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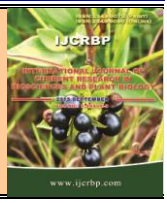

Original Research Article

Phyto-Remediation of Lake Ecosystems around Tourism Sites of Garhwal and Kumaun, Uttarakhand and their Conservation Status

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Abstract

Lakes are the fresh water resources in Garhwal and Kumaun region of Uttarakhand. Various lakes like Nainital, Bhimtal, Sataal, Naukuchiatal, Khurpatal etc. has a large human population depended upon them as a source of tourism and for potable water supply. Due to the topography and high slopes in and around Nainital, the water supply departments (Jal Sansthan and Jal Nigam) are mainly dependent upon lakes ecosystem to meet the demand of stakeholders. Therefore for regulating the tourism based economy, agricultural and social activities within the lake surrounding areas of Nainital district of Uttarakhand State, requires an urgent need to maintain the healthy status of lakes water ecosystem as a sustainable tourism resource. The main identified problems are of domestic and sewage contamination and heavy growth of weeds due to enrichment of nutrients which has even resultant into problem of eutrophication in past. Phyto-remediation by floating rafts technology was implemented for conservation of these fresh water resources along beautification of lakes and tourist sites. This technique has helped in reducing the growth of aquatic weeds like water hyacinth and helped Lake Fauna to survive. The main identified constraints were from fishermen and few contractors who are creating problems due to ignorance. They feel that it would harm their interests of tourism attraction, fish cultivation and its productivity. But the phyto remediation technology is rather going to help them. There are Hotel and Dhaba major drains through which the dirty water is entering into lake. Sewage lines get blocked quite often in rainy season due to choking and it overflows towards lake, polluting them further. Floating rafts as a source of phyto-remediation are helpful in reducing Sulphate, COD and BOD. It controls *E. coli* population in the lakes and helps in improving DO. Growth of *Canna* was wonderful. Regular monitoring is required to determine the pollution level, sedimentation load with follow up of aeration treatment of lake water to improve and maintain the water quality in lakes.

Keywords

Eutrophication
Lakes
Phyto-remediation
Tourism
Water quality

Introduction

Himalayas, the water tower of Asia, stores a significant quantity of fresh water in the form of glaciers, seasonal quantity of fresh water in snow cover, lotic form of natural aquifers, streams, rivers and along lentic form of wells, lakes and ponds as water resources for the entire Uttarakhand State and India. Hence these water resources of the Uttarakhand Himalayas are crucial for the people inhibiting in the mountain areas as well as for the downstream regions. The major lake and ponds along with their catchments have regional importance and stored water in these sustains down stream flow during the dry seasons. Thus drying up and polluted lakes and ponds, therefore are being seriously affecting the livelihood of Uttarakhand hill people residing nearby these lakes and ponds.

An appropriate conservation policy is required to be implemented at the earliest so that rural / urban areas ponds and lakes of Uttarakhand continue to provide resources to the people, increase fishery production and Tourism for the economic benefits of the Stakeholders / Community. Such a Phyto-remediation step will help to sustain plants, animals and human life and will also help in checking soil erosion, flood control, natural sewage treatment and shoreline stabilization and recharge natural aquifers. Thus, the main focus should be on conservation of the representative treasures of nature for sustainable and equitable development through a multi-prolonged strategy, with a stress on community-based approaches. Therefore, restoration / conservation of these lakes / ponds have a great significance.

Although a number of development plans have been evolved for a few lakes like Nainital, Bhimtal, Sataal, Naukuchiatal and Khurpatal, yet no significant steps have so far been taken through Phyto-remediation towards their conservation. To naturally restore these lakes, some of the important problems may be dealt with. These include parameters like protection of the existing lake body, to arrive at correct land-use strategy and also to arrive at watershed management, soil erosion, and flood control strategy for the Uttarakhand lake Tourism spots. In addition to assess the total raw sewage and sewerage entering the lake body and reduce the nutrients entering the lake, upgrading the fish potential, installation of buffer strips and raising the socio-economic status of people within the lake body catchments, periodic monitoring of lake and its surroundings and community participation and public awareness are equally important steps. A baseline data is needed on the water quality, socio-economic status of people living in the periphery of these lakes and the land-use pattern of the lake surroundings.

Therefore, an attempt is required to develop a phyto-remediation strategy for the conservation of the natural lake and pond eco-systems by identifying the causes of the deterioration of water quality and shrinking areas of these Lentic water bodies. The present research exercise was designed to study the impacts of human settlements on some rural and urban lakes of Nainital district using the phyto-remediation technology of floating rafts developed by NITTTR Chandigarh.

