WETLAND CONSERVATION THROUGH WATER QUALITY ASSESSMENT AND WILLINGNESS TO PAY

(A Case of Baral Danda Lake Complex, Kaski, Nepal)

Master of Science Thesis

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LETTER OF RECOMMENDATION

This is to certify that **Ms. Anima Shahi** has prepared this dissertation entitled "**Wetland Conservation through Water Quality Assessment and Willingness to Pay - A Case of Baral Danda Lake Complex, Kaski, Nepal**" under our supervision and guidance. This dissertation work reflects her original work and fulfills the requirements for the completion of Master of Science Degree in Environmental Science.

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I, **Anima Shahi**, hereby declare that the dissertation work entitled "**Wetland Conservation through Water Quality Assessment and Willingness to Pay - A Case of Baral Danda Lake Complex, Kaski, Nepal**" presented herein is my own work, done originally by me and has not been submitted or published elsewhere and all sources of information used are duly acknowledged. Errors, if any, are the responsibility of my own.

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ABSTRACT

The wetlands located at the periphery of Baral Danda Lake Complex (BDLC), Kaski, Nepal serves plethora of ecological and socio-economic benefits, yet they are subject to increasing natural and anthropogenic disturbances. This study aims in finding situation of wetlands conservation based upon the assessment of water quality index (WQI) of Bach (1980) in three lakes: Gunde, Neureni and Khaste of Lekhnath municipality. The study was carried out for two seasons; dry and rainy from March, 2010 A.D. to July, 2011 A.D. The socioeconomic analysis was done using contingent valuation method (CVM) for estimating willingness to pay (WTP) in lake conservation.

The lakes were found to be critical pollution (II-III) during dry season and severe pollution (III) during rest of the study period for Gunde and Neureni lakes. While Khaste lake accounted to be severe pollution throughout the study period. The indicator tolerant species of organic pollution recorded in three lakes also supported the results of WQI. Significant differences in Dissolved Oxygen (DO), Electrical Conductivity (EC), Free Carbon Dioxide (CO_2), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Orthophosphate ($O\text{-}PO_4^{2-}\text{-}P$) and Total Iron were observed for annual and seasonal data. Whereas, no significant differences were found in pH, temperature, total alkalinity as $CaCO_3$, total hardness as $CaCO_3$, chloride, ammonia and nitrate in comparison with WHO values and Nepal Drinking Water Guidelines. The lakes were not suitable for recreation purpose due to dense growth of algae and macrophytes. Neureni lake could be suitable for aquaculture than other two lakes and Khaste lake; suitable for irrigation water. All lakes water could be suitable for livestock watering.

Likewise, about 81.60% of respondents emphasized in lakes degradation with time and appealed for conservation. From WTP calculation, it was computed that aggregate WTP per annum to be around NRs. 391, 200 (US$ 4,400). This suggested the individual household WTP per annum to be NRs. 397.56 (US$ 4.47) i.e. NRs. 33/month/household. The maximum amount of WTP by respondents was negatively correlated with age of the respondents, time duration of living in the village and total number of family members. Degrading lake water quality and local people‘s strong willingness in lake conservation thus signified the need of wetlands conservation in BDLC.

Keywords: Water Quality Index, Wetland Conservation, Willingness to Pay

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Anima Shahi

May, 2012

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LIST OF ACRONYMS

AAPA	Aquatic Animals Protection Act
A. D.	Anne Domino
ANOVA	Analysis of Variance
APHA	American Public Health Association
ASCOL	Amrit Science College
BDLC	Baral Danda Lake Complex
BOD	Biochemical Oxygen Demand
BPP	Biodiversity Project Profile
$CaCO_3$	Calcium Carbonate
CBD	Convention on Biological Diversity
CBIP	Central Board of Irrigation and Power
CBS	Central Bureau of Statistics
CDES	Central Department of Environmental Science
CI	Chemical Index
CMS	Convention on Conservation of Migratory Species of Wild Animals
COD	Chemical Oxygen Demand
CSUWN	Conservation and Sustainable Utilization of Wetland Nepal
CVM	Contingent Valuation Method
DDC	District Development Committee
DFID	Department for International Development
DHM	Department of Hydrology and Meteorology
DNPWC	Department of National Parks and Wildlife Conservation
DO	Dissolved Oxygen
DOAD	Department of Agricultural Development
EC	Electrical Conductivity
EDTA	Ethylene Diamine Tetra Acetic Acid
EIA	Environmental Impact Assessment
GoN	Government of Nepal
GRS	Ganga River System
ha	Hectares
HH	Household

HMG/N	His Majesty's Government of Nepal
IEE	Initial Environmental Examination
ILBM	Integrated Lake Basin Management
INGO	International Non-Governmental Organization
IUCN	The World Conservation Union
km^2	Square kilometers
LPG	Liquefied Petroleum Gas
masl	Mean Average Sea Level
MFSC	Ministry of Forest and Soil Conservation
mg/L	milligram per liter
MPM	Market Price Method
NEPAP	Nepal Environmental Policy and Action Plan
NEPBIOS	Nepalese Biotic Score
NEPBIOS/BRS	Nepalese Biotic Score/ Bagmati River System
NGO	National Government Organization
NLCDC	National Lakes Conservation Development Committee
NSF WQI	National Sanitation Foundation Water Quality Index
RCNP	Royal Chitwan National Park
SLC	School Leaving Certificate
SODIS	Solar Disinfection
SPSS	Statistical Package for Social Science
TCM	Travel Cost Method
TDS	Total Dissolved Solids
TP	Total Phosphorous
TS	Total Solids
UGC	University Grants Commission
UNCCD	United Nations Convention to Combat Desertification
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Conventions on Climate Change
VDC	Village Development Committee
WHO	World Health Organization
WQI	Water Quality Index
WTP	Willingness to Pay
WWF	World Wildlife Fund

CHAPTER 1

1. INTRODUCTION

1.1. Background

Wetlands are critical, finite, vulnerable, renewable resource on the earth and plays an important role in our living environment, without it, life is impossible. Ponds, rivers and streams are freshwater wetland bodies providing important habitats and corridors for nature conservation, recreation, amenity and economic growth (Bhat *et al.*, 2009). An increasing number of surface water bodies have come under serious threat of degradation. Since the beginning of the industrial revolution, increasing human population, economic activities as well as shortcomings in their management have resulted in more pollutants being introduced into wetlands. Hence its conservation should be at the top most priority level for beautiful today and tomorrows.

Nepal is a small landlocked country located on the mid-Himalayan mountain section of Asia, which occupies one-third of the massive Himalayan chain of 2500 km. Nepal with its critical altitudinal variability in a relatively small area has a diverse wetland ecosystem (Siwakoti and Tiwari, 2002). Even though, Nepal is a mountainous country, it contains various types of wetlands, which are scattered all over the country. These wetlands are associated with fast-flowing rivers, rivulets, streams, fresh-water lakes, river flood plain, ponds, swamps, reservoirs and marshy lands (Shrestha *et al.*, 1987). It is estimated that there are over 6000 rivers in Nepal, forming a dendrite type of drainage flowing from north towards south (Sharma, 1977). It is estimated that water bodies cover about 7,31,500 hectares of land including irrigated rice paddies. About 54% of these lands are part of river, river basin and river flood plain systems (Adhikari, 2002). In Nepal, wetlands provide the numbers of services and goods for the consumptive and non-consumptive uses. However, these are being destroyed by a number of factors, particularly anthropogenic activities which in this country are closely associated with the socio-economic conditions of the people. Although wetlands throughout the country are under pressure, the most threatened wetlands are located in the lowlands and in the valley surrounded by the Siwalikhs and the Middle Mountain (Aryal, 2009).

1.1.1. Wetland definitions and classifications

Wetland was a nascent term for common people until recently. It is said that only in the 1970's it appeared in the Oxford dictionary. Before that wetlands were known by different names such as lake, pond, marsh, swamp, bog, fen, etc. Wetlands were named according to the landscape in which they were found. Therefore, even today, the term 'wetland' does not have even universally accepted definitions because of the plurality of users, regional variations, biological diversities and richness in cultural values. The meaning vary from place to place and person to person. It has many forms but the common content, i.e. water, is the blood stream of the wetland. Some of the common meanings that are in use around the world are briefly presented below (Bhandari, 2009):

i. A wetland is simply an area that is covered with water for a part of the day or year.
ii. Wetland is a place where people can get their feet wet without being able to swim.
iii. Wetland is neither a firm 'land' nor a body of open water; hence they occupy terrestrial position between land and water. The ecosystems that develop on such lands are dominated by the persistent of excess water, or saturated, or have the water table at, near or above the land surface.
iv. The important feature is that a wetland has to be wet. However, they do not have to be wet all the time. They become biologically the most productive when they dry out periodically.

1.1.1.1. The national definitions

The term "Wetland" is translated into "Simsar" in Nepali. "Sim" is a derivative of a Persian word "Sih", which means low-grade land not suitable for cultivation. "Sar" is a Sanskrit word meaning water. Thus, Simsar is interpreted as the landmass with water. There are over twelve terms usages in Nepal (Bhandari *et al*., 1994).

"Wetlands denote perennial water bodies that originate from underground sources of water or rains. It means swampy areas with flowing or stagnant; fresh or salt water that are natural or man-made, or permanent or temporary. Wetlands also mean marshy lands, riverine floodplains, lakes, ponds, water storage areas and agricultural lands." (National Wetlands Policy, 2003)

Wise use of wetlands is defined as – “the maintenance of their ecological character, achieved through the implementation of ecosystem approaches within the context of sustainable development”. Wise use thus has its heart the conservation and sustainable use of wetlands and their resources for the benefit of human kind (WWF, 2009).

Three general categories of wetlands are: (a) coastal or tidal wetlands, (b) inland or non-tidal wetlands, and (c) man- made wetlands. They vary widely because of soils, topography, climate, hydrology, water chemistry, vegetation and other factors including human disturbances. On the basis of ecological and geographical characteristics, wetlands are classified into five major types (CSUWN, 2009):

1. **Shallow lakes:** areas of permanent or semi permanent water with little flow (e.g. Ghodaghodi Lake Area in Kailali, Kamaldaha in Koshi Tappu Wildlife Reserve).
2. **Marshes/Swamps:** area where water is more or less permanently at the surface or causing saturation of the soil (e.g. Rani Tal in Kanchanpur and Nakrod tal in Kailali).
3. **Floodplain:** areas next to the permanent course of a river that extends to the edge of the valley (e.g. Koshi Tappu in Koshi River and Bandarjhula in Narayani River).
4. **Estuaries:** areas where rivers meet the sea and water changes from fresh to salt as it meet the sea (e.g. Sundarbans in India and Bangladesh).
5. **Coasts:** areas between land and open sea that are not influenced by rivers (e.g. coral reefs in Australia).

1.1.1.2. The international definitions

The World Conservation Union (IUCN) in Convention on Wetlands of International Importance especially as Waterfowl Habitat, better known as the Ramsar Convention, adopted the following definition of wetlands as written in Articles 1.1 and 2.1:

Article 1.1

“For the purpose of this convention wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.”

Article 2.1

“May incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands.”

Integrated Lake Basin Management (ILBM)

ILBM is a way of thinking that assists lake managers and stakeholders in achieving sustainable management of lakes and their basins. ILBM is a "Movement" to catalyze action from local-to regional- to-global levels (Muhandiki, 2010).

Principles of Lake Basin Management

• Harmony between humans and nature

• Lake drainage basin

• Long-term preventative approach

• Science and information

• Conflict resolution

• Stakeholder participation

• Good governance

(Source: Muhandiki, 2010)

1.1.2. Attributes of wetlands

Any land to be wetlands must have one or more of following three main components (Smardon, 2011):

1. Presence of standing water, either at the surface or within the root zone during all or part of the year,

2. Unique soil conditions (hydric soils), and

3. Presence of vegetation (and fauna) adapted to surviving under unique, saturated conditions (hydrophytes) and absence of flood-intolerant vegetation.

1.1.3. Wetland hydrology

Hydrologic conditions are extremely important for the maintenance of a wetland's structure and function. It is the hydrology of the wetland that creates the unique physico-chemical conditions that make such an ecosystem different from both well-drained terrestrial systems and deepwater aquatic systems. Precipitation, surface run-off, groundwater, tides and flooding rivers transport energy, sediments, organic matter and nutrients to/from and within wetlands. These hydrologic inputs and outputs also determine the water depth, flow patterns, and duration and frequency of flooding that, in turn, affects the biogeochemistry of soils and ultimately affects the selection of biota in the wetland (Smardon, 2011).

1.1.4. Scope of wetlands

Wetlands are essential for free ecosystem services that they provide to human. The most obvious are maintenance or improvement of water quality, groundwater discharge and recharge, erosion control, soil building, food chain production, nutrient cycling and biogeochemical processes, habitat for wildlife, and numerous socio-economic qualities such as food, forage, hunting and trapping, sites for research and environmental education, cultural heritage, open space preservation, aesthetic, tourism and recreation (DFID, 2007). They are also important because attention has been turned to using the wetland systems and the plant species occurring therein as 'bio-energy source' and also for use in pollution abatement projects to filter sewage, agricultural runoff, leachate from landfills, and acid mine drainage mitigation (Hollis, 1988). Also wetlands have been identified as valuable sources, sinks and transformers of a multitude of chemical, biological and genetic materials. They have been called the "kidneys of the landscape" as they function as downstream receivers of water and waste from both natural and anthropogenic sources. They are also termed as "biological supermarkets" for extensive food chain and rich biodiversity role they support. They have also been described as carbon sinks and climate stabilizers (Aryal, 2007). It is the constellation of these and other functions and values that world has at last come to realize that wetlands are not wastelands, only over the past two decades. Many studies have been conducted by ecologists and biologists to show various unknown uses of wetlands. All these have resulted in an appreciation of the need to take care of precious wetland resources (Sisodia *et al.*, 2006).

1.1.5. Functions and values of wetlands

For years wetlands have been viewed as wastelands (as the periodic standing water and waterlogged soils prevented their use for agriculture, forestry, or mineral production; for human habitation; or for commercial use), they are now being recognized as an important ecosystem that provides essential functions/services. Table 1.1 represents the ecosystem services provided by wetlands both natural and restored.

Table 1.1: Ecosystem services provided by wetlands (natural and restored)

Hydrology •Water storage and flood reduction •Barriers to waves and erosion •Maintenance of groundwater table •Maintenance of surface water levels •Stable shores and storm protection Wetlands function like natural sponges, storing water and slowly releasing it to downstream areas, lowering flood peaks. This reduces water's momentum and erosive potential, reduces flood heights, and allows for groundwater recharge, which contributes to base flow to surface water systems during dry periods. Also, coastal and inland wetlands adjoining rivers reduce the impact of tides and waves. This protects soil against erosion. Mangroves are particularly resistant.
Biogeochemistry •Maintenance of overall water quality •Cycling and transformation of nutrients and other elements •Retention of sediments •Retention and transformation of dissolved substances and pollutants •Accumulation of carbon / peat As water gets slowed by wetland, it moves around the plants allowing the suspended sediments to drop out and settle to the wetland floor. The reeds and grasses further increase this process. Retention of this sediment upstream can enhance the quality of ecosystems downstream along with lengthening the lifespan of downstream reservoirs and channels. This reduces the need for costly removal of accumulated sediments from dams, locks, etc. Wetlands also retain nutrients (especially nitrogen and phosphorous), through accumulation by microorganisms in the subsoil and/or absorption by vegetation. Hence we have nutrients from fertilizer application, manure, leaking septic tanks, and municipal sewage that are dissolved in water, filtered by the wetland leading to improved water quality and prevention in eutrophication
Habitat and food web support •Maintenance of primary productivity •Maintenance of characteristic plant communities that serve as habitat •Sustaining anadromous fish and other wetland-dependent aquatic species •Maintenance of biodiversity

(Source: Spray and McGlothlin, 2004)

Table 1.2 represents ecological functions to economic values of wetlands and is presented below:

Table 1.2: Ecological functions to economic values of wetlands

	Ecological functions	**Ecological effects**	**Societal economical values**		
			Intermediate goods and services	Final goods and services	Future goods and services
Hydro-Logical	Short-term surface water storage; long-term surface water storage, maintenance of high water table	Reduced down-stream flood peaks; maintenance of base flows and seasonal flow distribution hydrophytic plants	Flood control; water storage; irrigation and sub-irrigation water for agriculture	Flood damage security; reduced household utility costs; maintain sport fishing habitat in dry periods	Unique species, landscapes and ecosystems; bequest value; option value; undiscovered goods
Biogeo-chemical	Transformation and cycling of elements, retention and removal of dissolved substances, accumulation of peat, accumulation of inorganic sediments	Maintenance of nutrient stocks, reduced transport of nutrients, metals, etc; retention of sediments and some nutrients	Assimilation of wastes; pollution assimilation/ water purification	Higher water quality as an amenity	Unique species, landscapes and ecosystems; bequest value; option value; undiscovered goods
Habitat and food web	Maintenance of characteristic plant communities, maintenance characteristic energy flow	Food, nesting, cover for animals; support for populations vertebrates	Support for commercial fisheries & recreation; provision of commercial harvested natural resources		Unique species, land scapes and ecosystems; bequest value; option value; undiscovered goods

(Source: Spray and McGlothlin, 2004)

Table 1.3 represents the economic values of wetlands and is presented below:

Table 1.3: The total economic values of wetlands

Direct values	Indirect values	Option values	Non-use values
Production and consumption goods such as: water, fish, firewood, building poles, thatch, wild foods, medicines, crops, pasture, transport, recreation, etc.	Ecosystem functions and services such as: water quality and flow, water storage and recharge, nutrient cycling, flood attenuation, microclimate, etc.	Premium placed on possible future uses/applications, such as: agricultural, industrial, leisure, pharmaceutical, etc.	Intrinsic significance of resources and ecosystems in terms of: cultural value, aesthetic value, heritage value, bequest value, etc.

