Study of Himalayan Lakes in Nepal

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Abstract
Water resources of Nepal include rainfall, snow cover, surface water and Ground water. About 12% of total rainfall of Nepal is converted into snow which sustains the low flow of rivers during summer that occupy 15% of the total area. Loffer started to study of Himalayan lakes in Nepal then other scientist and socio-economist studied about lakes and ponds. Among them scientific studies occupy the highest percentage (i.e. 66%) then the other disciplines like management, general and socio-cultural. National and international scientists involve in Himalayan Lake studies. Limnology, (planktons, macrophytes, macro invertebrates, environmental change, and diatoms), surrounding vegetations, habitat type, water quality and holly aspects covered by the Himalayan lake study.

1. Introduction

Water resources in Nepal predominantly freshwater in nature and come from the annual precipitation by monsoon July-September and also by westerly. About 96% rainfall is from monsoon and only 4% is from westerly in the winter (Sharma 1997). On the physical basis, water resources can be divided into four categories, viz. i. Rainfall; ii. Snow cover; iii. Surface water (rivers, lakes, ponds); and iv. Ground water (deep & shallow). More than 6,000 rivers and rivulets are present in Nepal are belonging to four main drainage basins, viz. Saptakoshi, Gandaki, Karnali and Mahakali river basins with total catchment area 181,000 sq km (77.43%) is in Nepal and the rest in Tibet (Sharma 1997). It is estimated that the rivers cover about 395,000 ha and contribute about 43% of the country's water body (FDD 1992). The paddy fields retain a huge amount of rain water as they constitute a significant amount of water holding area (est. 325,000 ha) during the monsoon season. The rest of the water bodies are marshy land (1.61%), village ponds (0.70%), lakes (0.67%) and reservoirs (0.19%) (GON/MFSC 2002).

About 12% of total rainfall of Nepal is converted into snow which sustains the low flow of rivers during the summer. The land under perpetual snow is 15% of the total land of Nepal. Snow along with glaciers also acts as a balancing reservoir for water as well as heat of the sub-continent. Snow melt starts in March and continues up to August. Glacier is another important characteristic of the Himalaya. At least 80 glaciers have been listed; the longest being Chhuling Glacier in Manaslu area with total length of 14 km which extends from 7,000 m to 3,020 masl altitude. A study carried out by ICIMOD reported 2,323 lakes situated above 3,500 masl in Nepal (Mool et. al 2001).

2. Geographic coverage

Nepal boasts lakes of varied ecological conditions from subtropical lowland Terai to alpine high altitude providing opportunities for wide array of studies. Till date 163 literatures/publications including masters' degree thesis on the study of lakes and ponds in Nepal were listed from various sources of information (Bhuju & Gaire 2009). Besides these, 40 reports based on district level consultation and lake survey conducted by Nepal Academy of Science and Technology (NAST), National Trust for Nature Conservation (NTNC) and Central Department of Environmental Science, Tribhuvan University (CDES/TU) with support of National Lake Conservation Development Committee, Government of Nepal have been prepared.

Of the total 203 literatures, 66% were based on scientific objectives, mainly on water quality analysis, fisheries and limnology (**Figure 1**). Among scientific studies about 35 were Master degree thesis in different discipline of science mainly botany and environmental sciences. Eight percent of the studies had their management objectives. Some studies were also on general socio cultural aspects (1%). The first literature related to lakes of Nepal was the one by Löffler in 1969. He explored 24 high altitude lakes located at the altitude of 4,500 m – 5,600 masl in the Mount Everest region, and reported the first data on morphometry, temperature, chemistry and biology (Löffler 1969). During 1970s, the number of studies was eight, which increased to 20 during 1980s. During 1990s, the number of studies reached 58, thanks to the initiatives of academic centers, especially the Tribhuvan University. During 2001-2009, 76 studies on lakes and ponds were conducted (**Figure 2**).