Johri et al. (1989) has presented fish catch data for the period 1983-1988 for Bhimtal, Naukuchiatal and Sattal, which are managed by the Department of Fisheries. No data are available for Nainital, which is controlled by Nagar Palika (Nainital), an organisation responsible also for the monitoring of the inputs of pollutants in this lake. Mahseers (*Tor tor* and *Tor putitora*) dominated the catches in Bhimtal and Naukuchiatal, with 59.5 and 45.0% respectively of the total for the five-year period. Common carp followed, with 34.8 and 31.5% respectively, while in Sattal it formed 22.9% of the total catch. Indian major carps (*Labeo rohita*, *Cirrhinus mrigala* and *Catla catla)*, dominated the catches in Sattal with 64.1% of the total. Schizothoracines (e.g. *Schizothorax richardsonii*) represented 0.73 and 0.95% in lakes Bhimtal and Naukuchiatal, but were absent in Sattal. Silver and grass carps, introduced in Bhimtal in 1985-86, appeared in catches from that year onwards.

The average yields (kg ha^{-1} yr^{-1}) for the five-year period were as follows: Bhimtal (area 86.5 ha): 9.32; Naukuchiatal (65 ha): 0.74; Sattal (24.5 ha): 13.4. Bhimtal provides good conditions for catla and rohu, and Naukuchiatal for mrigal. The low yield for Lake Naukuchiatal seems to result from the lower fishing intensity. As a remedy it has been proposed to regularly stock this lake with fingerlings of mahseer, common carp, Indian major carps, silver carp and grass carp. Stocking the Kumaon lakes is considered essential for increasing fish yields, which, it is estimated, could be increased to 25-50 kg ha^{-1} yr^{-1} (Johri et al., 1989).

Around tourism sites, in the most common usage, it refers to the municipal waste water that contains a broad spectrum of contaminants resulting from the mixing of

waste water from different sources. Sewage is created by residences, institutions, hospitals and commercial and industrial establishments (APHA, 1998). Raw influents includes household liquid from toilets, baths, showers, kitchens, sinks and so forth that is disposed of via sewers. In many areas, sewage also includes liquid waste from industry and commerce. As rainfall runs over the surface of roofs and the ground, it may pick up various contaminants including soil particles and other sediments, heavy metals, organic compounds animal waste and oil and grease (FWPCA, 1998).

Consequently, the problem was taken up when effluents of these nearby Lake tourist spots, waste go into lake / pond ecosystem and change the physico-chemical quality of water and make it unfit for drinking and other uses. Since all natural waterways contain bacteria and nutrients, almost any waste compounds introduced into such waterways will initiate biochemical reactions. These biochemical reactions are measured as DO, BOD and COD in laboratory (Tchobanoglous et al., 2003). Both BOD and COD tests are a measure of the relative oxygen-depletion effects of a waste contaminant. Both have been widely adopted as a measure of pollution effect. The BOD test measures the oxygen demand of biodegradable pollutants whereas the COD test measures the oxygen demand of oxidizable pollutants.

Drinking water treatment efforts can became weighted down when water resources are heavily polluted by waste water micro-organism species. Pathogenic viruses, bacteria, protozoa and helminthes and other waste water micro-organism species, may be present in raw municipal waste water and will survive in the environment longer periods (Mane et al., 2005).

Sewage pathogens may be present in waste water at much lower levels than the coliform group of bacteria, which are much easy to identify and enumerate as number of total coliforms per 100 ml (Feng and Weagant, 2002). Various waste water micro-organisms species have an adverse impact on human health. Some illnesses from waste water related sources are relatively common (WHO, 1999). The objective of this study is to check the physical and chemical parameters of the lake / pond samples and to find the degree of pollution abatement after phyto-remediation implication in them.

The past records of seasonal variations in water quality of natural lakes of Nainital was undertaken (Singh et al., 2007) to analyze and compare some water quality parameters and the cations and anions load in waters of five natural lakes viz., Bhimtal, Naukuchiatal, Khurpatal, Sataal and Nainital, Uttaranchal during 2003-04 and 2004-05. The water samples were collected during summer and autumn seasons and were analysed for various parameters. The values of pH were found to vary from neutral to slightly alkaline well within permissible limits. The values of EC varied from 0.08-0.62 mS cm and that of DO, BOD, COD and alkalinity varied from 3.12 to 9.66,0.43-2.96, 65.1-373.1 and 53.1-296.4 mg L4, respectively. The concentrations of NI-14+-N, IC*, Na', Ca_2., Mg_2+, SO_4 2--S and Cl. in waters of different lakes varied from 0.14-2.07, 2.01-8.81, 10.04-44.03, 6.56-52.56, 4.33-11.08, 0.40-7.98, 0.05-1.08, 1.50-48.35, 5.05-29.85, 38.6-172.8 mg L-1, respectively. The hardness, SAR and RSC in waters of different, lakes varied from 38.6-172.8 mg L.1, 0.58-1.70 and 0.07-1.47 me L-1' respectively. Among all lakes studied, in relative terms Nainital was found to be most polluted while Punatal suffered minimum pollution. The water quality of these lakes declined during summer season when maximum tourist activities occurred. For conservation of these lakes as glory and pristine beauty of this region, a regular monitoring and effective regulatory measure are urgently warranted.

Phytoremediation: Types

Phytotransformation: Uptake of contaminants from soil and groundwater by plants and their subsequent transformation in roots, stems and leaves.

