Socio-cultural / ◘ Aesthetic
MAJOR PROBLEM	: ◘ Reduction in Area(Shrinkage) / ◘ Reduction in depth (Siltation) / ◘ Encroachment/ ◘ Algal Blooms ◘ Aquatic weeds / ◘ Decline or Loss of fisheries / ◘ Eutrophication /◘ Organic Pollution / ◘ Toxic pollution
SCIENTIFIC KNOWLEDGE	
Scientific Studies	: ◘ No Study / ◘ Only one study / ◘ Several studies / ◘ Many Studies /◘ Comprehensive & Detailed / ◘ All components / ◘ Few Components (◘ Water quality/ ◘ Algae / ◘ Plants / ◘ Zooplankton / ◘ Fish / ◘ Other)
Has the lake's state been monitored for several years?	: ◘ Yes / ◘ No
Scientific Studies	: ◘ Research Papers / ◘ NGO reports / ◘ Newspaper Reports / ◘ Government reports /◘ Published / ◘ Available / ◘ Restricted (◘ Unpublished
PUBLIC AWARENESS	
Are local communities aware of the problems of the lake?	: ◘ Yes / ◘ No
Are local communities interested in the restoration of the lake?	: ◘ Yes / ◘ No
Are there are active local conservation groups (NGOs) interested in the lake?	: ◘ Yes / ◘ No
RESTORATION ACTIVITIES REQUIRED	
	◘ Improvement of water quality by in-lake treatment ◘ Diversion and Treatment of Sewage ◘ Desiltation for removal of organic/toxic sediments ◘ Weed removal ◘ Shoreline protection ◘ Catchment treatment to check erosion and ◘ Others (Specify)

Any other information:	

Survey, Monitoring & collection of Lake were done.

The Composite samples were collected from three different zone Surface Middle & Bottom of Lake wherever boating facilities was available, otherwise samples were collected all around the lake and make it composite for following three zones as given Figure 3, 4, 5, & 6
Eastern Zone
Central Zone &
Eastern zone of Lake
Samples were collected to analyzed main following Physical, Chemical & Biological Parameters as per the standard method given in Limnological Method (Welch, 1948) and Water & Wastewater Examination APHA (2000):

Physical: pH, Transparency, Total Dissolved Solids
Chemical: Alkalinity, Ammonia, BOD, COD, Calcium, Copper, Dissolved Oxygen, Free CO2, Hardness, Manganese, Nitrate, Nitrite, Phosphate, Potassium, Sodium, Zinc.
Biological: Chlorophyll, Plankton, Total & Fecal Coliform

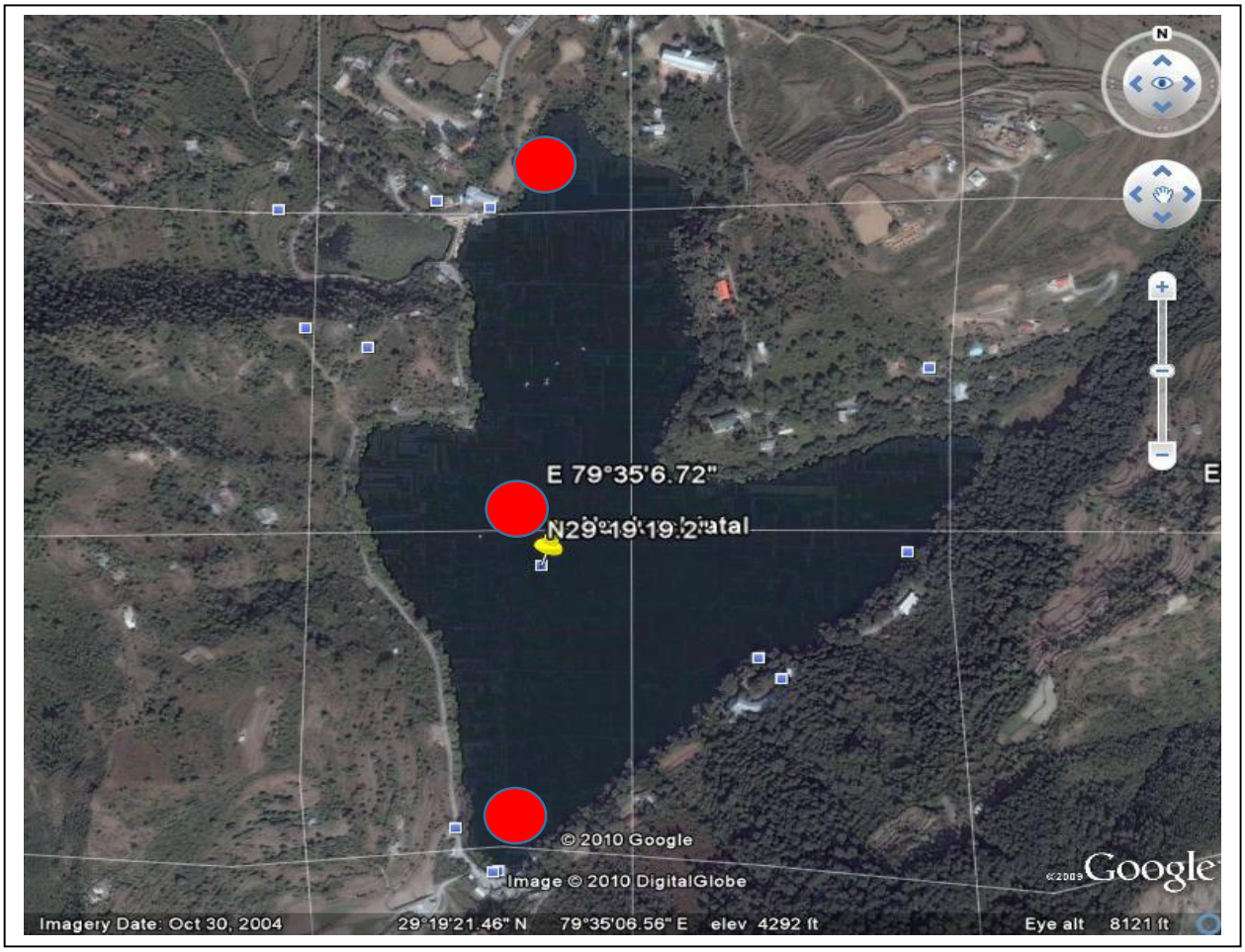

Figure-3 Location of Sampling Points in Naukuchiatal,

Figure 4 Sampling at Northern Side of Naukuchiatal

Figure 5 Sampling of Central Zone of Naukuchiatal

Figure 6 Sampling at Eastern Zone of Naukuchiatal

Simpson's Diversity Index:

Simpson's diversity index (also known as Species diversity index) is a measure of diversity. In ecology, it is often used to quantify the biodiversity of a habitat. It considers the number of species present, as well as the relative abundance of each species. The Simpson index represents the probability that two randomly selected individuals in the habitat belong to the same species

The term 'Simpson's Diversity Index' can actually refer to any one of 3 closely related indices.

Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). There are two versions of the formula for calculating D. either is acceptable but be consistent.

$D = \Sigma (n / N)2$	D = N(N-1)/ni (ni-1)
n = the total number of organisms of a particular species N = the total number of organisms of all species	

The value of D ranges between 0 and 1
With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give:
Simpson's Index of Diversity 1 - D
The value of this index also ranges between 0 and 1, but now, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species.
Another way of overcoming the problem of the counter-intuitive nature of Simpson's Index is to take the reciprocal of the Index:
Simpson's Reciprocal Index 1 / D
The value of this index starts with 1 as the lowest possible figure. This figure would represent a community containing only one species. The higher the value, the greater the diversity. The maximum value is the number of species (or another category being used) in the sample. For example, if there are five species in the sample, then the maximum value is 5.
i.e. "Values of D range from 0 to 1. A Diversity Index value of 1 represents very low species richness. A value of 0 represents very high species richness -- the value you get if there is only one species present,

III. RESULTS AND DISCUSSION:

The Naukuchiatal lake is a B shaped lake which lies between Longitude $29^0$19”.19.2” N Latitude E $79^0$35’.6.72”E, Altitude: 1350 m above mean sea level. The maximum depth of the lake is 2.13 to 40.3 m. The total volume of the lake is 8.13 Mm3. The shoreline is 3560 meters. The catchment area is 17.21 km2 (1,721.2 Hect.) km2 and 1.032 km2. The primary source of its water is the number of primary spring. The Lake is nine corners shaped. Hill slop and springs of the catchment area are the main sources of water in Naukuchiatal. The hydrologic studies related to water balance and sedimentation was done using radioisotopes for estimating/measuring the various components of the inflow and outflow into the lake. The components of outflows were the surface outflow, the subsurface outflow through the springs on the downstream side, and draft through wells for meeting the water supply of Sattal & Nainital city and evaporation loss from the lake surface. The mean water retention time for the lake was computed as 2.5 years for the mean annual total inflow 3.13 Mcm (NLRSADA, Jan 2003).

Water Quality & Pollution Status: The water quality of the lakes deepens largely on catchment characteristics, geology, and inputs of human activities. A catchment of poorly weathered rocks and impact the natural ecosystems will produce water with low fertility. A catchment with reactive rock and soils will produce more fertile waters. The inputs in the form of sewage, sullage, and remains of construction material along with forest runoff add to a multitude of organic and inorganic molecules that undergo a change in the body of receiving waters.The water quality monitoring is done to ensure that the concentration of particular chemicals are not exceeded, that no deleterious biological effects have occurred, to bring out species richness and/or diversity, to ensure long term sustainable use of aquatic ecosystem by human society and to determine compatibility with other components of the ecological landscape.

Water quality monitoring has many purposes viz to ensure, that the concentration of particular chemicals is not exceeded, that no deleterious biological effects have occurred, to bring out species richness and/or diversity, to ensure long term sustainable use of aquatic ecosystem by human society and to determine compatibility with other components of the ecological landscape. The Naukuchiatal is a Medium water body with nine shaped basin. The lake is monomictic and has one period of circulation in winters (January-February) and a prolonged stagnation period of ten months. The Florida Lakewatch Program monitors used the four water chemistry parameters to determine a water body’s trophic state: total chlorophyll, total phosphorus, total nitrogen, and Transparency (water clarity). These four parameters serve as indicators of a water body’s biological productivity — its ability to support life. The word “indicator” is employed here because biological productivity isn't something which will be measured directly. However, it can be estimated. Read on to find out how each parameter relates to the biological productivity of your water body and to its trophic state.

Chlorophyll — is the dominant green pigment found in most algae (the microscopic plant-like organisms living in a water body). Chlorophyll enables algae to use sunlight to make food. In fact, most algae are so dependent upon chlorophyll pigments for survival that a measurement of the concentration of all the chlorophyll pigments found during a water sample (called total chlorophyll) can be used to estimate the amount of free-floating algae in that water body. When large amounts of total chlorophyll are found within the sample, it generally means there are tons of algae present. Once we have an estimate of the number of algae in a water body, we can take it a step further and use this information to estimate a trophic state. Since algae are a basic food source for many aquatic animals, their abundance is a crucial factor in how much life a water body can sustain. In general, when measurements of total chlorophyll (i.e. Chlorophyll a,b,&c) are high (indicating lots of algae are present), the water body will be more biologically productive.

Phosphorus — is a nutrient necessary for the growth of algae and aquatic plants. It's found in many forms in water body sediments and dissolved in the water. Lakewatch uses a measurement called "total phosphorus" that has all the varied sorts of phosphorus during a sample. When this nutrient is in low supply (and all other factors necessary for plant and algae growth are present in sufficient amounts), low biological productivity are often expected. On the opposite end of the trophic state scale, highly productive water bodies usually have an abundance of phosphorus. In some water bodies, phosphorus may be at a level that limits further growth of aquatic plants and/or algae. When this is true, scientists say phosphorus is the "limiting nutrient."Nitrogen — is also a nutrient necessary for the growth of algae and aquatic plants. The sum of all sorts of nitrogen called "total nitrogen. are considered by Lakewatch measurement " When total nitrogen is in low supply (and other factors necessary for plant and algae growth are present in sufficient amounts), low biological productivity can be expected. Like phosphorus, nitrogen can be a limiting nutrient.

Transparency (Water clarity) — refers to the clearness or transparency of water. Water clarity is decided by using an 8-inch diameter disk, called a Secchi (pronounced SEC-ee) disk. The maximum depth at which the Secchi disk is often seen when lowered into the water is measured. Several factors can affect water clarity within the following ways:
free-floating algae in the water can make water bodies less clear;
dissolved organic compounds (called tannins) can cause water bodies to appear reddish or brown; and
Suspended solids (tiny particles stirred up from the water body's bottom or washed in from the watershed) can cause the water to be less clear.

Therefore these simple bases are considered in the present study for the assessment Water Quality & Pollution Status of Naukuchiatal Lake. (Figure 7) The composite water samples were collected from the North; Central & Eastern Zone of Lake (Figure 3, 4, 5, & 6) analyzed and compares trophic status with Table 3 & Figure 7

Table 3 . Comparison of Classification Schemes.