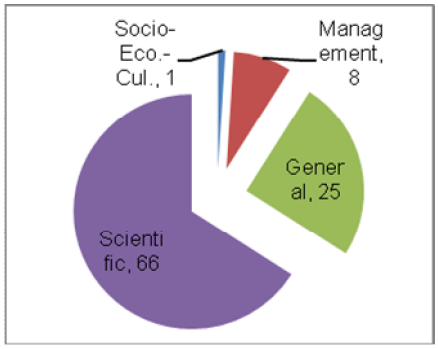

Figure 1: Study Research of Lakes in Nepal by Objectives

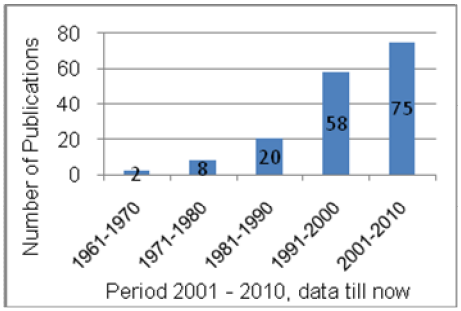

Figure 2: Lakes Studies in Nepal during Various Periods

By physiographic zones, majority of Nepal's lakes and ponds are located in the high altitudes (12%) and lowland (12%), but much of the studies conducted so far were in the middle mountains and Churiya, where 84 and 40 studies were carried out covering 76% of the total lake/pond studies in Nepal (**Figure 3**). Among the studies carried out in the middle mountains, most of them were in Pokhara and Kathmandu valley. From the remote high mountains, 21 publications were listed, half of which were based in Mount Everest region. Thus, there exists a stark discrepancy in the lakes studies in Nepal, which could be because of geographic remoteness and resource constraints. Of the total studies, majority (76%) was conducted by Nepali researchers, 15% by foreigners and the rest jointly (**Figure 4**).

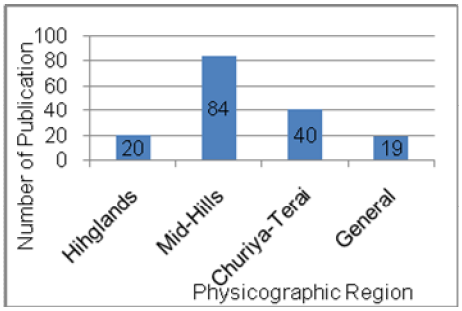

Figure 3: Lakes Studies in Nepal by Physiographic Zones

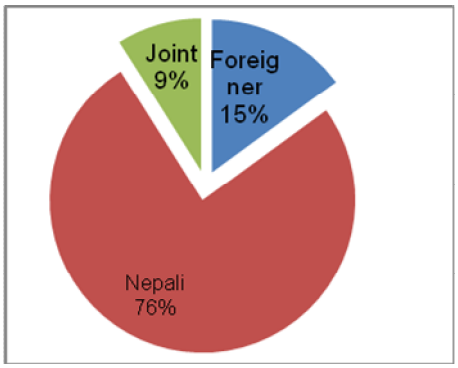

Figure 4: Research Studies Lakes of Nepal Origin of Researchers

3. Study Scope

The research studies carried out in the lakes and ponds of Nepal have covered various aspects of limnology (Ferro 1978, Okino & Satoh 1986 etc.), plankton, macrophytes, macroinvertebrates (Manca *et al.* 1998, Bhatt *et al*. 1999 etc.), environmental change (Lami *et al*. 1998, Sharma et al 2009), diatoms (Hickel 1973a, b; Lohman *et al.* 1988 etc.). Studies on the composition of vegetation surrounding the lakes have been carried out by Baral (1992), Bhattarai (1997) etc. in order to understand the habitat type. Some studies have included both the vegetation and water quality (Adhikari 2009, Neupane 2009, Khadka 2009) while others focused on the relationship between floral composition and water quality (Shrestha 2002). Studies on seasonal change in physical and chemical parameters of lake waters have been useful in categorizing the lakes and their status (Lohman *et al.* 1988, Gautam & Bhattarai 2008 etc.).

As the lakes have been religious sites and pilgrimage for many communities in Nepal, research study scope has extended to their socio-cultural values and conservation aspects. IUCN (1998) listed over 20 lakes and ponds that are considered very holy by various religious groups. The cultural importance of the lakes have been studied and reported by Baral (1992), Bhandari (2005). Recent studies of lakes have included listing the important dates of cultural/religious events (Neupane 2009, Khadka 2009 etc.). On the conservation management and local knowledge, the works by Shrestha (2004), Gurung *et al.* (2005), Wagle *et al.* (2007) are worth mentioning here.

4. Lakes in High Mountains

Aizaki (1985) studied trophic status and water quality of Lake Tilicho in Central Nepal Himalaya. The lake is one of the largest glacier-fed lakes with slightly turbid water color and strong chemical stratification. This study revealed a low concentration of total phosphorus (1– 6 mg/l) and total nitrogen (0.16 to 0.25 mg/l) in water. The chemistry of 31 lakes at altitudes between 4,530m and 5,480masl in the Khumbhu and Imja Khola valleys was considered, around a third of which was reported to have been made up of Na^+ and Cl^- of marine origin transported by the summer monsoon (Tartari *et al* 1997). Three groups of lakes with different levels of ion concentrations and silica were highlighted using cluster analysis. Palaeolimnological analysis of four Himalayan lakes (Piramide Superiore, Piramide Inferiore, Lake N. 40 & Lake N. 70) was carried out in the Everest region. Despite being characterized by very slightly polluted chemical conditions, the sedimentary record of phytoplankton and benthic algae in lake Piramide Inferiore and Lake N. 40, showed that there have been periods of high productivity.