(Source: Emerton, 1999)

Wetlands in Nepal have significant human use and values in terms of religion as well as culture. Wetland sites and dependent species have recreational, cultural and spiritual/religious values. The cultural identity can be linked with the people, their lifestyles and history with rivers and wetlands. The festivals in Nepal are the cultural and ritual reflections of seasonal variations and especially responses to the conservation of wetlands. The summer festivals are the celebration of high altitude wetlands and the winter ones in the lowlands. There are more than a dozen of wetland related festivals in Nepal including Chhathh, Maghi, Sithi, Naag Panchami, Teej etc. Pilgrims travel to holy lakes like Gosainkunda to bath which supposedly has medicinal as well as religious values. Nepal has some 103 ethnic and cast groups and among them the wetland dependent communities are some of the poorest and most marginalized people in Nepal (CSUWN. 2009).

1.1.6. Wetland conventions in Nepal

Nepal has shown its commitment to wetlands conservation, especially the conservation of waterfowl habitats of international importance, by signing the Ramsar Convention. It is also known as the “Convention on Wetland of International Importance” especially for water fowl habitat. Nepal became signatory to this convention in 1987 when Koshi Tappu Wildlife Reserve was designated as the list of Wetlands of International Importance popularly as Ramsar site (CSUWN, 2009).

Different wetland related conventions where Nepal has also signed are Convention on Biological Diversity (CBD), UNESCO, World Heritage Convention, United Nations Convention to Combat Desertification (UNCCD), United Nations Framework Convention on Climate Change (UNFCCC) and Convention on Conservation of Migratory Species of Wild Animals (CMS). The regional conventions are Convention for the Protection and Development of Marine Environment of the Wider Caribbean Region (Cartagena Convention), Convention for Protection of Marine Environment, The Coastal Region of the Mediterranean (Barcelona Convention) and Convention on Protection and Sustainable Development of the Carpathians (CSUWN, 2009).

1.1.7. Ramsar sites in Nepal

The area of Ramsar sites throughout the world is 192,809,323 ha (Ramsar, 2012). The area of Nepal's Ramsar sites is 34,455 ha (Ramsar-Nepal, 2012) representing 0.018% of total area of global Ramsar sites. More than 2,005 wetland sites have been included in Ramsar list in the world (Ramsar, 2012). Nepal's Ramsar sites represent less than 0.5% of total number of Ramsar sites in the world (Kafle and Savillo, 2009). Table 1.4 represents Ramsar sites in Nepal with location, area, elevation & designation date.

Table 1.4: Ramsar sites of Nepal

SN	Names	District	Area (ha)	Elevation (m)	Ramsar designation date
1.	Koshi Tappu Wildlife Reserve	Koshi	17,500	90	17/12/1987
2.	Beesh Hazar Tal	Chitwan	3,200	285	13/08/2003
3.	Ghodaghodi Lake Area	Kailali	2,563	205	13/08/2003
4.	Jagadishpur Reservoir	Kapilvastu	225	195	13/08/2003
5.	Gokyo Lake Complex	Sagarmatha	7,770	5,000	23/09/2007
6.	Gosainkunda Complex	Bagmati	1,030	4.700	23/09/2007
7.	Rara Lake	Karnali	1,583	2,990	23/09/2007
8.	Shey- Phoksundo	Karnali	494	3,610	23/09/2007
9.	Mai Pokhari	Ilam	90	2,100	28/10/2008
	Total		34,455		

(Source: Ramsar-Nepal, 2012)

1.1.8. Wetlands distribution in context of Nepal

Generally, Nepali term for wetlands, "Simsar", means fields with perennial source of water including swamps, paddy fields, water logged areas and ponds (CSUWN, 2009). Nepal can be divided into five ecological zones; these are High Himal (above 4000m), High Mountain (3000m-4000m), Middle Mountain (2000m-3000m), Siwalik (120m-2000m) and Terai (below 300m) (Aryal, 2009). Within these unique topographies of the country we find several types of wetlands such as water bodies and water saturated lands which are spread throughout the country in all the ecological zones and are shown in table 1.5.

Table 1.5: Wetland distributions according to ecological zones

Particulars	Number of wetland sites	Percent (%)
Highland	78	26
Mid-Hills	86	29
Lowland	133	45

(Source: Bhandari, 2009)

Approximately 6% of the total Earth's land surface are wetlands of which 2% are lakes, 30% bogs, 26% fens, 20% swamps and 15% floodplains (CSUWN, 2009). Nepal only has freshwater wetlands, both natural and artificial and no saline. Nepal's wetlands cover about 5% of Nepal's land area (Kafle and Savillo, 2009) and are shown in table 1.6.

Table 1.6: Nepal's wetland types in terms of present area and percentage.

Wetland types	Estimated present area (ha)	% of total
Rivers	3,95,000	53.27
Lakes	5,000	0.67
Reservoirs	1,380	0.19
Village ponds	5,183	0.7
Paddy fields	3,25,000	43.83
Marshy land	10,000	1.35
Total	7,41,563	100

(Source: Ministry of Forests and Soil Conservation, 2003)

According to reports of National Lakes Conservation Development Committee (NLCDC), of 5,358 lakes found in Nepal, 2,712 lakes (51%) are distributed below 500m, and 2,227 (42%) above 3,000m. Only 419 lakes (< 8%) are in the mid hills of altitudinal range between 500m and 2,999m (Bhuju *et al.,* 2009). According to Mool *et al.,* 2001, there are about 2,323 glacial lakes and 3,252 glaciers in Nepal's Himalayas. These lakes and glaciers cover the total area of 5,428 km of which glacial lakes alone occupy only 75 km of the total glacial areas. The highest freshwater lake is the Tilicho at 4,917 masl covering an area of 354 km. This is probably the highest and the largest freshwater lake in the world. Table 1.7 shows the distribution of glacier inventory in 2001 and 2010 in river basins of Nepal.

Table 1.7: Distribution of glaciers in the river basins of Nepal

	2001 glacier inventory			**2010 glacier inventory**			
Basin	**No. of glaciers**	**Total area (sq. km)**	**Mean area (sq. km)**	**No. of glaciers**	**Total area (sq. km)**	**Highest elevation (msal)**	**Lowest elevation (msal)**
Koshi	779	1,410	1.81	843	1,180	8,437	3,962
Gandaki	1,025	2,030	1.98	1,337	1,800	8,093	3,273
Karnali	1,361	1,741	1.27	1,461	1,120	7,515	3,631
Mahakali	87	143	1.65	167	112	6,850	3,695
Total	3,252	5,324	1.64	3,808	4,212		

(Source: after Mool *et al*. 2001a; Bajracharya *et al.,* 2010; Bajracharya and Maharjun, 2010)

1.1.9. Wetland's related policies and legislation in Nepal

1.1.9.1. Policies

Conservation and management of wetlands is reflected in various conservation policies of Nepal and are presented below.

National Conservation Strategy, 1988, has emphasized the need for sustainable use of land and natural resources (HMG/N, 1988).

The Master Plan for the Forestry Sector, 1989, emphasized the need to involve people in natural resources management (HMG/N, 1989). The plan stressed that land and forest resources should be managed and utilized on a long-term basis so as to conserve the forests, soil, water, flora, fauna and scenic beauty.

The Nepal Environmental Policy and Action Plan (NEPAP), 1993, have prioritized the need to identify and protect biologically significant marshes, wetlands, and water bodies. This plan is an effective initiative for the protection of wetlands and provides a good policy foundation. NEPAP was further elaborated in 1998 (NEPAP - II) and worked in different projects and mentioned that wetlands in Nepal have often been overlooked and that many wetlands are suffering from land and water pollution while others have been drained and converted to agricultural land (HMG/N, 1993).

The Forestry Sector Policy, 2000, stated that the soil, water, flora and fauna constitute the main elements of forestry; nevertheless, it has been silent on wetland conservation (HMG/N, 2000).

Nepal Biodiversity Strategy, 2002, explicitly addressed the wetland ecosystem. The strategy formulated a mixture of strategies to safeguard the wetland resources. It is the first government document that specifically catalogued and addressed wetland biodiversity and called for strategies to safeguard wetland habitats (HMG/N, 2002). Its implementation plan for 2006 has outlined integrated wetland management as priority projects (P-III) among the thirteen projects that will be implemented during the first phase of the plan (2006-2010) with the objective of developing integrated management plans at the watershed level to conserve wetland biodiversity and critical sites (GON, 2006).

The Government of Nepal has endorsed **National Wetland Policy, 2003**, with the objective of involving local people for management of wetlands and to conserve wetlands biodiversity with the wise use of wetlands resources. Emphasis is given to conserving wetlands by involving the local people, promoting awareness, using wetland resources wisely, preventing and controlling pollution and invasive species.

1.1.9.2. Legislations

Nepal does not have a specific law that deals with wetlands but wetland management would come within the purview of several resource laws. There are several acts and regulations which have relevance to wetland conservation and management.

Aquatic Animals Protection Act (AAPA), 1961, is one of the oldest acts in Nepal that recognizes the value of wetlands and aquatic animals and identifies as offence activities to introduce poisonous, noxious or explosive materials into a water source or to destroy any dam, bridge, fish ladder, or water system with the intent of catching or killing aquatic life (HMG/N, 1961).

National Parks and Wildlife Conservation Act, 1973, prohibits blocking or diverting of any river, stream or other sources of water flowing into a national park or introduction of any harmful or poisonous substance therein. The act lists many mammals, birds and reptiles in its appendix as protected animals that are wholly or partially dependant on wetlands (HMG/N, 1973).

Soil and Watershed Conservation Act, 1982, outlines the essential parameters necessary for proper management of catchments areas, including rivers and lakes. It provides legislative measures concerning soil and watershed conservation to properly manage the catchments of Nepal. It also empowers the government to declare any catchments area protected. Within the protected watershed the government could resettle, or relocate industries, businesses, and settlements. There is a long list of prohibited activities like clearing forest, quarrying stone, soil/ or sand, interfering with water bodies, establishing industries, allowing livestock to graze etc (HMG/N, 1982).

Electricity Act, 1992, prohibits blocking, diverting or placing hazardous or explosive materials in rivers, streams, or any water source. This act states that there should not be any substantially adverse effect on environment by way of soil erosion, flood, landslide, or air pollution while carrying out electricity generation, transmission or distribution (HMG/N, 1992a).

Water Resources Act, 1992, strives to minimize environmental damage to wetlands, esp. lakes and rivers, through environmental impact assessments studies. It promotes environment assessment, water quality standard, and avoids significant impacts on local environment in the course of water use. This act is a public trust doctrine and states that the persons willing to make use of water resources for collective benefits on an institutional basis should form a water users association (HMG/N, 1992b).

Forest Act, 1993, defines ponds, lakes, rivers or streams and riverine lands within the forest as national forest. This act also empowers the government to declare any part of national forests as a protected area if the area has environmental, scientific and cultural significance (HMG/N, 1993).

Environment Protection Act, 1996, stress that nobody can generate pollution in such a manner as to cause significant adverse impacts on the environment or likely to be hazardous to public life and people's health. This act directed authority to the Government of Nepal (GON), by a notification in the Nepal Gazette, to declare any place within Nepal containing natural heritage or aesthetic, rare wildlife, biological diversity, plant, and places of historical and cultural importance, which are considered extremely important from the viewpoint of environment protection, as an environment protection area. It has made Initial Environmental Examinations (IEE) or Environmental Impact Assessments (EIA) mandatory for development proposals (HMG/N, 1996).

Local Self Governance Act, 1999, provides immense autonomy to District Development Committees (DDCs), Municipalities and Village Development Committees (VDCs) to plan and act for protection of forests, environment, and conservation of biodiversity. This act lists out natural resources as property of the VDC and empowers VDC to levy taxes on the utilization of natural resources. Similarly, this act sanctions DDC to formulate and implement plans for conservation and utilization of forest, vegetation, biological diversity and soil. The act allows DDC to bring to a halt environmentally unsound developmental projects (HMG/N, 1999).

1.2. Statement of problems

Apart from being the habitat of birds, fishes and a variety of other aquatic life forms, including microorganisms, wetlands provide other ecosystem services, from maintaining the natural balance to sustaining human livelihoods. Unfortunately, there has been avoidance of wetlands through lack of appreciation of their role and the pressures of growing human needs (agriculture, urbanization) and sheer mismanagement of land resources. There is also a misconception that wetlands are only wastelands (Aryal, 2007). As a result, many precious wetlands have been sacrificed and converted to other uses throughout Nepal as well as elsewhere in the world. This trend has to be checked and reversed for the greater good. The degradation in the water quality affects the floral and faunal population along with the people dependent on these ecosystems. Hence, the conservation of wetlands deserves the utmost attention (Sisodia *et. al.,* 2006).

Pokhara valley is one of the ultimate domestic and international tourist destinations. It is famous for ecological sites, historical and cultural sites, recreational purposes, researchable purpose etc. There are nine lakes in Pokhara valley. The largest lake is Phewa (523 ha), Begnas is moderate (323 ha), Rupa is elongated covering about 120 ha. Others such as Khaste, Dipang, Maidi, Gunde, Neureni and Kamalpokhari are less than 20 ha in their surface area (Pant, 2008). These lakes are small water bodies compared to larger lakes and are generally unheard and unnoticed. In such water bodies environmental interference may cause rapid changes in trophic status of lake more frequently and are more prone to degradation. The present study focused on the assessment of WQI of some of these unnoticed lakes residing within Pokhara valley. The BDLC lies in Lekhnath municipality from where Gunde, Neureni and Khaste lakes are seen beautifully. Thus the site chosen posed perfect site to determine the water quality of lake water and study the local people's attitude in lake conservation.

1.3. Research questions

The following research questions can be explained by this study and are shown below.

i. What is the seasonal and annual variation in physico-chemical parameters in Gunde, Neureni and Khaste lakes?
ii. What is WQI rating for Gunde, Neureni and Khaste lakes?
iii. Are the local people in BLDC willing to pay for the wetland conservation?

1.4. Objectives

1.4.1. Broad objective

The broad objective is to study water quality of lakes and people's willingness to pay for wetland conservation in BLDC of Lekhnath municipality, Kaski, Nepal.

1.4.2. Specific objectives

The specific objectives of the study are as follows:

i. To determine the seasonal and annual variations of physico-chemical parameters of Gunde, Neureni and Khaste lakes.

ii. To assess the water quality rating based on Bach (1980) in Gunde, Neureni and Khaste lakes.
iii. To use Contingent Valuation Method (CVM) in estimating WTP for wetland conservation and analyze the local people's attitude in wetland conservation.

1.5. Scope of the study

The scope of the study deals with the assessment of WQI and local people's attitude in wetland conservation. The seasonal and annual variations in physico-chemical characteristics of water; WQI and its ratings were calculated. The questionnaire survey with local people's residing in the vicinity of lake helped in knowing their attitude and WTP for lake conservation. Thus this study encompasses physico-chemical characteristics and socio-economic aspects of wetland. Likewise, the study area is chosen in Lekhnath municipality, a garden city of seven lakes (Lekhnath Municipality, 2008). The conservation of this municipality's wetlands provides an ample scope to explore its uniqueness which will help in increasing the municipality fame.

1.6. Overview of the contents

The thesis is structured as follows:

Chapter 1: deals with general background and objectives of the study.

Chapter 2: provides with the literatures related to the study starting from the physico-chemical characteristics of water, WQI, general socioeconomic study and CVM to find WTP of study area.

Chapter 3: describes the overview on the study area and methodology used during the study.

Chapter 4: presents the results of the physico-chemical characteristics on the seasonal and annual variations of lake water; its WQI, local people's WTP for the lake conservation and general socioeconomic study of the lake periphery area.

Chapter 5: presents the discussion regarding the analysis of physico-chemical variation and WQI rating along with the socio-economic conditions among the residents within the lake periphery.

Chapter 6: posits the conclusions of the major findings and refer recommendations on the basis of the findings.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Review on physico-chemical characteristics of wetlands

The physico-chemical characteristics of the water are of great significance for any aquatic life. Each species has certain tolerance level and reflex action towards particular type and content of physico-chemical parameters. Generally, the degree of chemical pollution load is the clear indicator of the biological state of water as they are directly proportional to each other. Therefore, they help to provide a momentary picture of degree of pollution in any water bodies. The floristic and faunal diversity of wetland is influenced by several physico-chemical parameters such as water transparency, velocity, depth, hydrogen ion concentration, nutrients, etc. (Burlakoti, 2003).