Rhizosphere Bioremediation: Occurs in the root-zone, also known as phytostimulation or plant assisted bioremediation.

Phytostabilization: Refers to holding of contaminated soils in place by vegetation and immobilization physically or chemically) of contamination.

Phytoextraction: Use of metal-accumulating plants that translocate metals from the soil to their roots and concentrate.

Rhizofiltration: Use of plants to sorb, concentrate, and or precipitate metal contaminants from surface waters (treatment wetlands) or groundwater.

Use of algae and other aquatic macrophytes: Use of algae-bacterial symbiosis instead of bacteria alone in the secondary treatment plant of waste water is extremely

efficient. Algae in general and blue-green algae in particular, are used as they efficiently removed nitrates, nitrites and phosphates. They also provide oxygen, remove nutrients and other toxic elements and bacteria and aerobically degrade organic matter.

Other green aquatic plants like floating water hyacinths can also be used for treatment of waste water. This and other aquatic macrophytes are hazardous for common lakes and ponds but when added in the secondary treatment of waste water they reduce the BOD and COD significantly in industrial wastes from paper, dairy, sugar and textile industries. Due to their easy availability, easily cultivable rapid growth rate, high mineral intake and economic potential, water hyacinths are used for waste water treatment.

Study area

Nainital, Bhimtal, Naukuchiatal, Khurpatal and Sattal Lakes are situated at an altitude from 1220 to 1937 m, and all are at latitude 29^{o}N, within a short distance of each other, and within a 25 km radius of the town Nainital (Fig. 1). All lakes are small, with the largest one, Bhimtal, covering 72 ha. Lake Naukuchiatal is the deepest, with a maximum of 40.8 m. The water of Kumaon lakes is mostly slightly alkaline. The water stratifies in spring and mixes during winter. Lake Nainital is eutrophic, with a concentration of carbonates of 288 mg l^{-1}, nitrogen 512 g l^{-1}, and phosphorus 22.5 g l^{-1} (Sharma and Pant, 1985).

Naini Lake is a natural freshwater lake, of tectonic origin, located amidst Nainital city of Uttarakhand State. It is lunar-shaped and has an outlet at the southeastern end. Naini Lake is one of the major five lakes in Kumaon hills, the four other being, Khurpataal, Sattal, Bhimtal and Naukuchiyatal Lake. Balia Nala is the main feeder-stream of the Nainital Lake.

Increasing population, unplanned growth of human settlements and tourists together appear to have taken a toll of these all beautiful lakes that gives the Lake hill resorts of Nainital District its name. According to a recent study conducted by D K Pandey of the Dehradun-based Forest Research Institute, the water quality of the Naini lake has been steadily deteriorating and is highly polluted due to the addition of exogenous wastes, as a result of more than 37 per cent increase in human population in the catchment area of the lake and too many tourists. Also, high siltation resulting in reduction of lake depth, the depth of Nainital lake has reduced from its original depth of 29 m in 1871 to only 13m in 2007.

With an increasing amount of sewage, municipal and domestic wastes finding their way into the Naini lake, the quantity of organic matter in its waters has risen sharply. This has starved the lake of cleansing oxygen, pushing up the biological oxygen demand (BOD) by over 20 times over a 10 years period. From 15.5 parts per million (ppm) in 1981, the BOD shot up to 357.23 ppm in 1991. Similarly, the concentration of free carbon dioxide in the lake which depends on the population of aquatic organisms and the type of waste added to the water ecosystem has increased by 670 per cent over the same period.

In 1993, petition was filed by Dr. Rawat, a member of social action group called 'Nainital Bachao Samiti', who approached the Court seeking its assistance to pass such orders and give such directions as would prevent further pollution of already suffocating Nainital. By an order dated 14.7.1994, the Court had felt it fit, after having gone through the petition, to appoint a Commissioner for local inspection and to give report on various important points. A perusal of that report shows that on local inspection it was found that the lake has turned dark green with an oily surface and is now full of dirt, human faeces, horse dung, paper polythene bags and all sorts of other waste. Most of the sewer lines, which leak, ultimately disgorge the faecal matter into the lake through the drains, which open into it. One more petition was filed in 2006, in which a panel chaired by the state's chief conservator of forests directed that construction at Hanuman Garhi Park be stopped, which is at hillock.

Fig. 1: Nainital Lake and Khurpatal Lake.

Nainital Lake

Khurpatal Lake

Lake Nainital is the primary source of drinking water for Nainital. The seasonal tourist influx temporarily adds an average of 100,000 people to this area each year. From

1990–2007 seven tube wells that abstract bank filtrate were installed adjacent to Lake Nainital. Dash et al. (2008) found that the water from the tube wells have a better bacteriological quality than that taken directly from the lake using sand filter units. Only 99% reduction of total and fecal coliform counts was achieved by the sand filter units. Issues in Nainital are nitrogen species in water and pollutants from road run-off and urban sources via sewer canals entering the lake.