Rara, which is the biggest natural lake of the country, lies at an altitude of 2,990masl in far western Nepal. It covers an area of 9.8 km^2 and has only one outlet that joins the river Karnali that makes one of the three major river basins in Nepal. Thermocline in this lake was visible below 14m to 50m and was recorded as 7.5 to 7.6°C (Ferro 1978, 1979). Similarly, the morphology, physics, chemistry and biology of the lake measured high pH, conductivity and total hardness. The lake was classified as oligotrophic in limnological terms, meaning very slightly polluted based on the studies carried out on chlorophyll *a* estimation, total nitrogen and dissolved oxygen (Okino & Satoh 1986). Recently Sharma *et al.* (2009) studied on the impacts of global climatic change on biodiversity of high altitude lake Gokyo in Everest region.

5. Lakes & Ponds in Kathmandu Valley

Kathmandu valley is said to be a big lake and a legendary Manjushri drained it at Chovar gorge for the settlement. Natural lake as remnant of this is represented by Taudah near the gorge. Various biological component including phytoplankton and physicochemical parameters of water samples of Taudah pond in Kathmandu Valley have been studied by Hickel (1973), Bajracharya (1982) etc. A more detailed investigation on chemical aspects of Taudaha and Nagdaha – the largest ponds in the valley was performed Lohman *et al.* (1988), Jones *et al.* (1989). Similarly, ponds in Kirtipur and Bhaktapur have been studied both chemically and microbiologically (Joshi 1979, Parajuli 1997). From the studies, high levels of chloride and phosphate as well as coliform bacteria were reported.

6. Lakes in Pokhara Valley

Pokhara valley contains several lakes, the most popular are: Phewa, Rupa, Begnas and Khaste, which finally drain their water into the Saptagandaki river system. These lakes are well studied compared to other regions. Temperature, transparency, electrical conductivity, pH and alkalinity of the lakes were investigated followed by species composition, vertical distribution and seasonal variations of phytoplankton (Hickel 1973b). Three major lakes (Phewa, Begnas & Rupa Tal) were investigated in two seasons to examine the influence of monsoon on their limnological conditions (Lohman *et al.* 1988). Calcium concentration in Phewa Tal accounted for 66.3% of the cation and 43% in Begnas and Rupa Tal; anions

were predominantly bicarbonate in all three lakes. The most complete limnological investigation was carried out in Nepal in 1989, in which 50 lakes were surveyed, including the lakes from Pokhara Valley (Jones *et al.* 1989). Rai (2000) studied and analyzed limnological characteristics in three lakes of Pokhara (Phewa, Begnas & Rupa) from 1993 to 1997. The annual water temperature ranged from 12^0c to 29^0c in all lakes.

7. Lakes in Churiya-Terai Region

The wetland list prepared by IUCN (1996) mainly included lakes and ponds from the lowland Terai of Nepal. Devital, Lamital and Tamortal were investigated in Chitwan National Park and classified as oligotrophic. Limnological work on the lakes of far western region of Nepal is limited (Metcalf & Eddy 2000). Bhuju (2004) recorded some lakes in the dry lands of Churiya hills and highlighted their importance of. Recently, Adhikari (2009), Neupane (2009) and Khadka (2009) studied the water quality and surrounding vegetation of dryland lakes of Churiya hills in far western Nepal, viz. Mudka, Betkot and Jhilmila Tal. Studies were carried out in Beeshhazari at Chitwan (Jayana 1997, Burlakoti & Karmacharya 2004), Ghodaghoti at Kailali (Baral 1992, Bista *et al.* 2008 etc.).The compositions of benthic macroinvertebrates of two ponds in Mahottari district were studied (Mahato & Yadav 1984), where 31 taxa were recorded and the pond was classified as eutrophic.

8. Lakes & Biodiversity

It is estimated that nearly one fourth of Nepal's biodiversity is wetland/lake dependent (Bhandari 1992).The occurrence of lakes and ponds in diverse ecological zones have made it rich in flora, thus, supporting significant number of aquatic and/or fresh water dependent fauna (Jha & Lacoul 1998). Table 4 presents common flora and fauna found in wetlands of three different physiographic zones of Nepal, viz. High Mountains, Middle Mountains and Lowland Terai. The High Mountains include mainly glacial lakes and tectonic lakes such as Rara, Phoksundo, Tilicho and Gosai Kund. They are of oligotrophic type and contains less diversity of flora with reed and sedges. The glacial lakes do not contain fauna; however, the tectonic lakes contain some mammals (e.g. smooth otter, vole), birds (e.g. bar headed goose, shelduck, etc.), amphibians (e.g. Himalayan toad), and fishes (e.g. snow trout). The lakes of Middle Mountains are generally tectonic origin and rain-fed. The water is mesotrophic or eutrophic, and is comparatively rich in flora and fauna. The lowland Terai contains rivers with flood plains and ox-bow lakes, and they are mesotrophic or eutrophic with rich biodiversity.

9. Conclusion

The growing concern for environmental degradations, formulation and implementation of new environmental strategies study of Himalayan lakes is important. Study of Himalayan lakes is not satisfactory till date due to lack of technology and financial sustain in case of Nepal. Coverage of different theme and extend of all the geographic regions is needed to enhance.

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