The water temperature affects the physical, chemical and biological environment of the lake directly or indirectly. The pH is the measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. The conductivity is the measure of concentration of mineral constituents present in water and gives an idea about dissolved solids in water (Khopkar, 2004). The dynamics of oxygen distribution in lakes are governed but a balance between inputs from the atmosphere and photosynthesis, losses due to chemical and biotic oxidants (Wetzel, 1983). The carbon dioxide content of the water depends upon the temperature of water, depth of water, rate of respiration, decomposition of organic matter, chemical nature of the bottom and the geographical and physiological features of the terrain surrounding the water (Agrawal, 1999). The ionic composition of fresh waters is dominated by dilute solutions of alkali and alkaline earth compounds, particularly bicarbonates, carbonates, sulphates and chlorides. Nitrate is the common form of inorganic nitrogen entering fresh waters from the drainage basin in surface waters, ground water and precipitation and the ortho-phosphate is the only directly utilizable form of soluble inorganic phosphorus (Wetzel, 1983). The processes by which phosphorus and nitrogen are either washed downstream, locked into the sediment or denitrified ensure that the productivity of many lakes will largely reflect the contemporary nutrients supply and will increase or decrease in response to changes (Moss, 1998).

2.1.1. Outside Nepal

Bhat *et al.,* (2009), investigated the physico-chemical properties of urban ponds in Lucknow, India. Ten ponds were taken for the study purpose and different physico-chemical parameters like pH, turbidity, conductivity, DO, BOD_5, Total Solids (TS), Total Dissolved Solids (TDS), chloride, residual chlorine, alkalinity, total hardness and acidity were studied. The sources of pollution were identified as domestic sewage, kitchen flow and street runoff etc.

George *et al.,* (2008), studied the water quality studies in the Lake Sasthamkotta of Kerala, India. The study was conducted in the period of March 2006 to August 2006 and it revealed that the lake is facing degradation due to anthropogenic activities such as directing human waste, soil erosion due to destruction of vegetation and dumping of wastes from hotels and slaughterhouses. Since most of the people heavily depend on the lake water for livelihood, it seems an utmost attention in conservation.

Chaurasia *et al.,* (2007), studied the physico-chemical studies on some water ponds of Ayodhya-Faizabad, India. They found that the water quality was decreasing due to increased industrialization and population. Four lakes were studied and different parameters like TDS, BOD_5, alkalinity, ortho-phosphate ($O\text{-}PO_4^{2-}P$) were found beyond the permissible limits whereas pH, DO, total nitrate was within the limits.

Abdo, (2005), studied the physical and chemical characteristics of the water of Abu Za'baal ponds in Egypt. Determination of physical parameters (air and water temperatures, transparency, electrical conductivity (EU), salinity, TS, TDS and Total Suspended Solids (TSS) and chemical parameters (pH, DO, BOD_5, COD, HCO_3^-, CO_3^{2-}, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, NO_2^-, NH_3, PO_4^{--}, TP and SiO_2^- were carried out to identify the nature and quality of the water of Abu Za'baal Ponds. The results revealed that the values of most physical and chemical parameters were higher than those of freshwater, lower than those of saline water and in the same range of the brackish water.

Sisodia *et al.,* (2004), performed the water quality studies in reference to its physico-chemical characteristics in Jamwa Ramgarh lake, India. The constituents monitored included temperature, pH, EC, TDS, DO, alkalinity, hardness and chloride ion. A significant variation in these parameters was observed throughout the study period. And the study revealed that if such marked variation in the parameters prevailed then it will soon become an ecologically inactive lake.

Singh *et al.,* (1984), studied the physico-chemical characteristics of shallow water lakes during (1977-78) in Kumaon, India. The fluctuation of water level resulting from interaction between rainfall and evapo-transpiration had a noticeable effect on the water chemistry, especially pH. The pH of the water was alkaline in Naini Tal and Bhim Tal (above 8.0 for most part of the years) except for some parts during the winter in Naukuchi Tal (6.9).

2.1.2. Inside Nepal

Devkota, (2005), conducted the limnological study in Taudaha lake. He found that more and more freshwater bodies have become polluted by nutrients originating from agricultural, domestic and industrial sources as in Taudaha lake. This situation causes these freshwater bodies to become eutrophied.

Adhikari, (2002), conducted the study on Khaste and Dipang lakes located in Pokhara valley, Western Nepal. He found that the limnological parameters showed eutrophic nature of both lakes and lake posed luxuriant growth of macrophytes.

Acharya, (1997), studied physico-chemical parameters of water in Ghodaghodi and Nakhrodi lake. The lake water was found to be acidic in nature with the high amount of free CO_2 and moderate amount of DO. The presence of total nitrogen and total phosphorus showed the eutrophic nature of the lakes.

Bhattarai, (1996), studied the physico-chemical parameters and biotic community of Lami lake in Royal Chitwan National Park (RCNP). She found the water samples were within normal range (according to WHO guidelines) necessary for sustaining aquatic biota.

Jones *et al.*, (1989), carried out the limnological data of Khaste lake & Dipang lake at spring season. On the basis of nutrient like nitrogen, phosphorus and chlorophyll- a both lakes fall on the eutrophic category.

Jones *et al.*, (1989), carried out the most extensive limnological survey of 50 lakes and ponds of mid hills including Pokhara and Kathmandu valley and Terai plain belonging to Central and Southern Nepal. They found these lakes most dominated by bicarbonates and calcium as prevalent anion and cation respectively along with apparent regional variations in water chemistry. None of them was oligotrophic on the basis of total phosphorus.

Lohman *et al.,* (1988), sampled Kathmandu & Pokhara valley's lakes to investigate the pre & post monsoon seasonal changes. Their results indicated low alkalinity & conductivity in Pokhara valley lakes, suggesting that dilution from monsoon rains accounted for ionic composition changes between the spring and fall.

Swar, (1980), found mid hill lakes (Phewa, Begnas & Indra Sarobar) were moderately deep lakes, warm monomictic, nitrogen & phosphorus deficient ($3<N: p<50$) and were mesotrophic. Nutrient ratios changes when stratification was disrupted demonstrating the importance of internal processes in these lakes.

2.2. Water quality index of wetlands

One of the most daunting prospects facing water quality scientists is how to turn often very complex water quality data into information which is understandable and usable by nonscientists e.g., managers, planners and general public. In an attempt to convey the information content of data more simply, resets have been made to produce just one or perhaps a few numbers, which have been designed to integrate the data pool in some way. Such numbers are called indices (Gupta, 2003). The concept of indices to represent gradation in water quality was first proposed by Horton in 1965. It indicates the quality by an index number, which represents the overall quality of water for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water (Harkins, 1974). Once the water quality monitoring data are collected, there is a further need to translate them into a form that is easily understood and effectively interpreted. WQI plays an important role in such translation process. It is a communication tool for transfer of water quality data (Ball *et al*., 1980).

2.2.1. Outside Nepal

Kumar *et al.,* (2011), performed the spatio-temporal variation and water quality index evaluation in the Sabarmati river along its course in Ahmadabad city, India in relation to river front development and Kharicut canal to evaluate the pollution status and variation in physico-chemical parameters of water in five different sites. The study revealed that the nutrient parameters of water in downstream were elevated at corresponding levels to upstream and anthropogenic cause was identified as the major factors. Likewise, National Sanitation Foundation Water Quality Index (NSF WQI) values also revealed the high pollution load in the study area where human interferences were higher.

Tandel, *et al.,* (2011), used weighted arithmetic index method for assessing water quality index of small lakes in South Gujarat Region, India. The study dealt with the monitoring of variation of seasonal water quality index of some selected lakes. The lake water was found of good quality (WQI – 67.7 to 78.5) during both winter and summer seasons. However, WQI deteriorated slightly from winter to summer on account of the increase in microbial activity as well as increase in pollutants concentration due to water evaporation.

Sisodia and Moundiotiya, (2006), had assessed the water quality index of Kalakho lake in Rajasthan, India. The study revealed that the arithmetic water quality index of the lake exceeded acceptable levels at all the sampling stations due to the dumping of wastes from municipal and domestic sources and agricultural runoff. If the lake conservation program is not strengthened then the lake will soon become an ecologically dead lake.

Gupta *et al.,* (2003), discussed and compared five different water quality indices, arithmetic water quality index, multiplicative water quality index, unweighted arithmetic water quality index, unweighted multiplicative water quality index and Harkin's water quality index, which were considered for characterizing the coastal water quality at the Jawaharlal Nehru Port Trust, Bombay, India. The study revealed that from the comparison of different indices, multiplicative water quality index was the most suitable water quality index for coastal waters.

2.2.2. Inside Nepal

Different researchers have studied the river water quality studies using different water quality indices according to the suitability and appropriateness of the study.

Sharma, (2007), studied water quality studies in Ranipokhari pond, artificial pond at heart of Kathmandu valley and Nagdaha lake, a natural lake using benthic invertebrates as biological indicators. The study was carried out from October, 2005 to July, 2006 at eight stations of both Ranipokhari pond and Nagdaha lake. The sechhi disc, transparency, water depth, DO, oxygen saturation %, free CO_2, Total alkalinity, bicarbonates, hardness, calcium, magnesium, chlorides, ammonia, nitrogen, orthophosphate, EC, TDS, microbial coliforms all vary significantly. The physicochemical parameters were found to be lower in monsoon which may be due to dilution of water.

Shrestha, (2007), conducted the study of water quality using macro-invertebrates as biological indicators in Manahara river from October, 2005 to September, 2006 at seven stations from upstream to downstream of river. The water quality was found to be relatively degrading from station 1 to 7. The chemically determined water quality class using Bach Index and Ministry of Public and Works Water Quality Index as well as biologically determined saprobic index water quality class using Original NEPBIOS, NEPBIOS-BRS, Extended NEPBIOS and GRS Index were used for study. The cause of deterioration of water quality may be sewage pollution in river which was more in number in urban areas and sewage discharge. Station 1 to 4 was found to be suitable for aquatic life as fish and for drinking purpose. But should be treated for coiliforms and suspended solids before drinking.

ENPHO, (2006), conducted physico-chemical and microbiological studies of Phewa lake. The seasonal study (rainy and winter) was done in eleven different sites in the lake using 17 physico-chemical parameters and microbiological studies. The study revealed the water quality was poor in human interference site. Due to successive dilution of water in rainy season, the water quality of lake water was found to be lower than in winter season.

Shrestha, (2005), conducted the study of water quality index of Bishnumati river in the downstream with reference to physico-chemical parameters. She found that the quality of water was degrading mostly from Gongabu due to rapid population growth accompanied by haphazard urbanization.

Poudel, (2002), analyzed the quality of Bagmati river based on the biological and physico-chemical parameters. In the study, Biotic Index and NSF WQI were used for the analysis of biotic and chemical water quality of the river respectively.

Pradhan, (1998), carried out the water quality studies of Bagmati river system based on the saprobic water quality. Chemical water quality index was calculated with special reference to Bach (1980).

The Hydrology Division of HMG/Nepal, (1996), had since 1992 initiated an attempt to collect water quality samples of some of the main rivers in the Kathmandu Valley to monitor river water quality. The study showed that Bagmati, Bishnumati, Dhobi Khola, Manahara & Hanumante rivers are all polluted (In Shrestha, 2007).

Swar, (1980), has attempted to provide information of the status of limnological studies in Nepal before 1980. The second study is NPC/IUCN, (1991), which deals with water pollution studies before 1990. The third is related to the attempt made by Shrestha, (1995), describing the status of limnological studies before 1994 (In Shrestha, 2007).

Ferrow and Swar, (1978); Ferrow (1978/1979); (1981/1982), made the limnological investigations of lentic environment of the Pokhara Valley in order to make plan for management in fish culture. Swar and Fernando, (1980), reported the occurrences of crustacean zooplanktons in Begnas and Rupa lakes (In Shrestha, 2007).

Hickel, (1973), made an extensive study on physico-chemical parameters of water and phytoplanktons of four lakes in Pokhara Valley and identified altogether 76 species of phytoplanktons in the lakes of the Pokhara Valley (In Shrestha, 2007).

Loffer, (1968/69), is considered as the pioneer scholar in the field of limnological studies of lentic environment in Nepal. He studied the morphometry, physico-chemical parameters of water and planktons of 24 high altitude lakes and ponds. He observed the predominant nematods in most of the lakes. Molluscans, isopods, amphipods and fish were totally absent. He concluded that the most significant factors were change of light, temperature and water level between dry and rainy season due to monsoon (In Shrestha, 2007).

Brehm, (1953), is considered as the pioneer scholar in the field of freshwater zooplanktons of Nepal. He studied the occurrence of three genera of zooplanktons (*Diaptomus, Pseudodiaptomus* and *Cladocera*) in Kali Pokhari Pond of Eastern Nepal (In Shrestha, 2007).

Hamilton, (1822), described the occurrence of two groups of fishes (mugils and carps) in the Hill regions of Nepal. This is considered as the first scientific report of fish from Nepal (In Shrestha, 2007)

Kirkpatrick can be considered as the pioneer scholar in the field of freshwater environment of Nepal who described about some fishes (*Tor spp*., *Schizothorax spp*., *Barilius spp*., and *Anguilla spp*.) of Trisuli river in 1793 (In Shrestha, 2007).

Many water quality indices are used in assessing river water quality in Nepal, but till date and to the knowledge of researcher, very few research was found out regarding water quality index in the lentic ecosystems in Nepal.

2.3. Contingent valuation method of non consumptive values of wetlands

The absence of prices or markets for wetland goods and services, of close replacements or substitutes, or of links to other production or consumption processes, does not mean that they have no value to people. In particular, people value wetland ecosystems and species due to their indirect benefits (ecosystems services and functions), option benefits (possible future uses and applications) and non-use benefits (existence, cultural, heritage and bequest significance) (Table 1.3). These benefits are almost impossible to value using market prices. CVM infer the value that people place on ecosystem goods and services by asking them directly what WTP is for them or their willingness to accept compensation for their loss, under the hypothetical situation that they could be available for purchase. This involve communicating to participants a proposed change in the quantity or quality of the wetland resource, and the benefits it yields, and finding out the different amounts they would be willing to pay to preserve or maintain these values (Kasthala, *et al.,* 2008).

2.3.1. Outside Nepal

Gupta *et al.,* (2008), estimated the intangible benefits from improvement in water quality through CVM. A primary survey of 300 samples in Powai lake, Mumbai, India was conducted of in two rounds in 2005 and 2007 to estimate the same using regression tool. The results indicated that the average WTP is increased from 2005 to 2007 after adjusting for general price rise. The income, occupation and uses of the lake are the important attributes explaining WTP. The respondents attached more values to the aesthetic benefits.

Kasthala *et al.,* (2008), carried out research in the Mtanza Msona Village, Tanzania. In the survey, the non-consumptive benefits from the wetlands were evaluated by the people's actual behavior or consumption patterns, so a contingent valuation study was carried out via local resident's WTP. The majority of survey respondents indicated their WTP to conserve the wetlands to secure and preserve indirect (70% of households), option values (71%) and bequest values (79%) values. The majority of the respondents were WTP to preserve the wetlands for the bequest values so that they could be used by their future generation.

Khorshiddoust, (2004), studied different socio-economic factors affecting people's WTP and their attitude towards the environmental conservation in Tabriz, Iran. CVM was used to estimate the amount of WTP. The result showed immense amount of WTP averaging about $ 4.5 per month per person.

Seenprachawong, (2002), used two methods for the economic valuation of Thailand's Coral Reefs. One Travel Cost Method (TCM) and other was CVM. CVM method was usually targeted for the tourists for conservation of degrading coral reefs. In the study he found that both the domestic and international tourists were strongly willing to pay for the conservation of Coral Reefs in Phi Phi. The annual value of the area to visitors was over 8,200 million baht (US$205 million). He also found that the use and nonuse values of Phi Phi coral reefs represented an annual value of some 19,900 million baht (US$497 million).

Hokby and Soderqvist, (2001), estimated the demand for environmental protection amid different income groups in Sweden, and found that environmental improvements to be relatively more beneficial to low income groups. They also concluded that reduced eutrophication effects are an ordinary and price elastic good in applying WTP procedure.

Garrod and Willis, (1998), used this method for estimating the loss of welfare of travelers to recreation areas due to the installation of water pipelines in the United States and find that the WTP would be higher if the number of pipelines is reduced.

Shutz and Lindsay, (1990), estimated WTP for the conservation of groundwater in New Hampshire. The effects of variables such as the number of settlements years in the area, gender, age, the education level and income of the people were statistically significant.

Gramlich, (1977), was one of the earliest researchers who adopted the CVM for estimating public participation in an extraction of demand curve for fresh and clean water. The aim was to calculate the amount of WTP. He completed 165 questionnaires in Boston Metropolitan area and applied statistical models for his estimation. His results showed considerable WTP amounts.