Bhimtal and Naukuchiatal have moderate levels of nutrients and are mesotrophic. Lakes Khurpatal and Sattal are poor in nutrients. The rising level of nitrogen in Lake Nainital indicates an increasing pollution: in 1955 the ammonium nitrogen and nitrite nitrogen were 23 g l^{-1} and traces, respectively in 1975 the corresponding values were 156 g l^{-1} and 18 g l^{-1} (Pant et al., 1985). The result has been an increase in biological production, leading to a higher organic matter production and its deposition on the bottom, resulting in anoxic conditions in the bottom water layers. Winter mortality of fish in Lake Nainital and Lake Naukuchiatal is now a regular feature.

Materials and methods

The socio-economic data was collected by information gathered from Municipal Office, Block office, Villagers and local officials from Gram Shabha and Gram Panchayat. Water samples were collected from various five lakes nearby tourist sites of Nainital district in Uttarakhand State. The places from where the water samples were collected includes: Nainital, Bhimtal, Naukuchiatal, Khurpatal and Sattal. Water samples were collected once every month during April-June (in heavy tourist influx season) from two sides, middle of the lake and discharge / intake point at various monitoring spots.

The water samples were collected in prerinsed clean one liter polythene (plastic) bottle having double stopper facility to its full capacity without entrapping air bubbles inside it. When the water samples from all the monitoring sites were received, systematic analysis of the water samples was under taken. For analysis of samples, methods followed were of (APHA, 1998).

Temperature, pH and turbidity were measured by thermometer, digital pH meter (NIG 333) and UV – VIS Spectrophotometer. The most common physical assessment of water quality is the measurement of temperature. Temperature impacts both the chemical and biological characteristics of surface water. Total alkalinity, total hardness, DO, BOD and COD was measured by Titration method. Microbial analysis was done. After growing in mix culture, they were inoculated in selective media viz. EMB agar, Brain Heart infusion agar, Mac Conkey agar, Mannitiol Salt agar and nutrient agar for isolation of different micro-organisms in the lake / pond water samples. The various morphological characteristic of recovered isolates *viz.*, colony morphological (Colour, Shape, Arrangement and Gram Staining) and the biochemical tests carried out for identification of isolates (Holt et al., 1994). The bioremediation processes of treating water was carried out as per the details below and the step-by-step pictorial representation given in Figs. 2 to 7.

Part I:

Constructed and Floating Wetland: A Pilot Project to treat Hostel Mess Wastewater at NITTTR, Chandigarh

Part II : Replication in a Village

- **Experiment with Pond wastewater**
  - **Ponds and their Importance**
  - **Present Status : Waste Water Contamination**
  - **Constructed Wetland Treatment**
  - **Treatment by Floating Wetland**
  - **Water Quality Analyses**
  - **Conclusion and Future Course of Action**

Constructed Wetland:

A Pilot Project to Treat Institute Hostel Mess Wastewater

- **Sedimentation Tank**
- **Tank I (Filtration Bed)**
- **Tank II (Filtration Bed)**
- **Tank III (Filtration Bed)**
- **Collection Tank (Floating Rafts)**
- **Irrigation Tank**

Fig. 2: Constructed wetland: A Pilot Project to treat Institute Hostel Mess wastewater
I – Sedimentation Tanks : Each 1.2m x 0.70 x 1.50m

Tank I (Filtration Bed)
4.20m x 1.50m x 1.50m

Tank II (Filtration Bed)
4.20m x 1.50m x 1.50m

Tank III (Filtration Bed)
8.50m x 1.50m x 1.50m

Collection Tank
2.70m x 1.20m x 1.80m
Water Depth = 0.90 m

Fig. 3: Constructed wetland: Hostel Mess wastewater treatment and filtration beds.

Tanks filled up with filter medium

Trials of plants in the filtration beds

Fig. 4: Fabrication and testing of rafts.

Design of Raft

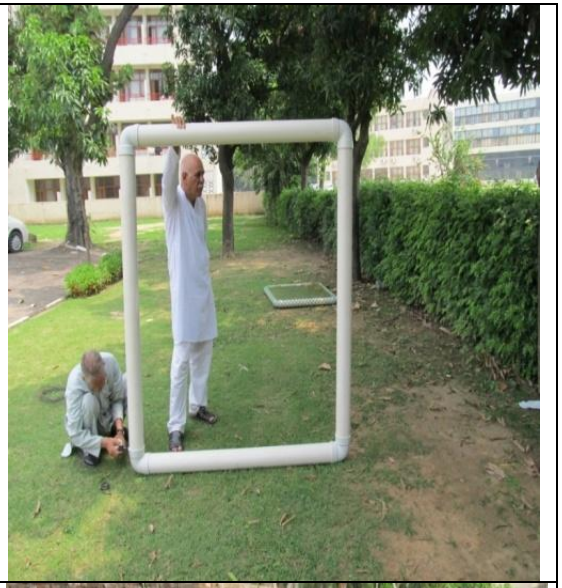
Materials Required

1. **PVC pipe 4" dia 4 sqm**
2. **PVC net 4 sqm**
3. **Coconut coir = 10 Kg**
4. **Adhesive, elbow, m seal etc.**
5. **Plants**