Trophic State Index	Trophic State Classification	Water Quality
≤ 60	Oligotrophic through Mid-Eutrophic	Good
61-70	Mid-Eutrophic through Eutrophic	Fair
>70	Hypereutrophic	Poor

Also see LAKEWATCH publication, "Trophic State: A Water body's Ability to Support Plants Fish and Wildlife" at http://lakewatch.ifas.ufl.edu/LWcirc.html.

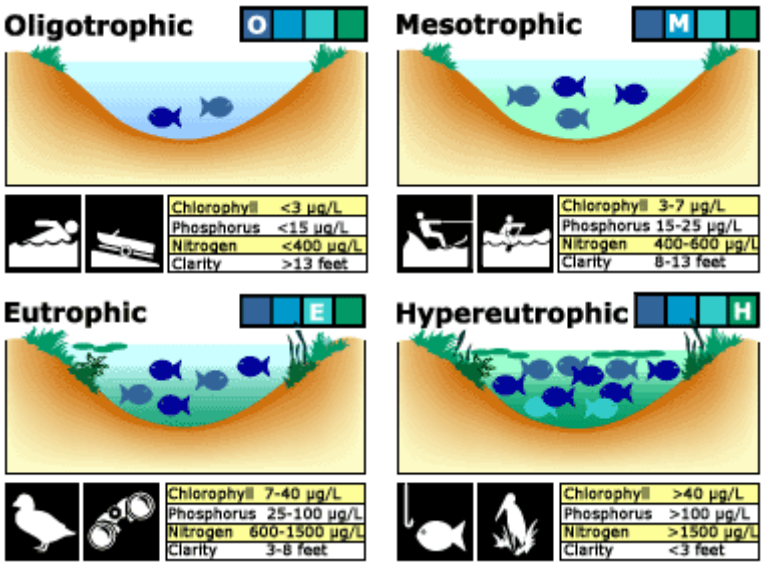

Figure 7 : Reference: Trophic State Index Calculation Method found on page 87 of the 1996 FDEP 305 (B) Report

The results are given in Table 4, Table 5 & Table 6 of Physico-chemical and biological profiles indicated that Naukuchiatal is discussed below:

Physical Characteristics: It is seen from Table 3 that the Temperature: The Air Temperature was 22.5 ºC whereas the Water Temperature ranged from 22.0 to 22.2 ºC from Northern to Eastern Zone of Lake. The temperature difference between the Western & Eastern Zone is higher than the Central Zone of Lake. This may be due to the effect of wind velocity and shoreline impact. pH: The pH ranged from 7.55 to 7.60 from Northern to Eastern Zone of Lake. The pH difference between North & South Zone is lower than the Central Zone of Lake. This may be due to the effect of photosynthetic activity of Phytoplankton. Transparency: Transparency was ranged from 1 meter from Northern, Central, and Eastern Zone of Lake. The Transparency uniformly distributed throughout the Lake. While comparing with FDEP (1996) report given in Figure 5, Naukuchiatal Lake is showing Mesotrphic Conditions of the lake. This may be due to the effect of storm-water drainage and other turbulence flow into the lake from the catchment area. Total Dissolved Solids: The Total Dissolved Solids (TDS) was ranges from 290 to 295 mg/l from Naukuchiatal to Eastern Zone of Lake. The TDS difference between to Northern & Eastern Zone is higher than the Central Zone of Lake. This may be due to the effect of drainage water and other turbulence flow into the lake from the catchment area.

Chemical Characteristics: It is seen from Table 3 that the Alkalinity: The Alkalinity was ranged from 144 to 145 mg/l from Northern to Eastern Zone of Lake. The Alkalinity difference between Western & Eastern Zone is lower than the Central Zone of Lake. This may be due to the effect of photosynthetic activity of Phytoplankton. Ammonia: The Ammonia was ranged from 0.05 to 0.10 mg/l from Northern to Eastern Zone of Lake. The conc. of Ammonia difference between to Northern & Eastern Zone is higher than the Central zone of Lake. This may be due to the effect of decomposition of organic matter in the Lake. Biochemical Oxygen Demand (BOD): The BOD was ranged from 2.3 mg/l from Northern to Eastern Zone of Lake. The BOD is very much less and uniforms throughout the lake. This may be no mixing extra and outsource of organic matter accumulation in these zones. Calcium: The Calcium was ranged from 30 to 32 mg/l from Northern to Eastern Zone of Lake. The Calcium difference between to Western & Eastern Zone is higher than the Central Zone of Lake. Chemical Oxygen Demand (COD): The COD ranged from 10 to 12 mg/l from Northern to Eastern Zone of Lake. The COD difference between to Northern & Eastern Zone is higher than the Central Zone of Lake. This may be due to the effect of storm-water drainage water from the catchment area and organic matter accumulation in these zones. Copper: The Copper was not detected in Lake. Dissolved Oxygen (DO): The DO ranged from 6.2 to 6.5 mg/l from Northern to Eastern Zone of Lake. The DO difference between to Northern & Eastern zone is lower than the Central Zone. This may be due to Photosynthetic activity and the mixing of atmospheric oxygen due to wind flow in the valley. Free Carbon Dioxide (Free CO2): The Free Caron Dioxide was not detected in any Zone of Lake which shows that all the Carbon Dioxide used in the photosynthetic activity

of Phytoplankton. Hardness: The Hardness was ranged from 180 to 182 mg/l from Western to Eastern Zone of Lake. The Hardness difference between to Western & Eastern zone is higher than the Central Zone. This may be due to the drainage of catchment water into the lake. Manganese: The Manganese has ranged uniformly ND to 0.01 mg/l from Northern to Eastern Zone of Lake. Nitrate: The Nitrate was ranged from 400 to 500 µg/l from Northern to Eastern Zone of Lake. The Nitrate difference between Western & Eastern Zone is higher than the Central Zone of Lake. While comparing with FDEP (1996) report given in Figure 5, Naukuchiatal Lake is showing Mesotrophic Conditions of the lake. Although The nitrate is slightly higher on both the side in comparison to the central zone this may be due to the effect of drainage water and other turbulence flow into the lake from the catchment area. Nitrite: The Nitrite was not detected in the sample. Phosphate: The Phosphate was ranged from 15 to 16 µg/l from Northern to Eastern Zone of Lake. The Phosphate difference between to Northern & Eastern Zone is higher than the Central Zone of Lake. While comparing with FDEP (1996) report given in Figure 5, Naukuchiatal Lake is showing Mesotrophic Conditions of the lake. Although The Phosphate is slightly higher on both the side in comparison to the central zone this may be due to the effect of drainage water and other turbulence flow into the lake from the catchment area. Potassium: The Potassium was ranged from 6.60 to 6.62 mg/l from Naukuchiatal to Eastern Zone of Lake. The Potassium difference between to Northern & Eastern zone is higher than the Central Zone. This may be due to the drainage of catchment water into the lake. Sodium: The Sodium was ranged from 10.5 to 10.63 mg/l from Northern to Eastern Zone of Lake. The Sodium difference between to Western & Eastern zone is higher than the Central Zone. This may be due to the drainage of catchment water into the lake. Zinc: The Zinc was ranged from 0.01 to 0.02 mg/l from Northern to Eastern Zone of Lake. The Sodium difference between to Western & Eastern zone is higher than the Central Zone. This may be due to the drainage of catchment water into the lake.