2.3.2. Inside Nepal

Chand, (2011), reported in his study in Nagdaha Lake about the willingness to pay per annum to be NRs. 980, 400 (US$ 83,072). The recreational values was found to be

NRs. 16, 12, 800 (US$ 21, 504) & for aesthetic values NRs. 47, 57, 000 (US$ 63, 426.67). The total economic valuation was computed to be NRs. 1876, 350, 200 (US$ 25, 018, 003).

Karki, (2011), conducted the economic valuation of Panchpokhari wetlands, Indrawati sub basin. She used CVM, Market Price Method (MPM) and TCM methods for the estimation of economic valuation of the wetlands. According to the study, the total monetary value of the wetland was found to be NRs. 1,331,569 per year by calculating the services provided by the wetland as livestock grazing (NRs. 247,500 per year), water feeding for livestock (NRs. 468,750 per year) and recreational value (NRs. 615,319 per year). It was found that the level of awareness about the wetland among the respondents/locals was quite higher and most of them were willing to pay for the conservation and management of the wetland up to NRs. 50 per month per household.

Awasthi, (2010), conducted the economic valuation of wetland ecosystem services in Taudaha lake using Contingent Valuation Method (CVM), Travel Cost Method (TCM) and Hedonic Price Method (HPM). From the study, maximum WTP value for user community and non-user community was found to be NRs. 1,011,200 (US$ 1,349.33) and NRs. 95,200 (US$ 1,269.34) annually respectively. Recreational and aesthetic value was found to be NRs. 16,206,000 (US$ 216,080) annually and existence value was found to be 42% change in property price i.e. 1,422,073,600 (US$ 18,960,981.33). The study revealed Total Economic Valuation (TEV) of Taudaha Lake to be NRs. 17,259,200 (US$ 230,122.67) where existence value is excluded.

Chand, (2010), studied the economic valuation of Ghodaghodi Lake. She calculated the willingness to pay among 75 household as NRs. 23, 37, 000 (US$ 31,453), recreational and aesthetic values to be NRs. 12, 44, 367 (US$ 16,749) & religious values to be NRs. 32, 86 (US$ 441.66).

Biodiversity Profile Project, (1995), identified 10 sites that merit immediate protection. Out of these ten sites three sites: Beesh Hazar Tal, Jagadishpur reservoir and lakes in Pahalmanpur Range Post – Ghodagodi Tal and its cluster in Kailali district have been recommended as sites that need to be given priority attention for conservation and management. The study also presents the valuation of resources in terms of attributes functions and uses. But CVM method was not used.

Till date no knowledge regarding the study of WTP for the lake conservation of Gunde, Neureni and Khaste lakes were found.

2.4. Socio-economic and environmental management

The ecosystem cannot be placed exclusively for conservation purpose without social and economic consideration. The understanding of the socio-economic characteristics of the respondents from the watershed area provides background information for their dependency on vegetation, conservation attitude, awareness and other issues that helps to develop a plan for the sustainable management of natural resources to uplift the people’s life style (Adhikari, 2002).

People in the vicinity of wetland are closely associated with the water bodies with most parts of their daily lives and livelihood. Most important is the food dependency in the wetlands. Wetlands are key contributors, supplying us with a broad range of wild and cultivated food sources such as fish (including shellfish), certain mammals, plants (rice, seaweeds, a range of leafy vegetables, fruits, and nuts, etc.), reptiles, amphibians, insects and other arthropods, snails and more. Two thirds of all fish consumed worldwide are dependent on coastal wetlands at some stage in their life cycle. Annual fish and seafood production in swamps and marshes worldwide has been estimated at an average of nine tons/km^2, 259 ha or 640 acres (Ramsar, 2007).

Besides rice farming and aquaculture, generally other managerial aspects for wetlands are new concepts for the common Nepalese people. Compilation of an inventory on wetlands of national significance and priority action plans, interdisciplinary approach to develop integrated rural development programme should established at a national level for policy formulation. Training of manpower oriented to the conservation of wetland and research on wetlands to generate necessary data and information concerning effective management of the wetlands are the issue on the wetland management (Bhandari, 1992).

2.4.1. Outside Nepal

Ranga, (2006), stated that though 94% wetland dependent people rely on fishing, considerable number of the world's wetlands also support agriculture for the people in the vicinity of wetland in Kerala, India. Due to the variability of livelihood options in a healthy wetland, life is fully supported in the wetland but due to varied number of factors such as lack of production and low yield, shortage and high cost of labor has decreased livelihood option for people of wetland.

2.4.2. Inside Nepal

Adhikari, (2002), conducted the study on Khaste and Dipang lakes located in Pokhara valley, Western Nepal. He reported that high in-migration from upland and lack of grazing land, eutrophicaiton, sedimentation, undefined lake boundary, degradation of water quality; encroachment and over growth of aquatic weeds were the major threats to the lake environment.

Bhandari, (1998), found siltation and vegetation succession as main threats to the Beehazar Lake. The man-made threats include overfishing, grazing, plant harvesting, collection of building materials and use of toxic substances in the water. The suggested conservation actions included the preparation of a community based management plan, demarcation of the conservation area, establishment of a conservation education centre, strategic environment assessment, confidence building and community awareness.

IUCN-Nepal, (1996), stated that several ethnic groups of people are dependent on wetland resources for their livelihoods in Nepal. They are Sunaha, Khanwas, Mallahs, Bote, Mushahars, Bantar, Gongi, Mukhia (Bihin), Dushad, Sahani, Kewat, Danuwars, Darai, Kumal, Barhamus, Dhangar, Pode, Kushars, and Majhi of Terai districts who depend primarily on fishing and aquatic resources for their livelihoods. Nepal's wetlands are mostly used for fishing (94%) then for grazing, irrigation, plant harvest, domestic use, fuel wood, wild life and religious use.

Sah, (1993), in his study in Koshi Tappu Wildlife Reserve observed that the wetlands site provided pastures for thousands of cows and domestic buffaloes and other construction materials which constitute considerable percent of the local economy.

CHAPTER 3

3. METHODOLOGY

3.1. Research design

The research design is given in the flow chart (Fig 3.1) as follows

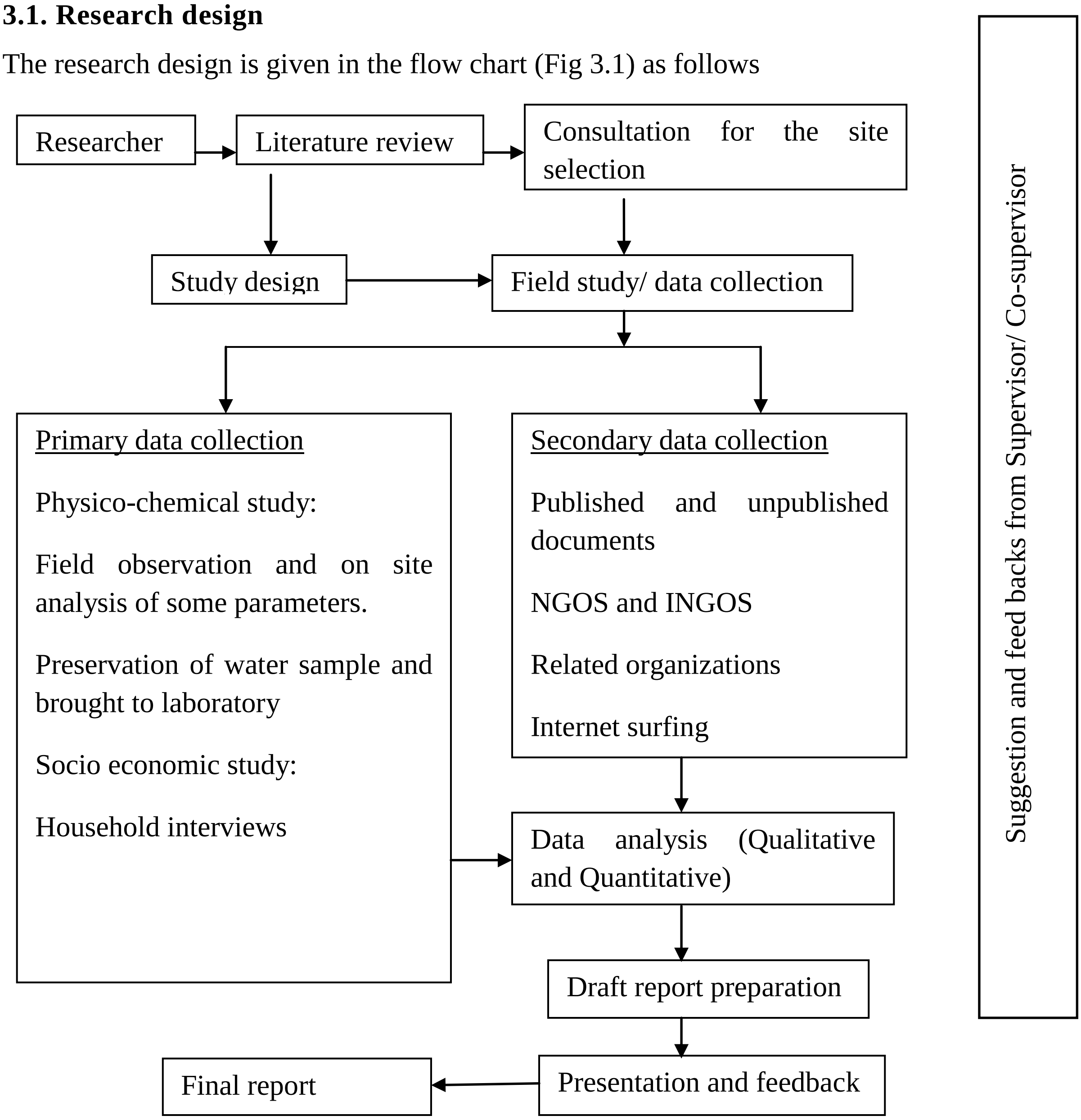
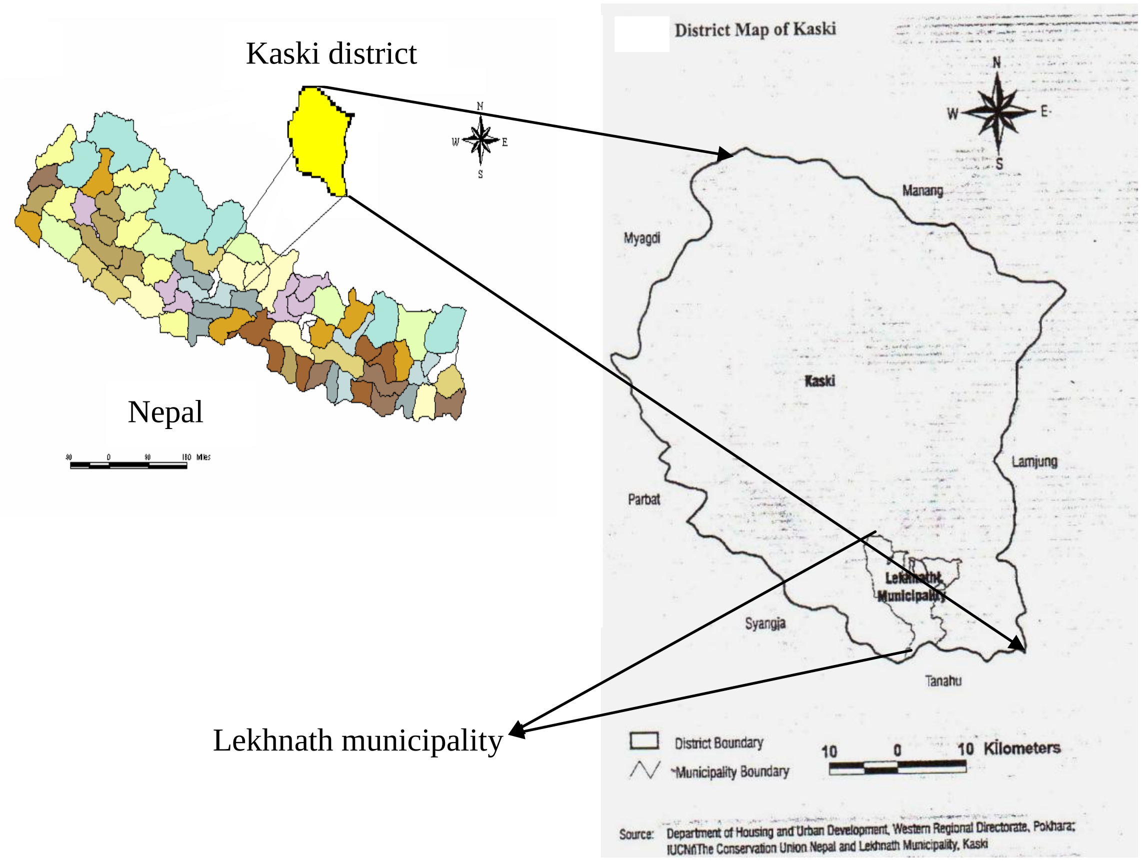


Figure 3.1: Flow chart of research design

3.2. Description of study area

3.2.1. Kaski district

Kaski district is one of the most important districts in geographical, social and economic consideration in the country. It attracts thousands of tourists every year for its scenic beauty and natural as well as heritage from within the country and the world over. It lies in the western region of Nepal between $27^0$6‘to $28^0$36‘N and $83^0$40‘to $84^0$12‘E. It covers an area of 20, 1856 ha. This district extends from 450 m to 7969 m in altitude. Kaski, a middle hill district in western Nepal, covers a land area of 2017 km^2 and has 1 sub-metropolitan city, 1municipality and 43 VDCs. The vegetation ranges from subtropical to alpine forest comprising mostly *Schima- Castanopsis*, Sal, Alder, Pines, Rhododendron, Oak and various types of alpine vegetation. Total population of the district is 380527 (2058 census). The Prithivi Highway, The Siddhartha Highway and The Pokhara-Baglung Highway are main Highway running through district. Pokhara is the district headquarter. The neighboring districts Lamjung and Tanahun are in the East, Parbat in the West, Manang and Lamjung in the North and Tanahun and Syangja lie in the South of Kaski. Madi, Seti and Modi rivers flow in this district. The major famous lakes and ponds include Fewa, Rupa, Begnas, Dipang, Maidi and Khaste. Total population is 3,80,527 with 1,84,995 male and 1,95,532 female. Population density is 189 per km^2. There are 85,075 households with an average household size of 4.47. Main religion is Hindu and Buddhist comes to the second. Nepali is main language. Besides, Newar, Gurung, Magar dialects are also spoken (Khanal, 2011).



Map 3.1: District map of Kaski

3.2.2. Lekhnath municipality

Lekhnath municipality is located in Kaski district in the Gandaki zone of northern-central Nepal. It is located in the south western part of the Pokhara valley, about 10 km southwest of Pokhara and about 190 km west of Kathmandu. Total area of this city is 69.15 km^2. Total population of the city is 30,107 as per the census carried out in 2001. Composition of the population is 86% Hindu, 8% Buddhist and 6% others. The town is very spread out and has no down-town or centre.

Lekhnath is named after the famous Nepali poet Lekh Nath Paudyal (1885–1966), but is also called the garden city of seven lakes. The seven lakes are Begnas, Rupa, Khaste, Depang, Maidi, Neureni and Gunde. Except Begnas and Rupa most of the other lakes are little known to the outsiders. Likewise, according to the survey data of Lekhnath municipality, the total area of Begnas lake was reported as 3.73 km^2, Rupa lake - 1.15 km^2, Khaste lake - 13.57 ha, Dipang lake - 8.98 ha, Gunde lake – 4.98 ha, Neureni lake - 2.83 ha and Maidi lake - 1.17 ha. Since few researches had been done in these lakes, the lakes are also in the threat to the degradation and disappearance (Pokharel, 2008).

Lekhnath possesses many terrains and Mountain view sites. It is also becoming a famous destination among trekkers as some of the comfortable and short trekking routes in Pokhara valley begin here. Rightly called eastern gateway to Pokhara, Lekhanth, is the place from where we can catch the view of the whole Annapurna range including Machhapuchhre (Fishtail), and Dhaulagiri. Gagangaunga, Shishuwa, Lekhnath chowk, Rajako Chautara, Satmane, Dhungepatan are some big and notable places of Lekhnath. Khudi-12, Bhandardhik-1, Begnash-10, Kholabesi-1, Talchock-7, Rithepani-2, Budhibazar-4, Gharipatan-5, Baraldada-4, Pachabhaiya-11 are small places of Lekhnath municipality.