Cost per Unit

1. **Rs. 2500 per raft**
2. **Rs. 500 for Plants**

Total = Rs. 3000 (33.3 £)



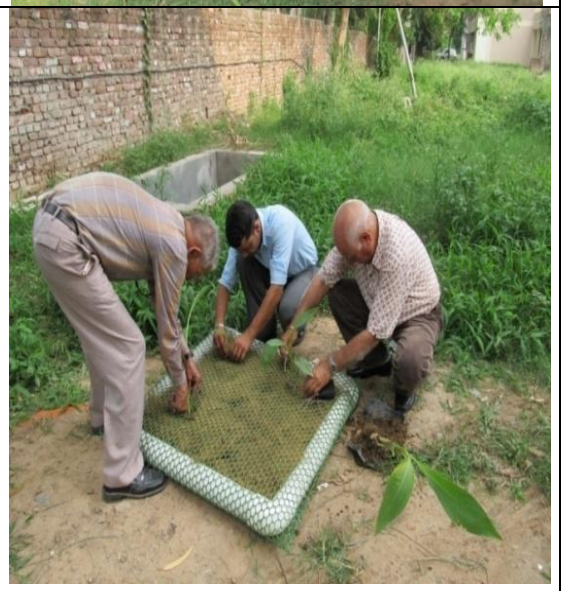


Fig. 5: Testing of rafts with *Canna* plants.

Collection tank (Fish pond)

Growth of *Canna* roots after two months

Fig. 6: Design and fabrication of a low cost boat (Appropriate Technology) Rs. 5000 (55.5£)

Growth of plants (after two months)

Floating rafts under trial

Fig. 7: Blossoming *Canna* flowers has improved the aesthetic look of the Padaul village pond.

- **Floating rafts are helpful in reducing Sulphate, COD and BOD.**
- **It controls *E. coli* population in the pond.**
- **It helps in improving DO.**
- **Growth of *Canna* was wonderful.**
- **Other plants like Khus khus, Money plants and Phragmitis are being tried.**

Results and discussion

The unplanned urbanization and haphazard residential agglomeration compounded by lack of adequate sewerage network facilities, leading to discharge of high volumes of domestic wastes in open drains. Infiltration / Seepage from such activities had contaminated the ground water along lake water, as evidenced by the presence of parameters like- TDS, hardness, nitrates, sulphates and florides in concentrations above the permissible limits. The present ongoing investigation conclude that the quality of water samples subjected to study was acceptable from physio-chemical parameters, while *E. coli*, an indicator of fecal pollution was found in all samples.

It was found that the all the lakes had a varied tropical status, ranging from meso-tropic to hyper eutrophic. It was an event of the past 10-30 years coinciding with a maked civilization evolution in the surrounding areas. As a result of heavy anthropogenic pressure, the lake systems were not only shrinking in their surface areas but their water quality were also deteriorating, posing hazards to the habitants. The main identified threats to these lake / pond ecosystem includes:-

(i) Pressure on the lake systems due to accelerated land-use which was promoting higher disposal of domestic refuse, garbage and sewage into the water.

(ii) Higher soil and silt load from surrounding hills, agriculture run-off, plant debris, other allocthoncous material resulting in the filling up of the lake periphery.

(iii) Land reclamation for agriculture and habilitation, and

(iv) Over-exploitation of the produce available in these lakes.

Large areas of lakes Sattal, Bhimtal, Nainital and Naukuchiatal are now infested with aquatic macrophytes, such as *Polygonum*, *Hydrilla*, *Potamogeton*, *Myriophyllum* and *Vallisneria*. In addition, Nainital also accumulates detritus from human activities around the lake. In Nainital, water is considered to be of poorer quality than in the other lakes, and this lake also has experienced with eutrophication problem.

Major findings

- Floating rafts are helpful in reducing sulphates, COD and BOD.
- It controls *E. coli* population in the pond.
- It helps in improving dissolved oxygen.
- Growth of *Canna* is excellent and aesthetic.

Constraints

- Fishermen and few contractors are creating problems due to ignorance. They feel that it would harm their interests of fish cultivation and its productivity. But the project is rather going to help them.
- There is one major drain through which the dirty water of whole village is flowing. The drain gets blocked quite often and it overflows towards pond, polluting it further.

Future course of action

- Another village - Salamatpur has been selected for the experiment.

- Filtration Bed will be constructed near to two inlets of the pond

Management and conservation status and strategies in Khurpatal Lake

Khurpatal is one of the many lakes in Nainital region. It lies in the depression formed by movements in the earth's crust. Steep slopes surround this water body. Ecological degradation begun in this lake due to excessive inflow of sediments and sewage from surrounding areas and pollution caused by dumping of solid waste in the water body.