Biological Characteristics: It is seen from the Table 3 that the Total Coliform: The Total Coliform was ranges from 45 to 50 MPN/100 ml from Northern to Eastern Zone of Lake. The Total Coliform difference between to Northern & Eastern zone is higher than the Central Zone. This may be due to drainage of catchment water into the lake. So water should be disinfecting before use for drinking propose. Fecal Coliform: The Fecal Coliform was ranges from 18 to 20 MPN/100 ml from Western to Eastern Zone of Lake. The Fecal Coliform difference between to Northern & Eastern zone is higher than the Central Zone. This may be due to drainage of catchment water into the lake. So water should be disinfecting before use for drinking propose. Chlorophyll: The Total Chlorophyll was ranges from 1.03 to 1.04 µg/l from Northern to Eastern Zone of Lake. The Chlorophyll difference between to Central & Eastern Zone is higher than the Northern Zone of Lake. While comparing with FDEP (1996) report given in Figure 5, the Naukuchiatal Lake is showing Mesotrophic Conditions of lake. Although The Chlorophyll is slightly higher on Central & Western Zone in compare to Central zone this may be due to effect of higher productivity water in these Zone. The Chlorophyll concentration in Central Zone may be due to high density of the phytoplankton as the Phosphate value is lower in this zone. It is seen from the Table 2 that the Trophic Status Index was calculated from North, Central & Eastern Zone of Naukuchiatal Lake by assessing Chlorophyll-a concentration. This is calculated as per the FDEP (1996) report. Based on Trophic Status Index it is clearly indicated that the on both the side Water Quality is Fair. Plankton: The biological community of Lake depend not only thermometry of the Lake, the trophic status also plays an active role. The presence of Nitrate-Nitrogen & Phosphate together with light penetration on the surface promotes the growth of algae. Over a period, a grazing food chain can be established. This Phytoplankton, Zooplankton, Benthos & Nekton can be established. The List of Identified Phytoplankton, Zooplankton & Benthos are given Table 3. It is seen from the Table 1 that The Plankton Density was ranged from 327 to 991 x10^5 cells/100 ml from Northern to Eastern Zone of Lake. The Plankton Density was higher in Eastern Zone than the North & Central Zone.

Table 4
Physico-Chemical & Biological Water Quality of Naukuchiatal

S.No.	Parameter	Unit	Obtained Values		
			Northern Zone	Central Zone	Eastern Zone
A.	Physical				
	pH		7.83	7.90	7.94
	Transparency	Meter	0.2	0.4	0.1
	TDS	mg/L	186	196	182
B.	Chemical				
	Alkalinity	mg/L	72	80	76

	Ammonia	mg/L	0.23	0.23	0.22
	BOD	mg/L	0.9	0.9	0.7
	Calcium	mg/L	19.2	8.0	12.8
	COD	mg/L	5.0	7.0	5.0
	Copper	mg/L	ND	ND	ND
	Dissolved Oxygen	mg/L	5.9	4.2	4.2
	Free CO2	mg/L	1.76	1.76	1.76
	Hardness	mg/L	144	96	80
	Manganese	mg/L	ND	ND	ND
	Nitrate	µg/L	ND	ND	ND
	Nitrite	mg/L	ND	ND	ND
	Phosphate	µg/L	0.73	0.93	0.23
	Potassium	mg/L	2.35	2.84	2.82
	Sodium	mg/L	8.61	5.38	8.39
	Zinc	mg/L	ND	0.01	ND
C.	Biological				
	Chlorophyll	µg/L	0.88	0.77	2.21
	Fecal Coliform	MPN/100 mL	100	16	34
	Plankton	Cells/mLx103	954	327	991
	Total Coliform	MPN/100 mL	230	30	80

The List of Identified Phytoplankton, Zooplankton & Benthos is given in Table 4. It is seen from Table 5 that The Plankton Density was ranged from 900 to 960 x10^3 cells/100 ml from Western to Eastern Zone of Lake. The Plankton Density was higher in the central Zone than the North & South Zone.

Table 5
Distribution and Density of Identified Phytoplankton, Zooplankton & Benthos at Different Zones in Naukuchiatal

SN	Northern Zone	No. of species (cells/L)	SN	Central Zone	No. of species (cells/L)	SN	Eastern Zone	No. of species (cells/L)
1	PHYTOPLANTON							
A	Chlorophycece		A	Chlorophycece		A	Chlorophycece	
1	Ankistrodesmus falcatus	206000	1	Ankistrodesmus falcatus	209000	1	Ankistrodesmus convolutes	106000
2	Colestrum microsporum	106000	2	Ankistrodesmus convolutes	209000	2	Colestrum microsporum	106000
3	Closterium simansis	106000	3	Colestrum microsporum	109000	3	Closterium longissiama	106000
4	Cosmarium botrytis	106000	4	Closterium simansis	109000	4	Cosmarium botrytis	106000
5	Closterium acerosum	106000	5	Closterium longissiama	209000	5	Closterium acerosum	106000
6	Chlorella vulgaris	106000	6	Cosmarium botrytis	209000		Crucigenia quadrata	106000
7	Crucigenia quadrata	106000	7	Crucigenia quadrata	209000	6	Chlorella conglarumeta	106000
8	Chlorococcum humicola	106000	8	Chlorella vulgaris	209000	7	Chlorococcum humicola	106000
9	Chlamydomona reinhardtii.	206000	9	Netrium lamellosum	309000		Chlamydomona reinhardtii.	206000