3.2.3. Site selection

The study sites were three lakes at BDLC which is situated in Lekhnath municipality in Kaski district. The site was chosen with reference for the study purpose. The present study was to know about the status of unnoticeable lakes in Lekhnath municipality. For this purpose, the surrounding three lakes in BDLC provided the feasible site for the study. The study sites are located in the ward number 4 and 6 of

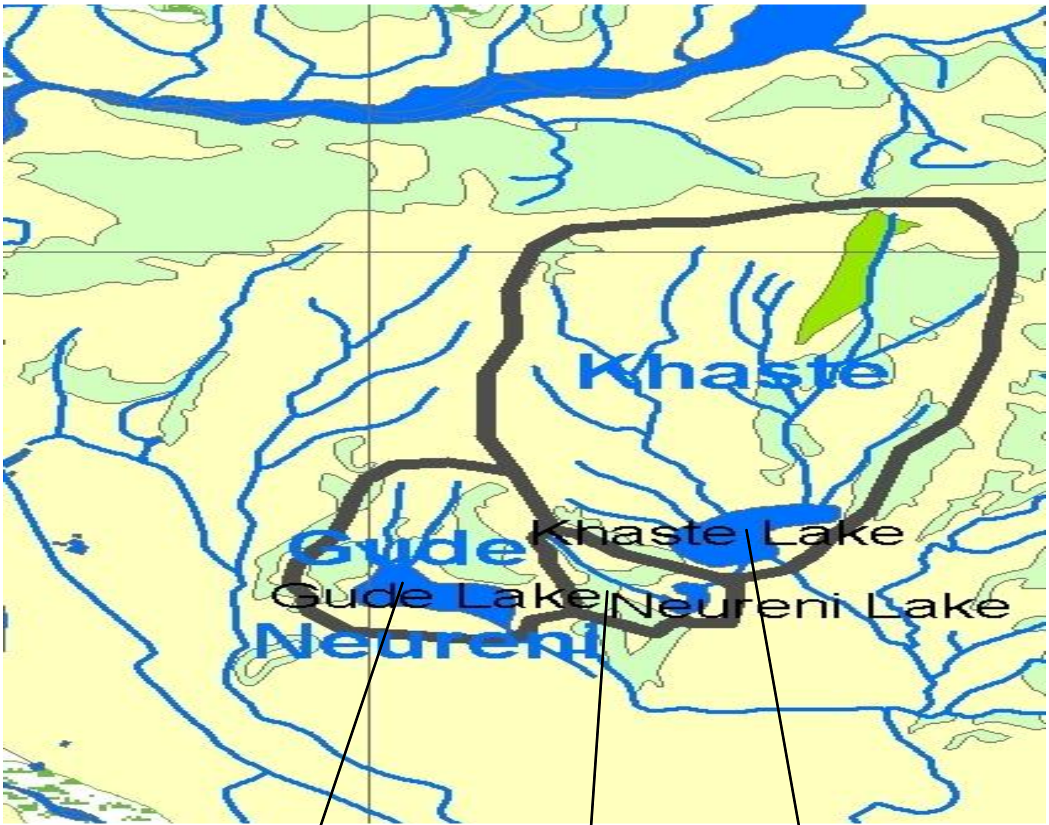
Lekhnath municipality. The names of three lakes for the study were Khaste, Gunde and Neureni.

i. **Gunde lake:** The Gunde lake (fig. 3.2) is situated in the eastern part of Pokhara valley near Khaste lake. Baral Danda separates the Gunde lake with Khaste and Nureni lakes. The area of the lake is about 0.15 km^2 and the depth is about 0.5 meter. The lake is overgrown by aquatic vegetation and swampy shore. Its southern side is surrounded by agricultural lands and in the western and northern side *Schima-Castanopsis* and *Shorea robusta* mixed forest are found. A newly constructed dam is situated in the southern side. The eastern side of the lake is road going uphill to the Baral Danda (Pant, 2008).

ii. **Khaste lake:** The Khaste lake (fig. 3.3) is situated at an elevation of 640m above sea level. It is situated in the eastern part of Pokhara valley. The area is about 0.64 km^2. The depth is about is about 1.5- 2 m. The inlet of this lake is Thulo Khola and the outlet is Gaduwa Khola. It is eutrophic and tectonic lake with associated swampy mats and grasslands cover more than 50% of the lake area. Its northern and southern parts are surrounded by agricultural land where as the eastern and western sides covered with *Schima-Castanopsis* and *Shorea robusta* mixed forest (Pant, 2008).

iii. **Neureni lake:** The Neureni lake (fig. 3.4) is situated at the side of Khaste lake. Among the seven lakes situated in the Lekhnath municipality, it is the smallest lake. The area of the lake is 0.15 km^2 and the depth is 0.5 m. The lake is also overgrown by aquatic vegetation and swampy shore. The lake is surrounded by agricultural land in the southern side, Khaste lake in the eastern side and forest in the western and northern sides (Pant, 2008).

3.2.4. Catchment area of lakes



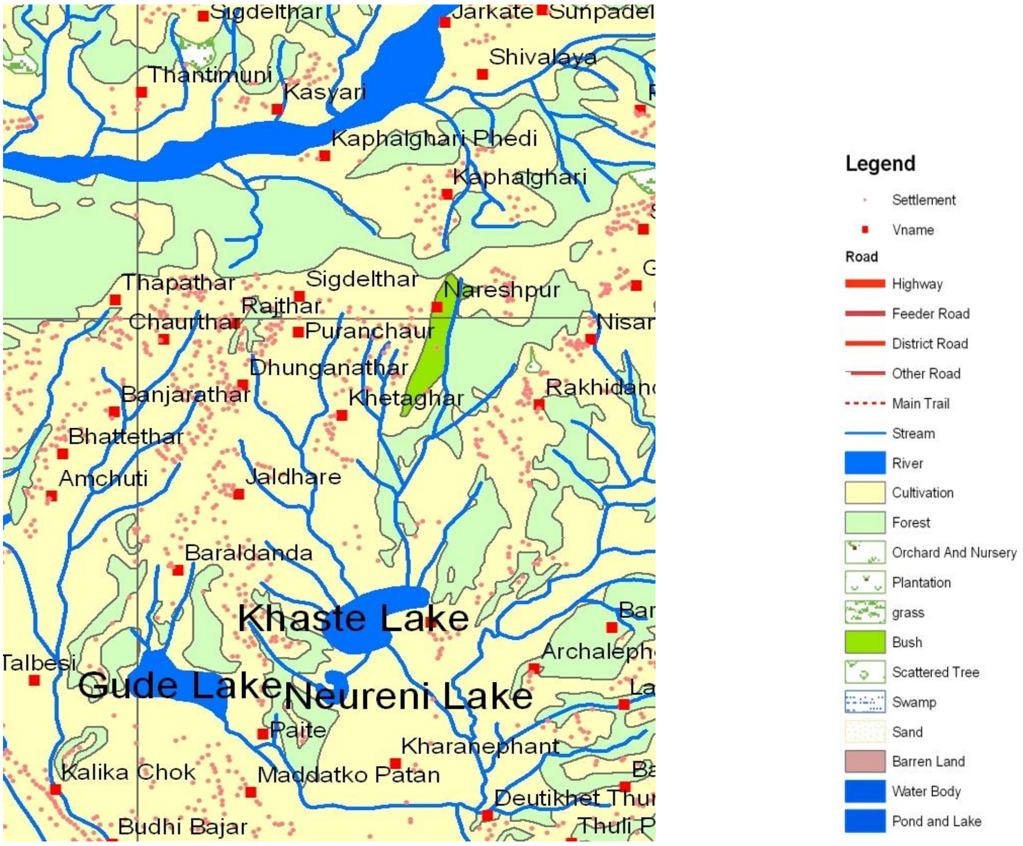
Map 3.2: Catchment area of lakes

Figure 3.2: Gunde lake

Figure 3.3: Khaste lake

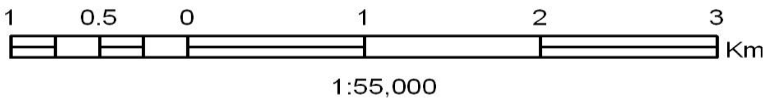
Figure 3.4: Neureni lake

3.2.5. Land use pattern of lakes



Map 3.3: Land use patterns of lakes

Scale:

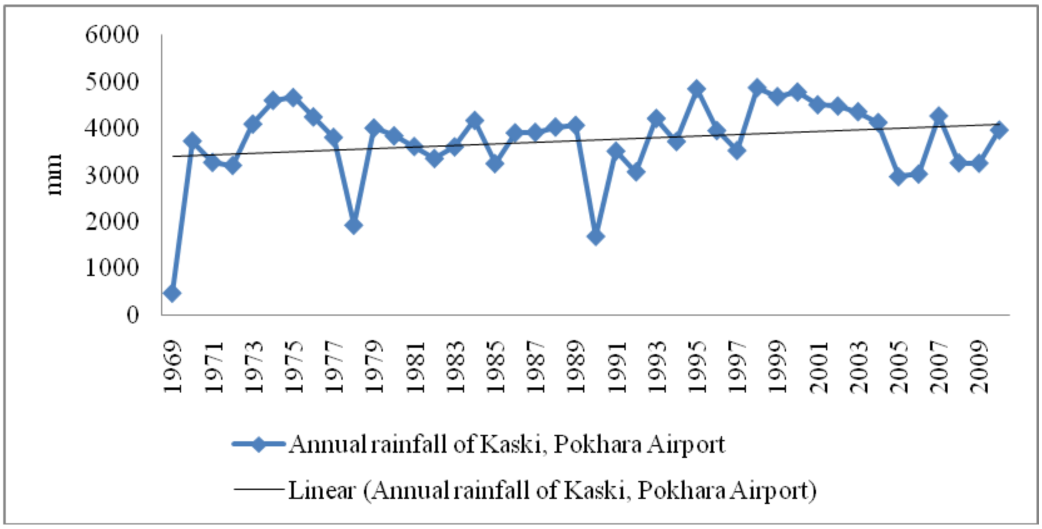


3.2.6. Climate

The study area enjoys the humid and sub-tropical with a monsoon rainfall pattern. It is characterized by moderate temperature, heavy monsoon rainfall and distinct seasonal variations. The average temperature in the valley floor ranges between 13°C and 22°C. The annual maximum temperature of 25.5°C and minimum temperature of 15.9°C was recorded in the year 2001 A.D. The annual rainfall averages 3700 mm with eighty two percent of precipitation occurring during the summer months from June to September. Local convection hailstorms in autumn and strong winds during the dry spring are the occasional local climatic phenomenon. Occasionally, ground fog appears from warm to hot warm. All climatological data are recorded at Pokhara airport, 10 km west from the study area (Adhikari, 2002).

3.2.7. Rainfall pattern

The mean of the annual rainfall of Kaski, Pokhara airport was found to be 4000.27 mm and its annual rainfall pattern is shown in figure 3.5. The rainfall data is presented in annex VII.

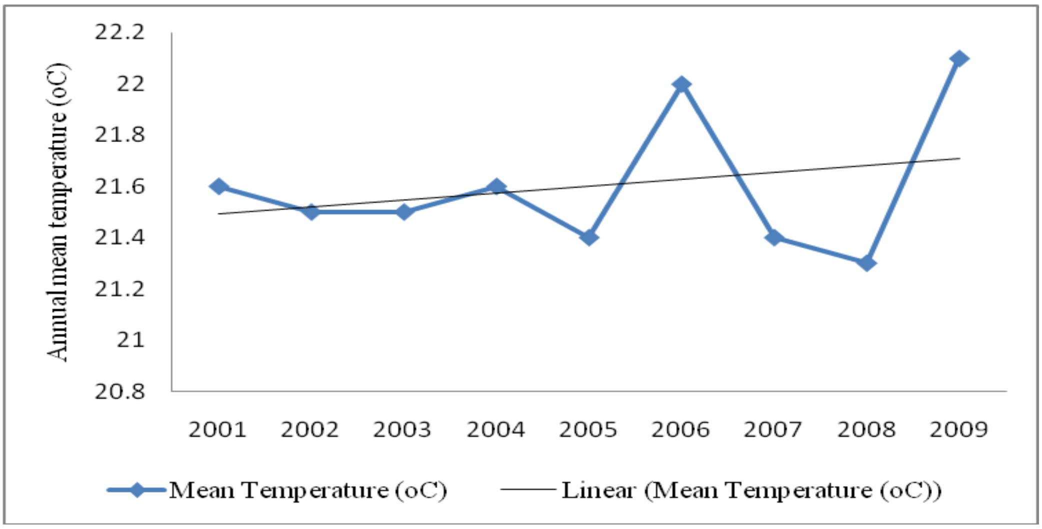


(Source: DHM, 2009)

Figure 3.5: Annual rainfall of Kaski, Pokhara airport

3.2.8. Temperature pattern

The mean annual temperature of Kaski, in Pokhara Airport was found to be 21.6°C. From fig 3.6, it was found that the mean temperature is increasing. The figure 3.6 represents the annual mean temperature of Kaski, Pokhara Airport and its data is presented in annex VIII:



(Source: DHM, 2009)

Figure 3.6: Annual mean temperature of Kaski, Pokhara airport

3.2.9. Geology

The soil of study area is dry to moist and yellow to brown in color. The soil at the bank of Khaste, Gunde, and Neureni Lakes comprises clay soil. The study area consists of Kuncha Formation with gritty phyllite and some band of quartzite. Most of the rocks are phyllite but these rocks contain high amount of muscovite-serite-chlorite. These minerals have very low hardness and it is easily weathered and eroded by geological agents and easily transported downstream. These minerals are very fine in texture. So, wind or water play significant role to transport them from one place to the other. The area occupied by such rock has gentle topography because the rock can be easily weathered and transported. However, in these samples the content of quartz is high but due to fine grain size, these grains are also easily transported and deposited in the lakes downstream and more prone to siltation in the lake (Manandhar *et al.*, 2011).

3.2.10. Flora

The study area is surrounded by *Shorea robusta* and *Schima-Castanopsis* mixed forest. *Shorea robusta* extend at the lower altitude of watershed zone (630m-1000m) occupying the lower parts of the southern, southeastern and southwestern hill slopes. The forest of *Schima-Castanopsis* is dominant in the northern, northeastern and northwestern parts of hill. The species associated with *Schima-Castanopisis* forests are *Bombax ceiba*, *Fiscus roxburghii*, *Toona ciliata*, *Engelhardia spicata*. Although natural vegetation in these forests has severally altered, the interior sometimes consists of primeval forest and provided shelter to different wild life and birds. Very limited grassland both in and outside the forested areas lying the watershed zone are dominated by *Imperata cylinderica*, *Artimisia vulgaris*, *Pteridium spp*, *Lygodium spp*, thorny bushes like *Rubus* and *Pyracantha* (Adhikari, 2002).

The lake associated watershed areas are very rich in both wetlands and terrestrial vegetation. Aquatic plants like *Azolla imbricate*, *Ceratophyllum demersum*, *Hydrilla verticillata*, *Potamogeton sp*, are frequently found in the lakes in submerged form. *Nymphoides indica*, *Ludwigia adscendens*, *Nelumbo nucifera* and *Trapa quadrisinosa* are the most dominant rooted floating species in the three lakes. *Oryza rufipogon* is luxuriantly growth in the marshy areas of lakes. *Polygonum hydropiper*, *Schoenoplectus mucronatus*, *Leersia hexandra*, *Ceretopteris thallictroids* are grown densely at the shore of lakes mainly in rainy and summer season. The adjacent grassland vegetation is dominated by *Cyperus species*. Introduction of *Eichhornia crassipes* in lakes is the cultural eutrophication (Adhikari, 2002).

3.2.11. Fauna

Forty three species of fish, reptile, amphibian and bird species were recorded from Khaste lake. Twelve species of fish from Khaste lakes were recorded (Oli, 2000). Total 19 bird species were recorded from Khaste (Oli, 2000). The varied habitats in the lake's forest, shrub land, grasslands, rice fields, marshlands, lakes and ponds can be attributed to the high faunal diversity (Oli, 1996). The long distance migratory Siberian Crane (Karyang Kurung), an endangered bird species visits the swampland of lakes. Other important bird species in these lakes are hawk, owl, teal, water cock, water duck and a variety of egrets, kingfishers and pond herons. After the introduction of erotic fish species (grass carp, silver carp, and bighead carp), commercial fish production is increased in Khaste lake (Adhikari, 2002). In Gunde lake macro invertebrates like Odonata, Water spider, Lymnaeidae, Viviparidae, Planorbidae, Hemiptera, Mayfly nymph, Physidae etc were seen around the lake area.

3.3. Data collection methods

The data collection for physico-chemical analysis was done by sampling of water from different sides of the lakes. The water samples for physico-chemical analysis were collected from three sites of Neureni Lake and Khaste Lake and from five sites of Gunde Lake at the seasonal interval from March, 2010 A.D. to August, 2011 A.D. The surface water samples were collected in pre cleaned one liter polythene bottle. The samples were collected in two seasons, dry (March) and rainy (July) season and for two years, i.e. in the year 2010 A.D. and 2011 A.D.

The bottles were tagged with date, time and site of sample collection. The parameters such as temperature, pH, conductivity, dissolved oxygen, free carbon dioxide, total alkalinity as $CaCO_3$, total hardness as $CaCO_3$, Ca-hardness as $CaCO_3$ and chloride were measured in the field. For analyzing other parameters, the water samples were carried in the laboratory of CDES, Kirtipur. All the parameters were analyzed following the standard methods used in APHA, 1998 and chemical methods for water pollution studies (Trivedy and Goel, 1986).