Construction of a new housing project adjacent to the Khurpatal by the Army Welfare Housing Organization (AWHO) caused afresh hue and cry among the villagers in the surrounding area when Dr. Ajay S. Rawat, Professor of History in Kumaondr3rf University filed a **PIL** against the illegal boring of groundwater in the area this January. AWHO announced a launch of a building project in the area this year. Khurpatal being located only 10 km from the Nainital town is also a favorite tourist destination. The constructors had already bought land very near to Khurpatal back in 2000-2001 and started boring wells in the area. The villagers in the area use the lake water for farming.

The villagers residing down hills stood against the exploitation of the groundwater, which they feared would affect their irrigation water. Due to the agitation of the villagers, the District Magistrate stepped into the matter and the construction was stopped. In the year 2006, the builders started the project again with drilling of borewells. The villagers brought this to the notice of the High Court (HC) of Uttarakhand. The court ordered a status quo against the boring activities. The sub divisional officer of the Nainital district ordered the Central Public Works Department (CPWD), to stop the activity.

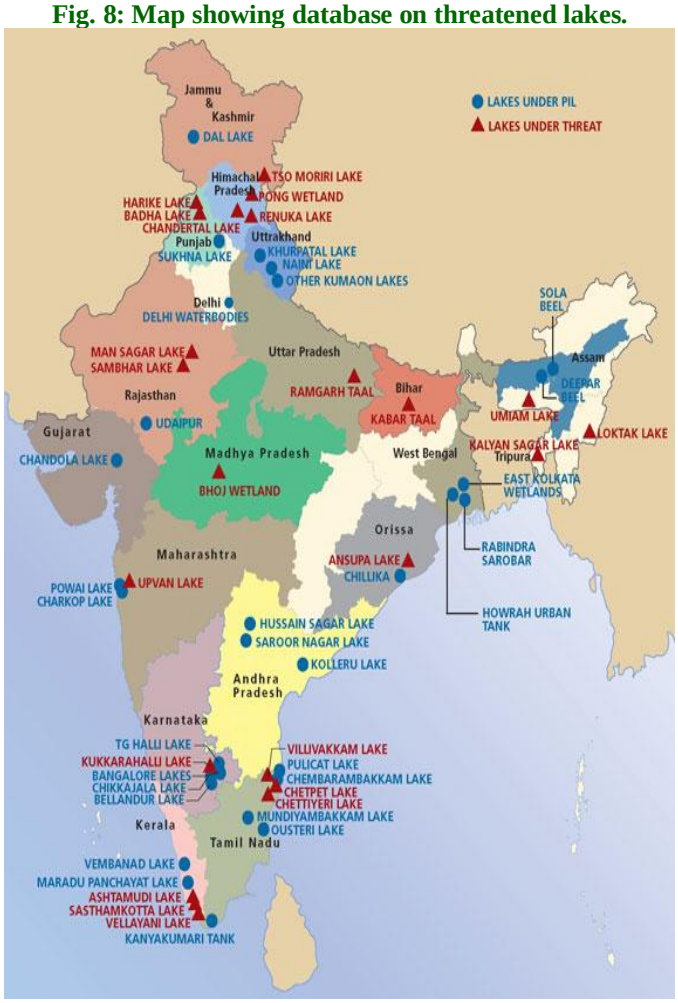
In response to the request of the villagers, the Commissioner of Kumaon Division approached the Department of Geology and Jal Nigam to submit a survey report on the impact of boring in the lake area. The survey report clearly mentioned how the mindless extraction of groundwater from the area would affect the springs in the downstream area. According to these experts, the lake acts as a source to these springs. The water of the lake passes through fractures to these springs. The farmers depend on these springs and the livelihood of these poor farmers will be affected. The temporary injunction was rejected in the HC but the villagers again appealed in the District Court and managed to get a stay order.

The final hearing is still pending. In spite of this stay order, AWHO again resumed illegal boring in the area. According to Rawat, there is a fear that the sewage of the building apartments will be directly connected to the water body. The advocate Rajiv Singh Bisht is very hopeful to get justice for the peasants. As a fist phase of achievement, Bisht explains that the court has ordered the Chief Conservator of Forest and District Magistrate of the Nainital District to visit the site and learn the impact of groundwater mining. Rawat is satisfied of the fact that the civil authorities had stopped the illegal pumping of groundwater, in spite of the fact that the court order is still pending.

Tiwari (2008) while studying the land use changes in Himalaya and their impacts on environment, society and economy: A study of the Lake Region in Kumaon Himalaya, India revealed that the traditional resource use structure in Himalaya has transformed considerably during the recent past, mainly owing to the growth of population and the resultant increased demand of natural resources in the region. This transformation in resource use practices is particularly significant in the densely populated tracts of Himalaya. As a result, cultivated land, forests, pastures and rangelands have been deteriorated and depleted steadily and significantly leading to their conversion into degraded and non-productive lands. These rapid land use changes have not only disrupted the fragile ecological equilibrium in the

mountains through indiscriminate deforestation, degradation of land resources and disruption of the hydrological cycle, but also have significant and irreversible adverse impacts on the rural economy, society, livelihood and life quality of mountain communities.

Fig. 8: Map showing database on threatened lakes.