10	Eudorina elegnse	206000	10	Chlorella conglarumeta	209000	8	Eudorina elegnse	206000
11	Scenedismus quadricauda	206000	11	Chlorococcum humicola	309000	9	Scenedismus quadricauda	206000
12	Scenedismus cummunis	206000	12	Chlamydomona reinhardtii.	409000	10	scenedesmus acuminatus	206000
13	Pediastrum simplex	106000	13	Eudorina elegnse	409000	11	Pediastrum duplex	106000
14	Pedistrum boryanum	106000	14	Scenedismus quadricauda	309000	12	Pedistrum boryanum	106000
15	Pleodorina starrii	106000	15	Scenedismus cummunis	209000	13	Pleodorina starrii	106000
16	Oocystis irrigularis	106000	16	scenedesmus acuminatus	309000	14	Oocystis irrigularis	106000
16	Pandorina morum	106000	16	Pediastrum simplex	309000	15	Pandorina morum	106000
17	Selenestrum bibraianum	106000	17	Pediastrum duplex	209000	16	Selenestrum bibraianum	106000
18	Micractinium pusilium	106000	18	Pedistrum boryanum	209000	16	Micractinium pusilium	106000
19	Planktospheria gilatinosa	106000	19	Pleodorina starrii	209000	17	Planktospheria gilatinosa	106000
20	Oscystis natanus	106000	20	Oocystis irrigularis	309000	18	Oscystis natanus	106000
21	Euastrum oblongum	106000	21	Pandorina morum	309000	19	Euastrum oblongum	106000
22	Actinastrum hentzshii	106000	22	Selenestrum bibraianum	109000	20	Actinastrum hentzshii	106000
23	Desmidium grevillii	106000	23	Micractinium pusilium	209000	21	Desmidium grevillii	106000
24	Dispora crucigenioides	106000	24	Planktospheria gilatinosa	209000	22	Dispora crucigenioides	106000
		12000	25	Oscystis natanus	209000			12000
		12000	26	Euastrum oblongum	209000			12000
		12000	27	Actinastrum hentzshii	209000			12000
		12000	28	Desmidium grevillii	209000			12000
		12000	29	Dispora crucigenioides	109000			12000
21		3006000	23		6709000	22		2906000
B	Dinophyceae	106000		Dinophyceae	309000		Dinophycecea	106000
1	Gymnodinium fuscum	106000	1	Gymnodinium. catenatum	309000	1	Gymnodinium fuscum	106000
2	Peridinium willei,	106000	2	Gymnodinium fuscum	309000	2	Peridinium willei,	106000
3	P. cinctum	106000	3	Peridinium willei,	309000	3	P. cinctum	106000
3		106000	4	P. cinctum	309000			106000
3		506000	4		1509000	3		506000
D	Bacillariophyceae	12000	D	Bacillariophyceae	9000	D	Bacillariophyceae	6000
1	Gomphonema intericatum	106000	1	Gomphonema intericatum	309000	1	Gomphonema intericatum	106000
2	Navicula sublaniris	106000	2	Navicula sublaniris	209000	2	Navicula lanceolata	106000
3	Nitzschia acicularis	106000	3	Navicula lanceolata	409000	3	Nitzschia acicularis	106000

4	Tabellaria fenestrata	106000	4	Nitzschia acicularis	309000	4	Tabellaria fenestrata	106000
5	Fragilaria cylindrus	106000	5	Tabellaria fenestrata	309000	5	Fragilaria cylindrus	106000
6	Diatoma vulgare	106000	6	Fragilaria cylindrus	309000	6	Diatoma vulgare	106000
7	Cymbella stuxbergii	106000	7	Diatoma vulgare	209000	7	Cymbella stuxbergii	106000
8	Rhopalodia acuminata	106000	8	Cymbella stuxbergii	109000	8	Rhopalodia acuminata	106000
9	Pinnularia appendiculata	106000	9	Rhopalodia acuminata	309000	9	Pinnularia appendiculata	106000
10	Gyrosigma spenceri	106000	10	Pinnularia appendiculata	509000	10	Gyrosigma spenceri	106000
11	Amphora Ehrenberg	106000	11	Gyrosigma spenceri	509000	11	Amphora Ehrenberg	106000
12	Asterionella formosa	106000	12	Amphora Ehrenberg	609000	12	Asterionella formosa	106000
13	Syndra ulna	506000	13	Asterionella formosa	409000	13	Syndra ulna	106000
		12000	14	Syndra ulna	609000			506000
13		1706000	14		5009000	13		1806000
E	Cyanophyceae	6000	E	Cyanophyceae	9000	E	Cyanophyceae	6000
1	Chroococcus giganteus	206000	1	Aphanocapsa holsatica	609000	1	Aphanocapsa holsatica	206000
2	Anabanena spiroids	206000	2	Chroococcus giganteus	309000	2	Chroococcus giganteus	206000
3	Merismopedia angularis	206000	3	Anabanena spiroids	509000	3	Anabanena spiroids	206000
4	Gomphosphaeria lacustris	106000	4	Merismopedia angularis	209000	4	Merismopedia angularis	106000
5	Microcystis auriginosa	206000	5	Gomphosphaeria lacustris	209000	5	Gomphosphaeria lacustris	106000
6	Spirulina platensis	106000	6	Microcystis auriginosa	209000	6	Microcystis auriginosa	106000
7	Oscillatoria acuminata	106000	7	Oscillatoria acuminata	209000	7	Spirulina platensis	106000
8	Nostoc caeruleum	106000	8	Nostoc caeruleum	209000	8	Oscillatoria acuminata	106000
9	Phormidium autumale	106000	9	Phormidium autumale	209000	9	Nostoc caeruleum	106000
10	Microcystis auriginosa	106000	10	Microcystis auriginosa	209000	10	Phormidium autumale	106000
		106000			209000	11	Microcystis auriginosa	106000
10		1506000	10		3009000	11		1406000
2	Zooplankton		2	Zooplankton		2	Zooplankton	
A	Rotifera		A	Rotifera		A	Rotifera	
1	Colurella obtuse	106000	1	Philodina roseola	409000	1	Philodina roseola	106000
2	Mytilina compressa	106000	2	Colurella obtuse	409000	2	Mytilina compressa	106000
3	Rotatoria tridenta	106000	3	Mytilina compressa	209000	3	Rotatoria tridenta	106000
4	Euchlanis dilatata	106000	4	Rotatoria tridenta	109000	4	Euchlanis dilatata	106000
5	Philodenivorous paradoxus	106000	5	Euchlanis dilatata	109000	5	Philodenivorous paradoxus	106000