Likewise, for socio-economic data collection, random sampling methods were used. The questionnaire method was used for the socio-economic data collection. The physico-chemical data analysis was done by using Microsoft Word 2007 and Microsoft Excel 2007 while the socio-economic analysis was done by using Statistical Package for Social Science (SPSS) Software version 16.0 for Windows.

3.4. Methods of results presentation

3.4.1. Physico-chemical parameters

Table 3.1 represents the lists of physico-chemical parameters for the study purpose. The detailed procedure for each parameter is presented in annex IV.

Table 3.1: List of physico-chemical parameters and measurement methods

Parameters	Measurement methods
Temperature	Thermometric
pH	Electrometric
Conductivity	Electrode
Dissolved Oxygen	Modified Winkler's iodometric method
Free CO_2	Oxidation and Titrimetric
Total Alkalinity as $CaCO_3$	Acid Titrimetric
Chloride	Argentometric Titration
Total hardness as $CaCO_3$	EDTA Titrimetric
Ca-hardness as $CaCO_3$	EDTA Titrimetric
Mg-hardness as $CaCO_3$	EDTA Titrimetric
Biochemical Oxygen Demand	Five days BOD & Winkler's method
Chemical Oxygen Demand	Oxidation and Titrimetric method
Ortho-phosphate	Ammonium Molybdate method
Ammonia	Phenate method
Nitrate	Phenol Disulphonic acid method
Total Iron	Phenanthroline method

3.4.2. WQI calculation

Bach (1980) developed index which is different from other indices. In this index for each parameter the transformed value raised to power of weight of the particular parameters assigned and is calculated and thus obtained eight values for eight parameters are multiplied to get chemical index of that site (Pradhan, 1998). The table used for obtaining transformed values of eight parameters (q_i) is presented in annex VI.

Calculation for Bach Index

$$CI = \prod_{i=1}^{n} q_i^{w_i}$$

$$CI = q_1^{w1} \times q_2^{w2} \times q_3^{w3} \times \ldots\ldots\ldots\ldots \times q_n^{wn}$$

Where, CI = Chemical Index

q_i = Transformed value of each parameter

wi = relative weight of nth parameter

q_i^{wi} = value for each parameter

Table 3.2: Parameters and their weight

S.No.	Parameters	Unit	Importance value (W_i)
1	Temperature	^oC	0.08
2	Oxygen saturation	%	0.20
3	BOD_5	mg/L	0.20
4	pH	-	0.10
5	NO_3^- - N	mg/L	0.10
6	O-PO_4^{2-} - P	mg/L	0.10
7	NH_4^+-N	mg/L	0.15
8	Electrical conductivity	µs/cm	0.07
9	Total weight		1.00

Table 3.3: Water Quality Rating based on Bach (1980)

S.No.	Chemical Index	WQ class	Color indicator	Rate
1	0 – 17	IV	Red	Excessive pollution
2	17 – 27	III – IV	Orange	Very severe pollution
3	27 – 44	III	Yellow	Severe pollution
4	44 – 56	II – III	Light green	Critical pollution
5	56 – 73	II	Green	Moderate pollution
6	73 – 83	I – II	Light blue	Low pollution
7	83 – 100	I	Blue	No or very low pollution

3.4.3. Socio-economic analysis

CVM is one of the first methods used for the analysis of environmental problems by different authors and researchers. CVM is used in the study to ascertain the value that local villagers place on the less tangible benefits associated with wetlands that do not arise from the direst use of resources or products (indirect, option and bequest values) (Khorshiddoust, 2004). The CVM survey incorporates two stages. The first, involves a general discussion with willingness on matters relating to their understanding of wetland resources, perceptions of changes in their quantity and quality over time, and involvement in/ perceptions of various programme which are ongoing and deal with wetland resources. This sets the scene for CVM and provides the background information and share awareness necessary to carry it out.

A second stage is then to elicit people's stated preferences and WTP for wetlands. A CVM survey was carried out of questionnaire respondents, eliciting their bids using a dichotomous choice method (which present an upper and lower estimate between which respondents have to choose). Villagers were asked whether they would be willing to pay for a conservation programme to secure indirect use, option and bequest benefits with the values of Rs. 1, Rs. 500 and Rs. 1,000. If the respondents answered yes to and initial question of WTP of Rs. 500, s/he was asked a second question about WTP Rs 1,000. Conversely, if the first question is refused, a second question was asked of about Rs 1. Taking into account the fact that respondents' WTP may be below or above the stated amount, additional questions was asked about the maximum WTP.

Structured interviews involving a questionnaire (Annex III: Household questionnaire) were administered each of 38 HHs surveyed among 984 HHs i.e. about 4% of the sample size. Since due to time constraints the survey was taken only within 5 km of lake area so 38 number of HHs complement the study purpose. The questionnaire comprised both closed and open ended questions. The respondents were asked questions about their general socio-economic, demographic, occupation and income sources, as well as about the incidence, levels and value of wetland resource use. The questionnaire also included a section designed to elicit 'respondents' WTP for wetland indirect and non-use benefits.

For the socio-economic analysis SPSS software version 16.0 was used for the analysis of results. Both primary and secondary socio-economic data were collected. Secondary data compromised a review of government statistics, and other studies carried out on livelihoods and economic activities in Lekhnath municipality. Primary data constituted information on HH socio-economic profile. The correlation matrix table was obtained by the help of SPSS software version 16.0.

Estimation of wetland indirect use, option and bequest values using CVM

WTP Rate

Aggregate $WTP_a = \sum i\,[(\Theta i) \times (\eta j) \times (\Theta i\ wtp)]$ ………………………….. (1)

where: WTP_a = willingness to pay for wetland goods and services per annum

Θi = percentage of the sample in category I

ηj = total number of households of the area

Θi wtp = mean maximum amount of money individual household is willing to pay for wetland indirect use values, optional use value and bequest value per annum in order for their continuous existence.

Individual household WTP_a = Aggregate $WTP_a / \eta j$ ……………………………. (2)

ηj = aggregate number of household in Baral Danda

(Source: Kulindwa *et al.*, 2006, cited in Kasthala *et al.*, 2008)

3.4.4. Statistical analysis

The seasonal and annual variation of the physico-chemical parameters of water of three lakes was tested for its significant of variation. The independent sample t-test was used for the calculation of its significance because the sample size was few. And hence for the individual lakes, t-test was used was used for both seasonal and annual data individually.

CHAPTER 4

4. RESULTS

4.1. Analysis of physico-chemical parameters

The data of physico-chemical parameters of Gunde lake, Neureni lake and Khaste lake were taken in dry and rainy for two years (2010 - 2011 A.D.). Different sampling sites were used for data collection but the mean values of those sampling sites were taken for further analysis of data. The values of sampling sites and its mean values with standard deviation are presented in annex I and II.

4.1.1. Gunde lake

4.1.1.1. Physico-chemical parameters

The mean physico-chemical parameters of Gunde lake were analyzed on the basis of seasonal and annual variation. The data in table 4.1 represents the values from dry season and rainy season and from 2010 A.D. to 2011 A.D.

Table 4.1: Mean seasonal and annual variation of physico-chemical parameters

Physico-chemical parameters	Dry season, 2010 A.D.	Rainy season, 2010 A.D.	Dry season, 2011 A.D.	Rainy season, 2011 A.D.
Temperature (°C)	17.60	26.33	26.25	28.10
pH	8.02	7.27	7.55	7.90
EC (µs/cm)	35*	26*	126.50*	57.80*
DO (mg/L)	4.22^	4.59^	5.47	6.42
Free CO_2 (mg/L)	21.36*	22*	14.30*	21.12*
Total alkalinity as $CaCO_3$ (mg/L)	40	16.67^	37.50	26
Chloride (mg/L)	13.63	38.81	29.11	23.85
BOD_5 (mg/L)	12.97*	16.20*	12.15*	14.40*
COD (mg/L)	52*	60*	64*	56*
Total Iron (mg/L)	0.96*	0.45*	1.32*	1.02*
Total hardness as $CaCO_3$ (mg/L)	19.20	21.33	54.25	30.60
Ca-hardness as $CaCO_3$ (mg/L)	7.20	9.33	4.01	7.93
Mg-hardness as $CaCO_3$ (mg/L)	12	12	50.24	22.66

* indicates value exceeded WHO guidelines for drinking water ; ^ indicates didn't meet WHO guidelines for drinking water

From table 4.1, the mean temperature in 2010 A.D. of Gunde lake in dry season was found to be 17.60^{o}C which increased to 26.33^{o}C in rainy season. In 2011 A.D., the mean temperature increased from 26.25^{o}C to 28.1^{o}C in dry and rainy season respectively. It showed the increase of temperature from 2010 to 2011 A.D. The mean pH values in 2010 A.D. decreased from 8.02 in dry season to 7.27 in rainy season. In 2011 A.D., the mean pH values were 7.55 in dry and 7.90 in rainy season respectively. The mean pH value was found to be high in dry season, 2010 A.D. and low in rainy season, 2010 A.D. This means year 2010 A.D. showed marked pH variation. The mean EC in the year 2010 A.D. was 126.50 µs/cm in dry season, 2011 A.D. which is the highest value than other times of sampling. In Gunde lake, mean DO values in dry and rainy season, 2010 A.D. were 4.22 mg/L and 4.59 mg/L respectively. This values were below 5 mg/L, which is the standard value for WHO drinking water guidelines. In 2011 A.D., the mean values of DO were 5.47 mg/L and 6.42 mg/L respectively. The mean free CO_2 for 2010 A.D. were 21.36 mg/L and 22 mg/L respectively; 14.30 mg/L and 21.12 mg/L in dry and rainy season in 2011 A.D. respectively. The values were found to exceed WHO values for drinking water. The mean total alkalinity as $CaCO_3$ of all the samples were found to be within the range of WHO values for drinking water. The mean chloride values of dry and rainy season for the year 2010 A.D. and 2011 A.D. was found to be within WHO range for drinking water i.e. 250 mg/L. The total hardness as $CaCO_3$, Ca-hardness as $CaCO_3$ and Mg-hardness as $CaCO_3$ were determined. The mean total iron were found to be 0.96 mg/L and 0.45 mg/L for dry and rainy season respectively in 2010 A.D. and in 2011 A.D., it was 1.32 mg/L and 1.02 mg/L for dry and rainy seasons respectively. The mean total iron values were higher in dry season than rainy season. The mean total iron values far exceeded WHO guidelines for drinking water. The mean BOD_5 was determined and found that it exceeded WHO guidelines for drinking water. Also the mean COD values was found to exceed WHO guidelines for drinking water. The correlation matrix table of different parameters for Gunde lake is presented in annex IV.

(**Note:** The studied physico-chemcial parameters have been also compared with Nepal water quality guidelines for different purposes like drinking water, recreation, livestock watering, aquaculture and protection of aquatic ecosystems and are analyzed in discussion section)

4.1.1.2. Nutrient salt analysis

The nutrient salt analysis were analyzed taking ortho-phosphate, ammonia and nitrate into consideration. The mean values of orthophosphate were 0.09 mg/L, 0.06 mg/L, 0.10 mg/L and 0.12 mg/L in dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The mean values of ortho-phosphate was found to increase significantly from rainy season, 2010 A.D. till rainy season, 2011 A.D. The mean values of orthophosphate exceeded WHO values for drinking water. The mean values of nitrate in 2010 A.D. were found to be 0.82 mg/L and 0.67 mg/L for dry and rainy season respectively. In 2011 A.D., it was 1.76 mg/L and 2.88 mg/L in dry and rainy season respectively. The mean values were found within WHO guidelines for drinking water. Likewise, the mean values of ammonia were 0.04 mg/L and 0.42 mg/L in 2010 A.D.; in 2011 A.D., it was 0.04 mg/L and 0.87 mg/L for dry and rainy season respectively and showed within WHO values for drinking water. Fig 4.1 shows the graphical representation of mean seasonal and annual values of ortho-phosphate, nitrate and ammonia of Gunde lake.

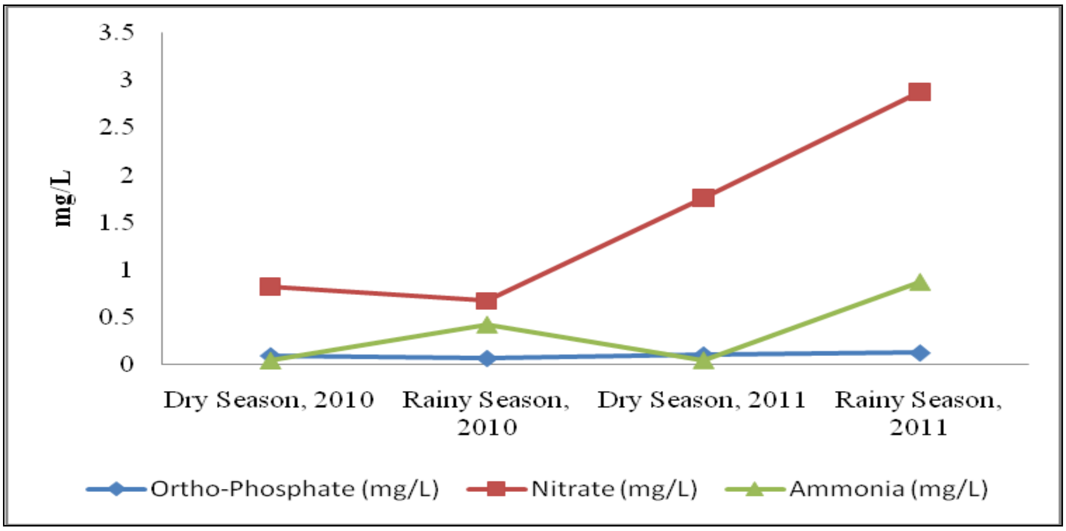


Figure 4.1: Nutrient salt analysis of Gunde lake

4.1.2. Neureni lake

4.1.2.1. Physico-chemical parameters

The physico-chemical parameters of Neureni lake were analyzed and interpreted on the basis of seasonal and annual variations. Various parameters like temperature, pH, conductivity, DO, free CO_2, total alkalinity as $CaCO_3$, chloride, BOD_5, COD, iron, total hardness as $CaCO_3$, Ca-hardness as $CaCO_3$ and Mg-hardness as $CaCO_3$ were determined. The mean temperature was found to be 19°C, 24°C, 27.67°C and 30°C for dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The temperature was maximum in rainy season in 2011 A.D. Also, the temperature data showed gradual increase in temperature from 2010 to 2011 A.D. The mean pH values were found to be 7.87, 7.37, 7.47 and 7.67 for dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The pH was found to be within WHO guidelines for drinking water. Likewise EC of two seasons in two years was 35.33 µs/cm, 45.67 µs/cm , 159 µs/cm and 48.33 µs/cm respectively. The mean EC values was highest in dry season in year 2011 A.D. The mean seasonal and annual values for various physico-chemical parameters are shown in table 4.2.

Table 4.2: Mean seasonal and annual variation of physico-chemical parameters

Physico-chemical parameters	Dry season, 2010 A.D.	Rainy season, 2010 A.D.	Dry season, 2011 A.D.	Rainy season, 2011 A.D.
Temperature (°C)	19	24	27.67	30
pH	7.87	7.37	7.47	7.67
EC (µs/cm)	35.33*	45.67*	159*	48.33*
DO (mg/L)	5.40	5.40	4.87^	6.30
Free CO_2 (mg/L)	30.80*	20.53*	17.60*	16.13*
Total alkalinity as $CaCO_3$ (mg/L)	46.67	23.33	76.67	26.67
Chloride (mg/L)	14.20	42.60	22.72	17.51
BOD_5 (mg/L)	13.52*	8.10*	10.13*	16.40*
COD (mg/L)	22*	20*	15.60*	19.60*
Total Iron (mg/L)	0.54*	0.49*	1.15*	1.47*
Total hardness as $CaCO_3$ (mg/L)	40	32	83.33	27.66
Ca-hardness as $CaCO_3$ (mg/L)	12	11.33	24.05	7.21
Mg- hardness as $CaCO_3$ (mg/L)	28	20.67	59.28	20.45

* indicates value exceeded WHO guideline for drinking water; ^ indicates didn't meet WHO guidelines for drinking water

In 2010 A.D., the mean DO values were 5.40 mg/L and 5.40 mg/L in both dry and rainy season respectively. This showed same DO values in year 2010 A.D. The mean DO value then decreased to 4.87 mg/L in dry season of 2011 A.D. but increased significantly to 6.30 mg/L in rainy season in the similar year. The mean free CO_2 was

30.80 mg/L, 20.53 mg/L, 17.60 mg/L and 16.13 mg/L in dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectivley. The mean values of free CO_2 showed significant decreasing trend from 2010 to 2011 A.D. The mean total alkalnity as $CaCO_3$ was 46.67 mg/L and 23.33 mg/L in dry and rainy season in 2010 A.D.; 76.67 mg/L and 26.67 mg/L in dry and rainy season in 2011 A.D. respectively. Accordingly, the mean values of chloride were found to be 14.20 mg/L, 42.60 mg/L, 22.72 mg/L and 17.51 mg/L respectively for 2010 A.D. to 2011 A.D. The value was maximum in rainy season of 2010 A.D. and minimum in dry season of 2010 A.D. The mean BOD_5 values were found to exceed WHO guidelines for drinking water and showed least value in rainy season of 2010 A.D. The mean COD values were determined and found to be maximum in dry season, 2010 A.D. The mean total iron was found to be 0.54 mg/L, 0.49 mg/L, 1.15 mg/L and 1.47 mg/L respectively. The values were far greater than WHO guidelines for drinking water. The total hardness as $CaCO_{3,}$ Ca-hardness as $CaCO_3$ and Mg-hardness as $CaCO_3$ were also determined and found to be within WHO guidelines for drinking water. The correlation matrix table is presented in annex IV for Neureni lake.