It has been observed that the agricultural production has declined, water sources are drying up fast due to decreased ground water recharge and a large number of villages are facing enormous deficit of critical resources, such as food, fodder, firewood and water, mainly due to unabated deforestation. As a result, the rural people, particularly the women, have to travel considerably long distances to collect fodder and firewood and to fetching water. It is therefore highly imperative to evolve a comprehensive and integrated land use framework for the conservation of the biophysical environment and sustainable development of natural resources in Himalaya. The land use policy would help local communities in making use of their natural resources scientifically and judiciously, and thus help in the conservation of the biophysical environment and in the increasing of the productivity of natural resources. The study indicates that conservation of forests and other critical natural resources through community participation, generation of alternative means of livelihood, and employment in rural areas can help increase rural income as well as restore ecosystem services. The database on threatened lakes in India is shown in Fig. 8.

Management and conservation

Traditionally, water was seen as a responsibility of citizens and the community collectively took the responsibility of not only building but also of maintaining the water bodies. Since independence, the government has taken control over the water-bodies and water supply. This, over time, has led to the neglect of the water bodies and catchments areas. People have become used to getting water at the turn of a tap and are no longer interested in maintaining water bodies.

However, there is still hope as concerned citizens across the country have come together to fight to halt this degradation of urban water bodies. In state after state, citizens and NGOs have filed legal cases for protection of urban lakes. Public Interest litigations (PILs) have been filed for the protection of the water bodies in many cities. It is believed that the ecological degradation of the Himalayan lakes has not yet reached the state of no return. Dal and Wular lakes in Kashmir, and Nainital in Uttarakhand, have especially been adversely affected by pollution and poor management of land in their catchments. The lakes are undergoing eutrophication and biological degradation.

The following discusses some ways of improving the current situation

In recent years the increase in land use as a result of intensive agriculture and urbanisation in watersheds has resulted in an increased input of organic waste into rivers and lakes. This has led to eutrophication of some lakes, and pollution of streams. Lakes Nainital and Bhimtal in Kumaon, and lakes Wular and Dal in Kashmir are examples of such an impact. Lake Dal is facing a serious problem of shrinkage. Between 1911 and 1984 the open water area was reduced from 1507 ha to 700 ha, while marshy areas increased from 800 to 1530 ha. 40,000 to 52,000 t of dead aquatic plants and other organic material from intensive agricultural and

horticultural activities on the margins of the lake are added annually. Lake Dal is also suffering from the input of domestic waste from anchored boats, lakeside hotels and settlements along its shore. This alarming situation calls for urgent phyto-remedial measures, if Lake is not to disappear in the not so distant future.

Biological contamination of water

Ground water pollution is caused by coming water from seepage pits, refuse dumps, septic tanks and barnyards percolates into the layers of the earth, reaches the ground water table and pollutes it. It could be many years before the polluted water shows up in the underground water resources. Nutrient-rich water is also rich in different types of bacteria, protozoa, worms and other types of organisms. These micro-organisms use the carbon from various compounds to build up their bodies. Water bodies polluted with organic matter are a good medium for the growth of protozoa. Most worms and parasites enter through food chain and infest the internal organs of man and animals thus making them sick.

The degree of pollution with pathogenic bacteria is measured by the presence of *Escherichia coli* or *E. coli* (gram negative rod shaped bacteria). These series of bacteria are present in the intestine of human beings and animals. Although they are harmful to human beings the numbers in which they are present indicate the degree to which water is polluted with human and animal excrements (as shown in Table 1).

Table 1. Extent of pollution in water bodies by *E. coli*.

Presence of *E. coli* per litre in water	Water condition
10,000	Heavily polluted
1,000	Polluted
100	Slightly polluted
10	Satisfactory
3	Suitable for drinking

Nainital Lake has also undergone eutrophication in past, due to the increased input of nutrients from various human sources. Direct eutrophication can be measured both by quantitative and qualitative methods. Table 2 illustrates the qualitative features of both oligotrophic and eutrophic water bodies. The results obtained in the present study on the water quality parameters in artificial pond water and Padual are shown in Tables 3 and 4.

Table 2. Characteristic of oligotrophic and eutrophic water bodies.

Parameter	Oligotrophic	Eutrophic
Production (plant and animal)	Low	High
Variety	Many species	Few species
Distribution	To great depth	Trophogenic layer
Diurnal migration	Extensive	Limited
Water blooms	Very rare	Frequent
Plant nutrient flux	Low	High
Oxygen lower level	Present	Absent
Water quality for domestic use	Good	Poor
Presence of Salmon fish	Present	Absent

On the other hand, measurement of oxygen, biological productivity and the nutrient level in water provides a direct quantitative measurement for eutrophication. Sometimes, oligotrophic lakes are purposefully turned into eutrophic lakes by controlled addition of fertilizers (nutrients) for fish cultivation. Water pollution leading to eutrophication is a threat not just to fisherman but also to those who depend on Tourism and other recreational activities on water bodies.

Table 3. Artificial pond water quality analyses results.