6	Anuropsis fissa	106000	6	Philodenivorous paradoxus	309000	6	Anuropsis fissa	106000
7	Brachionus nilsoni	106000	7	Anuropsis fissa	309000	7	Brachionus nilsoni	106000
8	Brachionus caudatus	106000	8	Brachionus nilsoni	209000	8	Brachionus dedutata	106000
9	Brachionus angularis	106000	9	Brachionus dedutata	409000	9	Brachionus caudatus	106000
10	Cephalodella abstrusa	106000	10	Brachionus caudatus	409000	10	Brachionus angularis	106000
11	Epiphanes brachionus	106000	11	Brachionus angularis	109000	11	Cephalodella abstrusa	106000
12	Monostyla arcuata	106000	12	Cephalodella abstrusa	409000	12	Epiphanes brachionus	106000
13	Keratella cochlearis	106000	13	Epiphanes brachionus	109000	13	Monostyla arcuata	106000
14	Keratella cruciformis	106000	14	Monostyla arcuata	109000	14	Keratella cochlearis	106000
15	Keratella tropica	106000	15	Keratella cochlearis	109000	15	Keratella cruciformis	106000
16	Polyarthra vulgaris	106000	16	Keratella cruciformis	109000	16	Keratella americana	106000
17	Trichocerca gracilis	106000	17	Keratella americana	409000	17	Keratella tropica	106000
18	Anuraeopsis, fissa	106000	18	Keratella tropica	209000	18	Polyarthra vulgaris	206000
		12000	19	Polyarthra vulgaris	309000	19	Trichocerca gracillis	106000
		12000	20	Trichocerca gracillis	309000	20	Anuraeopsis,	106000
		12000	21	Anuraeopsis,	409000			106000
18		1806000	21		5309000	20		2206000
B	Cladocera		B	Cladocera		B	Cladocera	
1	Daphnosoma exisum	106000	1	Daphnosoma exisum	109000	1	Daphnosoma exisum	106000
2	Simocephalus serrulatus	106000	2	Simocephalus serrulatus	109000	2	Simocephalus serrulatus	106000
3	Diphnia longspina	106000	3	Diphnia longspina	109000	3	Diphnia longspina	106000
3		306000	3		309000	3		306000
C	Copepoda		C	Copepoda		C	Copepoda	
1	Cyclops vicinus	206000	1	Cyclops vicinus	109000	1	Cyclops vicinus	106000
2	Microcyclops varicans	106000	2	Microcyclops varicans	309000	2	Microcyclops varicans	306000
3	Tropocyclops pracinus	106000	3	Tropocyclops pracinus	109000	3	Tropocyclops pracinus	106000
4	Eucyclops serrulatus	106000	4	Eucyclops serrulatus	109000	4	Eucyclops serrulatus	106000
4		506000	4		609000	4		606000
3	Benthic Organism		3	Benthic Organism		3	Benthic Organism	
A	Oligochaeta		A	Oligochaeta		A	Oligochaeta	
1	Tubifex tubifex	106000	1	Tubifex tubifex	109000	1	Tubifex tubifex	106000
2	Oligochaeta unid	106000	2	Oligochaeta unid	109000	2	Oligochaeta unid	106000
2		206000	2		209000	2		206000
B	Hirudinea		B	Hirudinea		B	Hirudinea	

1	Hemclepsis marginata	106000	1	Hemclepsis marginata	109000	1	Hemclepsis marginata	106000
2	Glossiphonia weberi	106000	2	Glossiphonia weberi	109000	2	Glossiphonia weberi	106000
3	Barbronica weberi	106000	3		109000	3	Barbronica weberi	106000
3		306000	3		309000	3		306000
C	Odonata	12000	C	Odonata	9000	C	Odonata	12000
1	Anax junius	106000	1	Anax junius	109000	1	Anax junius	106000
2	Libellula sp	106000	2	Libellula sp	109000	2	Libellula sp	106000
2		206000	2		209000	2		206000
D	Coleptera	12000	D	Coleptera	15000	D	Coleptera	12000
1	Helocharis lintus	106000	1	Helocharis lintus	109000	1	Helocharis lintus	106000
2	Bidessus sp	106000	2	Bidessus sp	109000	2	Bidessus sp	106000
3	Haliplus sp.	106000	3	Hyphoporus sp	109000	3	Hyphoporus sp	106000
3		306000	3		309000	3		306000
E	Diptera	12000	E	Diptera	15000	E	Diptera	12000
1	Chironomids	106000	1	Chironomids	109000	1	Chironomids	106000
1		106000	1		109000	1		106000

Biodiversity: Naukuchiatal Lake aquatic ecosystems showed rich and diverse phytoplankton, Zooplankton & Benthic Organism population Table 6. Phytoplankton in the collections belonged to Chlorophyceae, Cyanophyceae, Bacillariophyceae. Zooplankton collection belongs to the Rotifers, Cladocera & Copepods whereas the Benthic organism collection belongs to the Oligochaeta,. Hirudinea, Odonata, Coleoptera, Diptera.

During the study, $389x10^5$ species belonging to 206 genera were recorded for Phytoplankton, $326x10^5$ species belonging to 27 genera of Zooplankton, and $34x10^5$ species of 33 Genera of $32x10^5$ Benthic organism. Station-wise list of Phytoplankton, Zooplankton, and Benthos of all the three stations are given in Table 6 & Figure 8

Table 6
Distribution of Genera & Species of Phytoplankton, Zooplankton & Benthic Organism in Naukuchiatal Lake

SN	Class of Plankton & Benthos	North Zone		Central Zone		Eastern Zone		Total	
		Genera Nos	Species (cells/L)	Genera Nos	Species (cells/L)	Genera Nos	Species (cells/L)	Genera Nos	Species (cells/L)
A	Phytoplankton								
1	Chlorophycease	21	3006000	23	6709000	22	2906000		
2	Dinophyceae	3	506000	4	1509000	3	506000		
3	Bacillariophyceae	13	1706000	14	5009000	13	1806000		
4	Cyanophyceae	10	1506000	10	3009000	11	1406000		
		65	8530000	72	21545000	69	8830000	206	38905000
B	Zooplankton								
1	Rotifera	18	1794000	21	5294000	20	2194000		
2	Cladocera	3	294000	3	294000	3	294000		
3	Copepoda	4	494000	4	594000	4	594000		
		9	1018000	9	1127000	9	1118000	27	3263000

C	Benthic Organism								
1	Oligochaet	2	206000	2	209000	2	206000		
2	Hirudinae	3	306000	3	309000	3	306000		
3	Odonata	2	206000	2	209000	2	206000		
4	Coleptera	3	306000	3	309000	3	306000		
5	Diptera	1	106000	1	109000	1	106000		
		11	1130000	11	1145000	11	1130000	33	3405000