4.1.2.2. Nutrient salt analysis

The nutrient salt analysis was interpreted with respect to mean values of ortho-phosphate, nitrate and ammonia. The mean values of ortho-phosphate was found to be 0.09 mg/L, 0.08 mg/L, 0.07 mg/L and 0.10 mg/L in dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The mean values of ortho-phosphate was found to be higher than WHO guidelines for drinking water. The mean values of ammonia was 0.02 mg/L, 0.37 mg/L, 0 mg/L and 0.10 mg/L in dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The mean values of ammonia were found to be less in Neureni lake as compared with WHO values for drinking water. Likewise, the mean values of nitrate was found to be 1.03 mg/L, 0.67 mg/L, 0.49 mg/L and 2.75 mg/L for dry and rainy season in 2010 A.D. and 2011 A.D. respectively. The mean values of nitrate were found to decrease from dry season, 2010 A.D. to dry season, 2011 A.D. but increased sharply in rainy season, 2011 A.D. The values were found within WHO guidelines for drinking water. The mean values of seasonal and annual variation of ortho-phosphate, nitrate and ammonia are shown in figure 4.2.

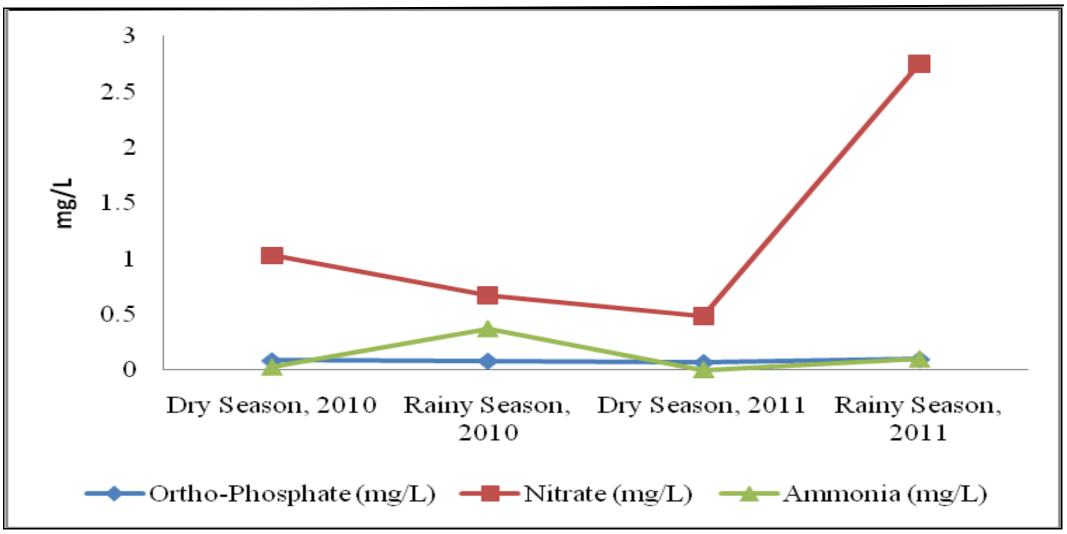


Figure 4.2: Nutrient salt analysis of Neureni lake

4.1.3. Khaste lake

4.1.3.1. Physico-chemical parameters

The physico-chemical characteristics of Khaste lake was determined taking various parameters like temperature, pH, EC, DO, free CO_2, chloride, total alkalinity as $CaCO_3$, total iron, BOD_5, COD, total hardness as $CaCO_3$, Ca-hardness as $CaCO_3$ and Mg-hardness as $CaCO_3$ into consideration. The mean seasonal and annual variations of physico-chemical parameters are shown in table 4.3. The mean temperature was found to be 29.33^oC, 26.67^oC, 28.33^oC and 32^oC for dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The mean temperature was found to be highest in rainy season in 2011 A.D. and lowest in rainy season of year 2010 A.D. The mean pH value was found to be 6.93, 7.34, 7.43 and 7.30 for dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The mean pH was found to be high in dry season, 2011 A.D. and low in dry season in 2010 A.D. Likewise the mean EC of two seasons in two years were found to be 38, 32.67, 40 and 21.67 µs/cm respectively. The EC was found to be highest in dry season of year 2011 A.D. and lowest in rainy season in the same year. Table 4.3 represents the mean seasonal and annual variations of various physico-chemical parameters of Khaste lake. The mean DO was found to be 7.57 mg/L and 5.27 mg/L in dry and rainy season respectively in 2010 A.D.; 4.10 mg/L and 6.40 mg/L for dry and rainy season respectively in year 2011 A.D. The mean DO value was maximum in dry season of year 2010 A.D. and minimum in dry season of 2011 A.D.

Table 4.3: Mean seasonal and annual variation of physico-chemical parameters

Physico-chemical parameters	Dry season, 2010 A.D.	Rainy season, 2010 A.D.	Dry season, 2011 A.D.	Rainy season, 2011 A.D.
Temperature (°C)	29.33	26.67	28.33	32
pH	6.93	7.34	7.43	7.30
EC (µs/cm)	38*	32.67*	40*	21.67
DO (mg/L)	7.57	5.27	4.10^	6.40
Free CO_2 (mg/L)	11.73*	24.93*	12.47*	11*
Total alkalinity as $CaCO_3$ (mg/L)	43.33	20	23.33	21.67
Chloride (mg/L)	10.88	44.49	18.46	32.18
BOD_5 (mg/L)	31.09*	27.34*	16.20*	17.20*
COD (mg/L)	87.67*	80*	76*	64*
Total Iron (mg/L)	1.50*	0.46*	1.76*	2.44*
Total hardness as $CaCO_3$ (mg/L)	25.33	16.67	59.33	9.33
Ca-hardness as $CaCO_3$ (mg/L)	11.33	9.33	4.27	2.40
Mg-hardness as $CaCO_3$ (mg/L)	14	7.33	55.06	6.93

* indicates value exceeded WHO guideline for drinking water; ^ indicates didn't meet WHO guidelines for drinking water

The mean free CO_2 were also determined to be 11.73 mg/L, 24.93 mg/L, 12.47 mg/L and 11 mg/L respectively for dry and rainy season in 2010 A.D. and 2011 A.D. The mean total alkalnity was found to be 43.33 mg/L, 20 mg/L, 23.33 mg/L and 21.67 mg/L respectively. Likewise, the mean chloride values were found to be 10.88 mg/L, 44.49 mg/L, 18.46 mg/L and 32.18 mg/L for dry and rainy season for 2010 A.D. and 2011 A.D. respectively. The mean chloride content was found to be minimum in dry season and maximum in rainy season of year 2010 A.D. The mean BOD_5 and mean COD values were found to be 31.09 mg/L, 27.34 mg/L, 16.20 mg/L and 17.20 mg/L; 87.67 mg/L, 80 mg/L, 76 mg/L and 64 mg/L for dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. Both the values of BOD_5 and COD were found to exceed WHO guidelines for drinking water. The total iron were found to be 1.50 mg/L, 0.46 mg/L, 1.76 mg/L and 2.44 mg/L respectively for dry and rainy season. The total iron values were maximum in rainy season of 2011 A.D. and minimum in rainy season of 2010 A.D. The values exceeded WHO guidelines for drinking water. The mean total hardness as $CaCO_3$ were found to be 25.33 mg/L, 16.67 mg/L, 59.33 mg/L and 9.33 mg/L respectively for dry and rainy season for 2010 A.D. and 2011 A.D. The mean total hardness as $CaCO_3$ was found to be highest in dry season of 2011 A.D. The Ca- hardness as $CaCO_3$ was also found to be 11.33 mg/L, 9.33 mg/L, 4.27 mg/L and 2.40 mg/L; Mg-hardness as $CaCO_3$ was 14 mg/L, 7.33 mg/L, 55.06 mg/L and 6.93 mg/L for dry and rainy season respectively.

4.1.3.2. Nutrient salt analysis

The mean values of ortho-phosphate were 0.04 mg/L, 0.11mg/L, 0.14 mg/L and 0.10 mg/L in dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The ortho-phosphate values far exceeded WHO guidelines for drinking water. The mean values of ammonia were found to be 0.02 mg/L, 0.65 mg/L, 0.01 mg/L and 0.10 mg/L in dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The values were found within WHO guidelines for drinking water. Likewise, the mean nitrate were 1.08 mg/L, 0.71 mg/L, 0.88 mg/L and 2.89 mg/L respectively. From fig. 4.3, dry season, 2011 A.D. has maximum values of orthophosphate, rainy season, 2010 A.D. has maximum values of ammonia and rainy season, 2011 A.D. has maximum values of nitrate and are also presented below.

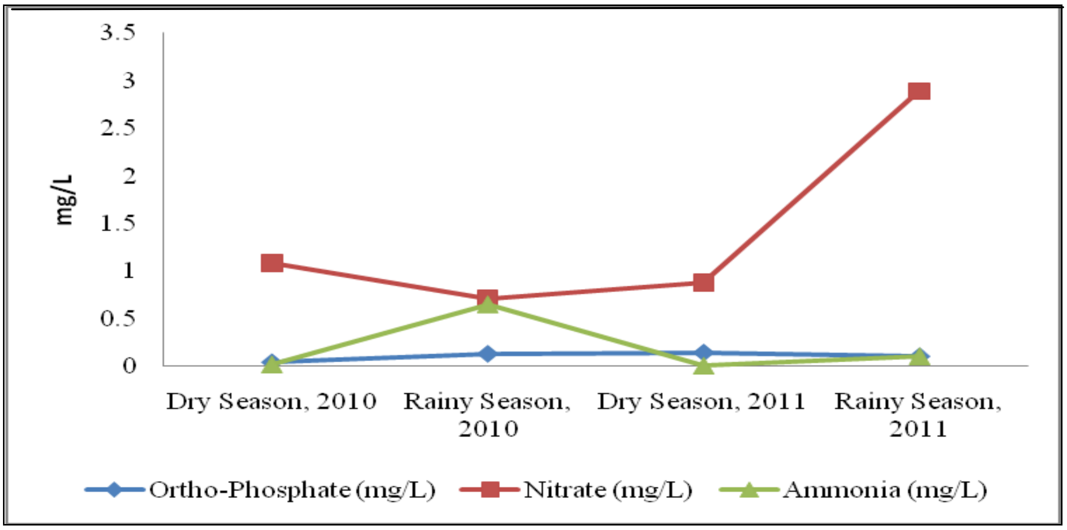


Figure 4.3: Nutrient salt analysis of Khaste lake

4.2. Analysis of mean Water Quality Index (WQI) of three lakes

4.2.1. Gunde lake

The seasonal and annual variation of mean WQI of Gunde lake was determined and also shown in figure 4.4. The mean values of WQI was 44.52, 31.62, 39.38 and 31.79 for dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The bar graph in fig 4.4 showed that there is decreasing pattern in mean WQI in dry season as well as rainy season from year 2010 A.D. to 2011 A.D. There is decreasing pattern in mean WQI from one to another year.

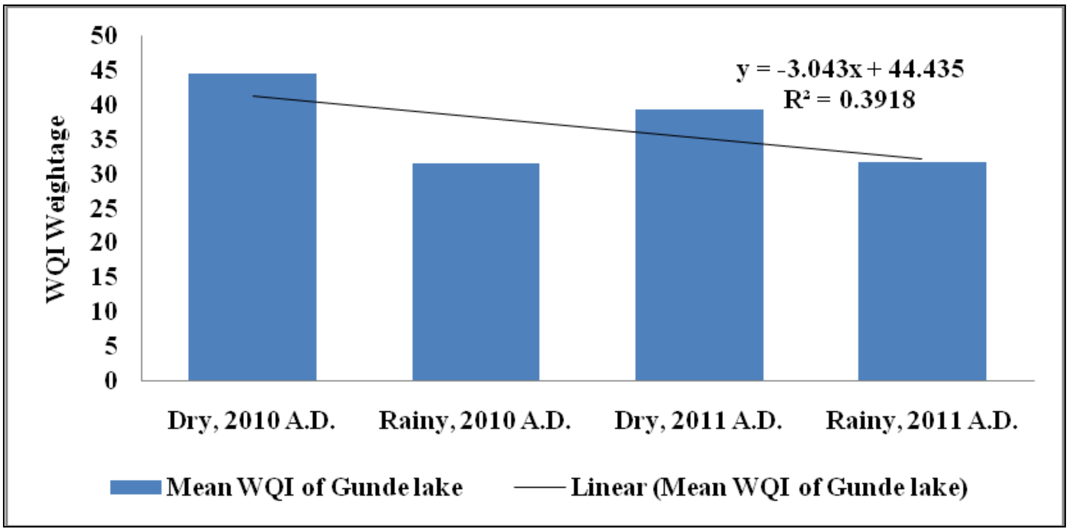


Figure 4.4: Seasonal and annual variation of mean WQI of Gunde lake

4.2.2. Neureni lake

The mean water quality index for Neureni lake was found to be 49.94, 49, 40.59 and 32.44 for dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. respectively. The linear mean WQI showed that there is decreasing pattern in mean WQI in dry season and rainy season from year 2010 A.D. to 2011 A.D. There is also decreasing pattern of WQI from one year to another year. The seasonal and annual variations of mean WQI of Neureni lake is shown in fig 4.5.

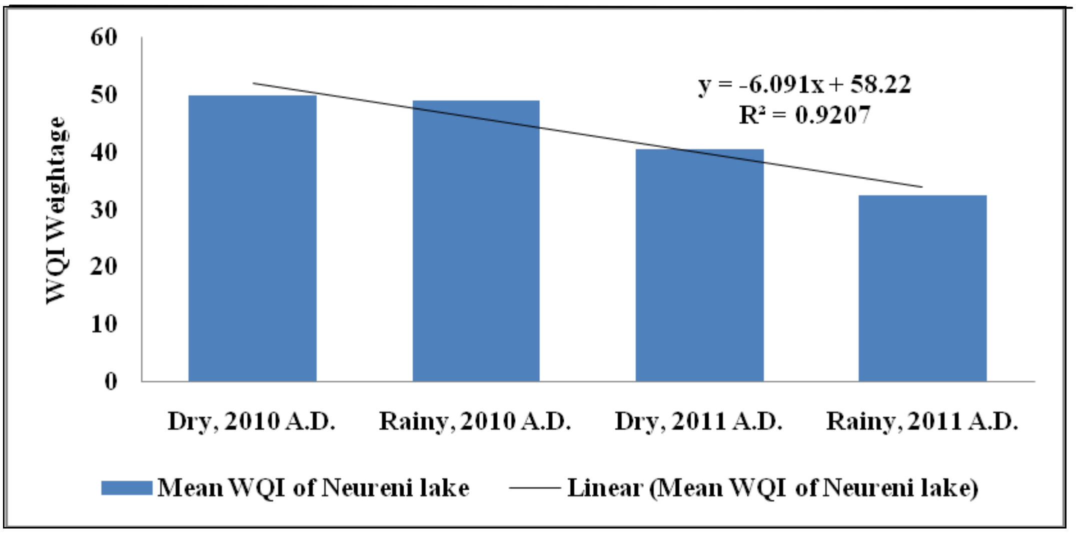


Figure 4.5: Seasonal and annual variation of mean WQI of Neureni lake

4.2.3. Khaste lake

The mean water quality index of Khaste lake for dry season, 2010 A.D., rainy season, 2010 A.D., dry season, 2011 A.D. and rainy season, 2011 A.D. was found to be 33.90, 30.33, 31.14 and 29.94 respectively. The values in fig. 4.6 showed the decreasing pattern in mean WQI in dry as well as rainy season from year 2010 A.D. to 2011 A.D. Also there is decreasing pattern in average WQI from 2010 A.D. to 2011 A.D.