Sr. No	Parameters	1st set of samples		2nd set of samples		3rd Set of samples				4th set of samples			
		4th August, 2011		31st August, 2011		23rd October, 2011				12th December, 2011			
Collection point→		Entry	Exit	Entry	Exit	Entry	Exit	Central	Drain water	Entry	Exit	Drain water	2nd Pond
1.	Colour	316	1018	433	437	460	227	305	573	105	115	195	93
2.	Turbidity(ntu)	33	139	30	45	22	11	11	40	7	5	6	4
3.	pH	6.77	6.99	6.77	6.84	7.08	7.18	7.2	6.97	6.58	7.3	6.9	6.95
4.	Total Hardness (mg/lit)	88	120	120	180	160	145	160	420	160	145	385	160
5.	Total Dissolved Solids (mg/lit)	350	383	245	240	365.3	337.5	367.5	877.5	367.5	356.2	1015	296.2
6.	Sulphate (mg/lit)	60	250	60	92	3.87	5.37	10.19	33.83	4.2	3	16.7	5.38
7.	Nitrate (mg/lit)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
8.	C. O. D. (mg/lit)	520	520	100	80	204	76	44	548	256	198	220	200
9.	D.O. (mg/lit)	5.2	5	5	5.2	11.6	12.2	12	4.4	14	10.6	9	11.4
10.	B.O.D. (mg/lit)	60	60	37.8	38.8	217.6	2.2	34	650.4	196	95	145.4	118.4
11.	*E. coli*	present	present	present	present	absent	absent	absent	absent	absent	absent	absent	absent
12.	Microbial count (MPN)	-	-	-	-	nil	nil	nil	nil	1	1	2	2

Table 4. Results of water quality parameters at Padual.

Sr. No.	Parameters	5th set of samples			6th set of samples	
		9th February, 2012			10th April, 2012	
		Entry point	Exit point	Drain water	Entry point	Exit point
1.	Colour	293	223	467	881	833
2.	Turbidity (ntu)	16	9	33	55	50
3.	pH	7.15	7.08	7.42	8	8.07
4.	Total Hardness (mg/lit)	206	190	355	230	224
5.	Total Dissolved Solids (mg/lit)	532.5	451.5	1173.8	594.8	600
6.	Sulphate (mg/lit)	35	19	54	48.2	40
7.	Nitrate (mg/lit)	Nil	Nil	Nil	13.2	13.2
8.	C. O. D. (mg/lit)	276	220	320	60	48
9.	D.O. (mg/lit)	11	4	4.2	10.4	7
10.	B.O.D. (mg/lit)	477	440	390	70.4	82
11.	*E. coli*	absent	absent	absent	absent	absent
12.	Microbial count (MPN)	nil	nil	nil	-	-

Eutrophication can be controlled by:

(a) Limited inputs of nutrients through treatment of waste water before discharge into water bodies.

(b) Removal of dissolved nutrients from water bodies using physical, chemical or biological means.

(c) Harvesting algal blooms to check recycling of nutrients supply to water through their death and decay.

(d) Reduction of amount of nutrient solubilized in water through stimulation of bacterial multiplication, to disrupt the algal food web.

Construction of embankments to protect crops against flooding, and planting trees along the margins under a social forestry programme have also contributed to the process of shrinking of the lakes. The shallowness of the lake has become a hindrance for navigation, including recreational boating. The changes have also adversely affected fish production and the growth of lotus and *Trapa* plants, and the number of game birds has been declining.

In the Kumaon, the growing demands of local residents to meet the challenge of increasing tourism and other development programmes have increased pressure on Lake Nainital. Kumaon Himalaya, especially the lakes, have been witnessing a dramatic increase in recreation. In Nainital, the numbers of tourists increased from 1,60,000 in 1958 to 6,80,000 in 1986 (Singh, 1989). Lake Nainital has been so badly damaged by the input of sewage that it cannot fully recover even if the pollution discharge into the lake is diverted (Sharma and Pant, 1985). Fish kill in some Kumaon lakes has now become an annual occurrence.

In 1988, in the State Jammu and Kashmir there were 9976 full-time fishermen. In Kumaon Himalaya there are no such professional fishermen, but angling is common in Bhimtal, Naukuchiatal and Sattal. Fishermen fishing Gobindsagar and Pong reservoirs in Himachal Pradesh are organised in cooperative societies. More attention needs to be paid to prevent indiscriminate fishing, and to the enforcement of closed seasons and mesh size limits. Environmental aspects, especially rehabilitation of watersheds to prevent excessive siltation of rivers and lakes, and prevention of pollution to reduce the rapid eutrophication of some lakes and reservoirs, also need to be urgently addressed.

Enhancement of lake and reservoir fish stocks will require continuous hatchery production of a sufficient number of stocking material, especially common carp and the indigenous mahseers and schizothoracines. In some lakes, where it would not lead to an increase in the rate of eutrophication, a pilot scale cage culture could be tested and introduced. Lakes holding already self-sustaining stocks should be carefully managed to avoid overfishing. Some of these water bodies should be selected as fish sanctuaries.

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