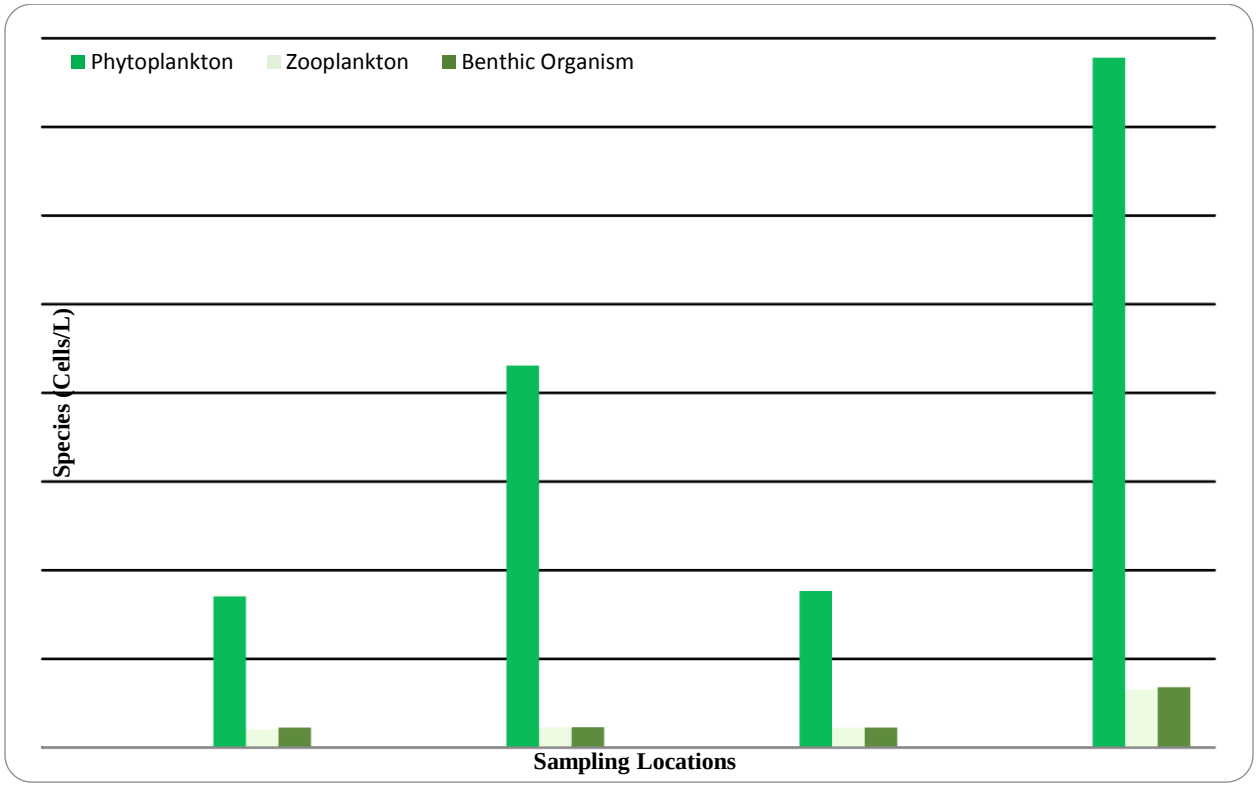

Figure – 8
Distribution of General & Species in Naukuchiatal Lake

In the present study, Simpson's Diversity Index is used for assessment of Species richness in Naukuchiatal. The Diversity Index Vales of Each group of Phytoplankton, Zooplankton & Benthic organism is given in Table -7 as follows:

Table 7
Species Diversity Index of Naukuchiatal Lake

		Simpson's Diversity Index (D)=N(N-1)/ni(ni-1)#			
		North Zone	Central Zone	Eastern Zone	Total
A	Phytoplankton				
1	Chlorophycease	4.20538E-11	1.12418E-11	5.4708E-11	1.93165E-23
	Dinophyceae	2.34342E-11	5.2699E-12	1.17171E-11	1.3729E-21
2	Bacillariophyceae	5.36002E-11	7.25386E-12	4.78288E-11	1.64335E-22
3	Cyanophyceae	3.96819E-11	9.94027E-12	5.56445E-11	2.07426E-22
B	Zooplankton				
1	Rotifera				

2	Cladocera	9.38179E-11	1.49013E-11	7.80859E-11	2.15592E-22
3	Copepoda	6.40779E-11	6.28397E-11	6.40779E-11	8.21196E-21
C	Benthic	4.68684E-11	3.23554E-11	3.26765E-11	2.61631E-21
1	Oligochaet				
2	Hirudinae				
3	Odonata	4.71298E-11	4.57865E-11	4.71298E-11	1.66591E-20
4	Coleptera	6.40779E-11	6.28397E-11	6.40779E-11	8.21196E-21
5	Diptera	4.71298E-11	4.57865E-11	4.71298E-11	1.66591E-20

The Diversity is "0" in Naukuchiatal lake shows that very high species richness which shows the Mesotrophic to Eutrophic Condition of Lake.

While comparing the TSI results of Chlorophyll, with Figure No 7 and Table 8 the Lake Water Quality falls in 19-20 which is Fare Water Quality. But it's northern zone indicating some alarming conditions due to uncontrolled of domestic waste into the lake from its catchment. Therefore, at this stage, only Lake Restoration activities are required to be undertaken,

Table 8 : Assessment Trophic Status of Naukuchiatal

Sampling Location in Naukuchiatal Lake	Chlorophyll (µg/L)				TSI of Chl.a 16.8+14.4*Chl a #	Trophic Status Index Range (TSI)	Assessment of Lake Quality
	a	b	c	Total			
North Zone	0.19	0.18	0.51	0.88	20	60	Fair
Central Zone	0.13	0.19	0.46	0.77	19	50-60	Good
Eastern Zone	0.14	0.08	2.00	2.21	19	50-60	Good

TSI As per FDEP305 (B) Report 1996 (For lakes: 0-59 is good, 60-69 is fair, 70-100 is poor.)

Lake Naukuchital located in the Kumaun Himalayan region in northern India, is a major drinking water source, Fisheries, Recreation & Religious to the people living in and around the lake basin.

Major Problem: Naukuchiatal is showing signs of accelerated eutrophication as a result of human activities within the catchment basin. The excessive deforestation, construction of roads, cutting of Hill slopes, mushrooms growth in Hotels, building & Industries have created the varied ecological problems of Naukuchiatal. the main environmental issues are as follows

(i) Physical Growth and Environment: The main issues that face Naukuchiatal are:

a. Hilly terrain surrounding the Lake, forest areas and ecologically fragile areas restrict the physical expansion within the municipal boundary;
b. thanks to limited space for construction within NNPP, there's an instantaneous got to develop townships outside NNPP to depopulate the town and accommodate the longer-term population;
c. Although ecologically sensitive areas are earmarked as 'prohibited areas' within the plan, there's a high incidence of unauthorized construction within these areas;
d. Many buildings in the old city areas are during a dilapidated condition;
e. Growth of Rural and squatter settlements is resulting in environmental degradation f. Natural disasters occur if the construction of the buildings is not sound ;
g. Landslides on surrounding hills, and h. Pollution in Naukuchiatal.

(ii) Sewerage: A skeleton sewerage system isn't laid within the Naukuchiatal site. Rapid urbanization and inadequate sewage system led to the matter of overflowing of sewage in stormwater drains ultimately discharging into Naukuchiatal. to place an end to the present, under the NLCP, there should be one-two STPs of 1 mld that ought to make be available during this region.

(iii) Storm Water Drainage: During a hill town like Nainital, adequate stormwater drainage facilities are required to stop erosion and control of pollution to lakes and water bodies. Investments are needed to deal with the requirements of (a) repairs and reconstruction of drains in critical sections, (b) additional cross walls and catch-pits, (c) provision of screens at outfalls, (d) disconnection of side drains from sewers and (e) removal of an obstruction in drains.

(iv) Solid Waste Management: NNPP's estimated total daily MSW generation ranges between 1 MT to 2 MT during peak and non-peak tourist seasons. There is no mandatory requirement of Solid Waste Disposal practices in town, which is burdened with an inefficient collection system, environmentally unsound disposal practices and unplanned dumping at a site down a gorge like formation. It thus requires immediate and sustained effort to upgrade to a suitable level.

(v) Heritage and Tourism: Naukuchiatal may be a known destination within the northern tourist circuit of India. Tourists are attracted by the sweetness of Naukuchiatal surrounded by hills, lush green forest areas, and its rich cultural heritage. Its rich heritage must be conserved and showcased to market tourism through diverse means like interpretation centers, experiential museums, walks, publications, etc. Other elements that require attention are an indication of model architectural elements and restoration of heritage buildings like cemeteries, churches, old temple sites. Sattal has the potential to tap high-end tourism by the event of eco-tourism and adventure tourism.

(vi) Local Poor: Naukuchiatal has slums scattered over the world, providing shelter to quite about 1000 population, Access to basic services on an overall basis isn't regrettable although conditions vary. the bulk (85%) of all the households have an in-house water connection. Of the sample households, 97 percent have a latrine within the house. a number of the BPL families don't have a pour-flush toilet. The most issue is the ownership of land. Of the below poverty level (BPL) population, 40 percent of households and 14 percent of the poor don't have any legal rights of the land.

The following Restoration Activities in Naukuchiatal are required

- Improvement of water quality by in-lake treatment
- Diversion and Treatment of sewage
- Shoreline protection
- Catchment treatment to sea erosion

Lake Management Action Plan: The environment of a city is a critical determinant of the health of its inhabitants and consequently productivity. The environmental pollution in the city is becoming a major concern due to the increase in population, urbanization, and transportation in recent years. To protect the environment and mitigate urban environmental pollution, the following strategies are suggested:

The concerned authorities should provide adequate provisions for parks, green belts, and plantation of trees at the planning stage for the development of an area.
Protection of environmental resources such as forest, land, water body, etc.
The government of Uttarakhand (GoU) should frame bye-laws to incorporate environmental protection laws.
Government of Understanding should take necessary measures to make it mandatory for use of alternative fuels (i.e. CNG, Battery operated vehicles, etc.) for public transport vehicles and improve the traffic management system of the city, particularly in the Mall Road for mitigation of air pollution.
Compliance of the MSW (Management & Handling) Rules, 2000 including identification and selection of alternative sites for landfill and composting for safe disposal of MSW of the city.
Wider coverage of the city by sewerage network and house connections and providing treatment facilities of the sewage for its safe disposal.
Proper maintenance of the existing sewers and water supply pipelines to ensure minimum leakage.
Storm Water Drainage

The sector vision clearly states that the Government of Understanding is fully aware of the sector goal to have a problem-free storm water drainage system in the whole of the town. The strategies that ought to be in place are:
1. Strict control against dumping of garbage in the drains.
2. Awareness campaign to educate the masses.
3. Regular cleaning and maintenance of drains.

4. Banning the use of plastic bags.
5. Discontinue the practice of connecting the toilet outlets to the drains.
6. The practice of diversion of surface drains into sewers should be stopped.

IV. CONCLUSION

The main aim of this study was to understand the level of organic pollution and nutrient concentration in the lake and results revealed that concentration of all the important parameters which mainly govern the lake chemistry is beyond the permissible limits and threshold level of eutrophication. By perusing the results of the Trophic State Index, it can be concluded that Naukuchiatal is an organic polluted and nutrient-enriched lentic ecosystem. The concentration of Total Phosphorous and Total Nitrogen is mainly responsible for Naukuchiatal eutrophication and having significant impacts on lake water quality. These nutrients can also enhance the rate of cultural eutrophication and increase lake productivity which reflects through the presence of floating blue-green algae such as ***Microcystis aeruginosa*** and several macrophytes in the Naukuchiatal at Northern Zone. The increase of the Organic pollution load may be due to Decay and the decomposition of these biological species, reduction in the euphotic zone, and hypolimnetic dissolved oxygen contents. Over the period of about a decade, several good conservation and management actions had been taken to reduce the pollution and nutrients loading in the Naukuchiatal under Bhoj wetland conservation and management project funded by JBIC but present limnetic chemistry of the Naukuchiatal revealed that the time has come to further restart or continue the conservation practices to minimize the pollution load.

As far as conservation and management are concerned, primarily, emphasis should be laid on the overall prevention of external nutrient input into the lake thus Lake drainage basin is the logical starting point for planning and management actions. Secondly, site treatment should be to encourage the lake to restore its natural process. Water Quality of Lake may be improved through the improvement of internal ecological processes through natural eco-technologies or other in-lake treatment measures that will be required for up-gradation of water quality. Augmentation of water, not only mass-scale rainwater harvesting will be required in the immediate lake fringes but also channelization of stormwater drains with proper screening and silt trapping will be needed to increase the water volume with reduced nutrient content. The setting of nutrient criteria and nutrients discharge standards specific to Naukuchiatal will play a key role to regulate the nutrients load into the lake.

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