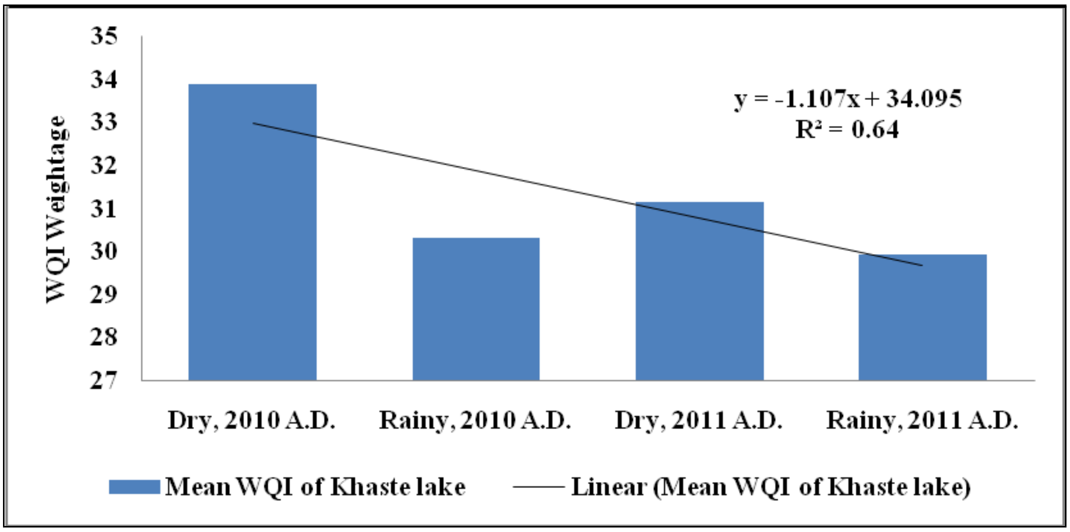


Figure 4.6: Seasonal and annual variation of mean WQI of Khaste lake

4.2.4. WQI rating for three lakes

Based on Bach (1980), the water quality index and its rating of lake water were assessed for Gunde lake, Neureni lake and Khaste lake. Gunde lake was rated to be critical pollution in dry season of 2010 A.D., severe pollution in rainy season, 2010 A.D., severe pollution in dry season, 2011 A.D. and severe pollution in rainy season, 2011 A.D. Neureni lake was rated to be critical pollution in dry season, 2010 A.D., critical pollution in rainy season, 2010 A.D., severe pollution in dry season, 2011 A.D. and severe pollution in rainy season, 2011 A.D. Similarly, in Khaste lake in dry and rainy season in 2010 A.D. and 2011 A.D., it was rated to be severe pollution. Table 4.4 showed that water quality rating of Gunde lake and Neureni lake was decelerated from critical pollution to severe pollution from year 2010 A.D. to 2011 A.D. But Khaste lake had constant rating as severe pollution from dry season, 2010 A.D. to rainy season, 2011 A.D. i.e. entire field study duration.

From table 3.3, the water quality class (WQ class) for Gunde lake was found to be (II –III) in dry season, 2010 A.D. to III in rainy season, 2010 A.D., dry season, 2011

A.D., and rainy season, 2011 A.D. respectively. Neureni lake accounted water quality class (II-III) in dry and rainy season, 2010 A.D. In dry and rainy season, 2011 A.D., it was in WQ class III. Khaste lake however accounted in WQ class III throughout the study period.

Table 4.4: WQI and its ratings of three lakes

Sr. No	Name of lakes	CI of dry, 2010	Rate	CI of rainy, 2010	Rate	CI of dry, 2011	Rate	CI of rainy, 2011	Rate
1	Gunde lake	44.53	Critical pollution	31.62	Severe pollution	39.38	Severe pollution	31.79	Severe pollution
2	Neureni lake	49.94	Critical pollution	49.00	Critical pollution	40.59	Severe pollution	32.45	Severe pollution
3	Khaste lake	33.90	Severe pollution	30.33	Severe pollution	31.14	Severe pollution	29.94	Severe pollution

CI indicates Chemical Index

Independent sample t-test

The independent sample t-test was used to test the significant difference of WQI among lakes seasonally and annually. The significant differences in the physico-chemical parameters of lake water of Gunde lake, Neureni lake and Khaste lake between season and year were calculated.

a) Gunde lake:

i) Season wise - The data followed the normal curve but the variance was not equal.

t = 3.525, d.f. = 9.064, P = 0.006, showed significant difference among season.

ii) Year wise – The data followed the normal curve and the variance was also equal.

t = 0.886, d.f. = 13. P = 0.392, showed no significant differences between two year.

b) Neureni lake:

i) Season wise - The data followed the normal curve and the variance was also equal.

t = 0.881, d.f. = 10, P = 0.399, showed no significant difference among season.

ii) Year wise – The data followed the normal curve and the variance was also equal.

t = 3.759, d.f. = 10. P = 0.004, showed significant differences among two year.

c) Khaste lake:

i) Season wise - The data followed the normal curve and the variance was also equal.

t = 1.378, d.f. = 10, P = 0.198, showed no significant difference among season.

ii) Year wise – The data followed the normal curve and the variance was also equal.

t = 0.865, d.f. = 10. P = 0408, showed no significant differences between two year.

4.2.5. Macro-invertebrates and WQI

The zooplanktons, micro-invertebrates and macro-invertebrates of three studied lakes were found to support the obtained results of WQI and its rating (Manandhar *et al.*, 2011). There are various zooplanktons, micro-invertebrates and macro-invertebrates commonly associated with various degree of organic pollution. The names of zooplanktons, micro-invertebrates and macro-invertebrates of three lakes are listed down in table 4.5:

Table 4.5: Names of different benthic fauna in different lakes

Sr. no.	Names of lakes	Names of zooplanktons	Names of micro-invertebrates and macro-invertebrates
1	Gunde lake	**Protozoans**-*Amoeba radiosa, Paramecium sp.* **Rotifera**-*Branchionus*	**Insecta**-Diptera-**Chironomidae**-*Chironomus* (Blood Worm). Coleoptera-**Psephenidae**- Aquatic beetle (Water Penny) **Crustacean**-Decapoda-Shrimp. Cladocera-**Daphniidae**-*Daphnia*. **Bosminidae**-*Bosmina*. Copepod **Molluscan-** Gastropod- Physidae, Lymnaedae, *Helisoma*
2	Neureni lake	**Protozoans**- *Amoeba radiosa, Paramecium sp, Ceratium, Plenroxus, Euglena,Dinoflagellates, Didinium* **Rotifers**-*Asplanchna, Keratella, Branchionus*	**Helminths larva**- *Cercaria*, larva of *Fasciola*, *Miracidium* larva, *Planaria* **Nematodes**-*Ascaris* egg **Insects**-Diptera-**Chironomidae**-*Chironomids*.**Simullidae**-Blackfly larva, Odonata-**Libellulidae**- Dragonfly nymph. Plecoptera- Stonefly nymph. Tricoptera- Caddisfly larva. Coleoptera-**Psephenidae**-Water beetle. Hemiptera-**Nepidae**-Water Scorpion. **Scarabaeidae**- Scarabaeid beetle larva.

			Arachnida- Hydrachenellae- *Arrenurus* (Water mite). **Crustaceans**-Cladocera-Daphnia, *Bosmina, Chydorus.* Copepoda-Cyclops. Ostracoda-*Cypris*.*Brachiopoda-Diaphanosoma*,Arthopoda-*Metanauplius larva*, Nauplius larva **Molluscan**-Snail, Gastropod- *Helisoma*
3	Khaste lake	**Protozoans**-*Amoeba radiosa, Paramecium sp, Chlamydomonas, Arcella, Didinium, Chilomanas, Euglena* **Rotifera**-*Asplanchna, Keratella, Branchionus*	**Nematodes**-*Trichinella, Spiralis* (adult male), *Ascaris* egg **Crustaceans**-*Nauplius* larva, Copepoda-*Cyclops*. Cladocera-*Bosmina, Daphnia, Chydorus.* Ostracoda- *Cypris,* **Insecta**-Diptera-**Chironomidae**-*Chironomids*. Coleoptera- **Psephenidae**-Water beetle. Hemiptera. **Molluscan**-Snail, Gastropod- *Helisoma*

(Source: Manandhar *et al.*, 2011)

4.3. Results of socio-economic analysis in Baral Danda

4.3.1. Respondent's general personal information

4.3.1.1. Gender and age composition

Among the household (HH) survey on 38 respondents in the lake periphery of Gunde, Khaste and Neureni lakes, 26.30% of them were male and 73.70% were female. Most of them were found to be in the age group of (30-40) years and in (40-50) years range. The bar graph for sex of respondents is shown in fig 4.7 and histogram of age of the respondents is shown in fig 4.8.

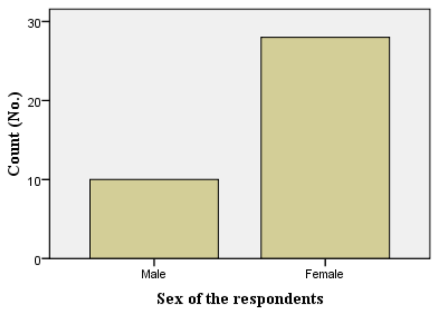


Figure 4.7: Sex of the respondents

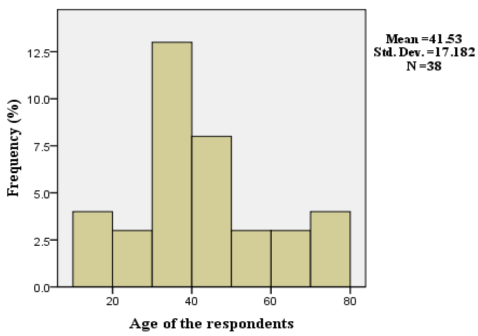


Figure 4.8: Age of the respondents

4.3.1.2. Education

About 42.10% of the respondents in the questionnaire survey were found to acquire primary education only and 34.20% of them gained secondary education. Likewise, 7.90% of respondents have passed both SLC and college. On contrast 7.90% were the respondents who never visited the school.

4.3.1.3. Religion and caste

All the respondents were Hindu. The respondents were found to be from different castes like Dhungana (26.30%), Bastakoti (18.40%), Baral (15.80%), Adhikari and Lamichanne (10.50%), Biswakarma (5.30%). The different castes like Dahal, Gahatraj, Tiwari, Timilsina, Bhandari were each found to be 2.60%.

4.3.1.4. Total family members of respondents

The total family members in respondent’s house were found to be different among household. Among them, 23.70% have one family members in their home, 21.10% have family size no. 4 or 6, 7.90% have 3 or 7 or 8 family members, 5.30% have 9 family members and 2.60% have family members as 12 or 15 in their home.

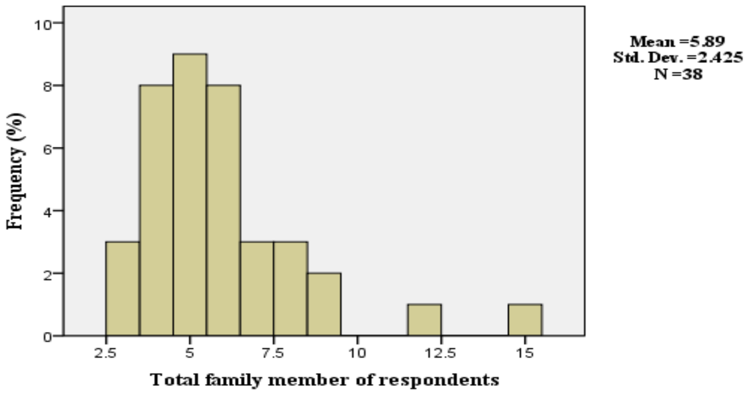


Figure 4.9: Total family members of respondents

4.3.1.5. Migration

About 32.40% of respondents were living in the village from (10-20) years. 21.10% respondents lived between (0-10) years and 15.80% of respondents were living from (30- 40) years. Figure 4.10 represents the respondents time duration of living in the village.

Figure 4.11 represents the reasons in moving into the village.

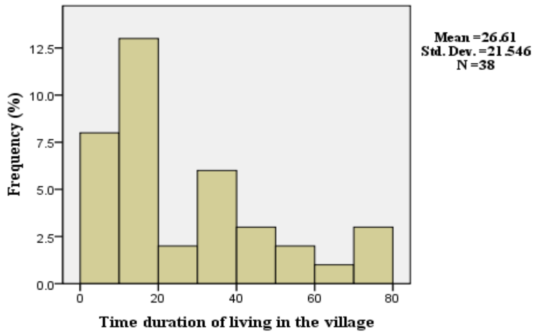


Figure 4.10: Respondent's time duration of living in the village

Figure 4.11: Respondent's reasons to move into the village

4.3.2. Respondent's housing environment and lifestyle

4.3.2.1. Housing information

About 65.80% of respondents had floor and walls of concrete type and 26.30% of respondents had mud floor with stone walls. Likewise, 94.70% of the roofing materials were from tin and 5.30% from concrete. Figure 4.12 represents the flooring materials of the respondent's house and figure 4.13 represents the roofing materials of the respondent's house.

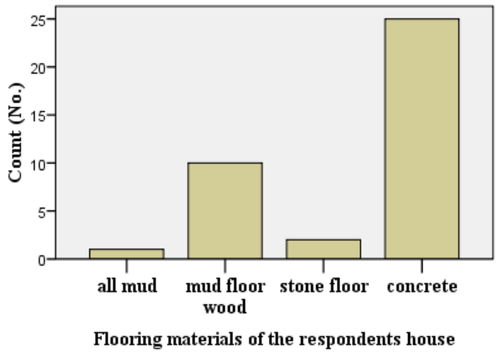


Figure 4.12: Flooring materials of the respondents house

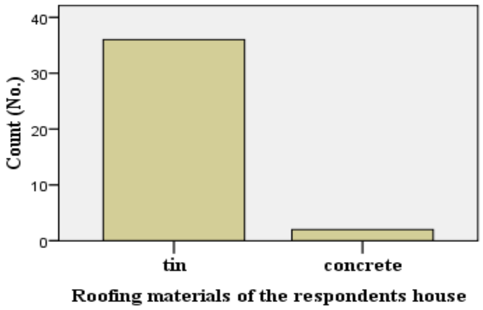


Figure 4.13: Roofing materials of respondents house

4.3.2.2. Fuel type and livestock raising by respondents

The main fuel type used by the respondents was firewood and biogas i.e. 34.20%. Different fuel types used by respondents are shown in table 4.6.

Table 4.6: Fuel type used by respondent's house

Fuel types	Frequency	Percent (%)
F	13	34.20
F + L + E	1	2.60

F + E + B + L	1	2.60
B + L	1	2.60
B	1	2.60
L	3	7.90
F + L	2	5.30
F+ B	13	34.20
F + E+ B	1	2.60
F + E + B+ C	2	5.30
Total	38	100.0

(**Note:** F= Firewood; L= LPG; E=Electricity; B=Biogas; C=Coal)

4.3.2.3. Drinking water

The main drinking source of water was from private tap i.e. 47.40% and about 21.10% get the water facilities from village well. About 18.40% shared yard tap facilities. In the dry season some respondents also go to nearby spring to fetch water. It was also found that 65.80% of respondents don't do any water treatment for drinking. Further table 4.7 represents the sources of water and table 4.8 shows the water treatment methods done for drinking purpose by respondents.

Table 4.7: Sources of water

Sources of water	Frequency	Percent (%)
Private tap	18	47.4
Y	7	18.4
V	8	21.1
V+ S	2	5.3
S + R	1	2.6
Red cross help	1	2.6
S + R + Y	1	2.6
Total	38	100.0

(**Note:** V= Village well, S= Spring, R= Rain water harvesting, Y= Yard tap)

Table 4.8: Water treatment methods

Treatment methods	Frequency	Percent (%)
None	25	65.8
Boiling	6	15.8
Filter	4	10.5
Filter+ boiling	2	5.3
None+ SODIS	1	2.6
Total	38	100.0

4.3.2.4. Economic activity and future adoption to strengthen the income

About 39.50% of respondents had crop farming as the chief income and rest of them had incomes through different sources. Figure 4.14 represents different economic activities in the respondent's household.

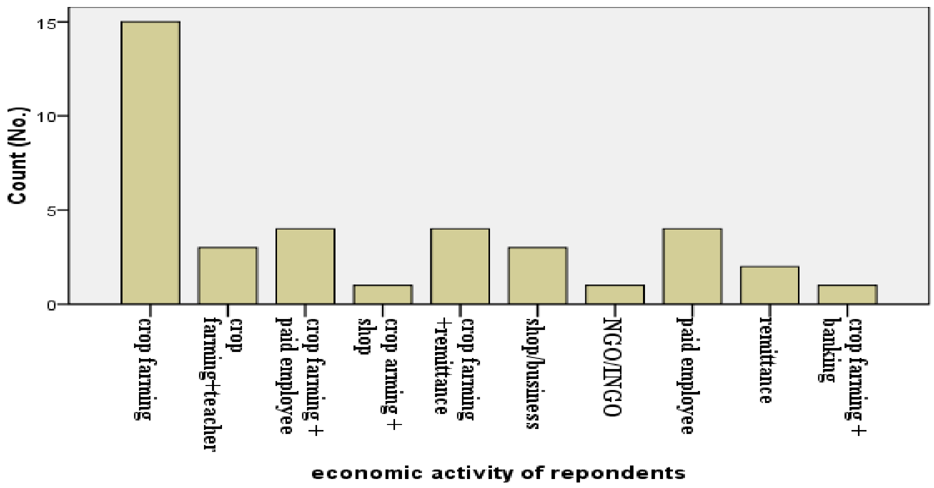


Figure 4.14: Economic activity of respondents

To increase in respondent's income, 28.90% thought to uplift their vegetable farming and earn money from it, 2.60% of them thought to enlarge their existing shop, raise the livestock farming and also open new business in their area. Ironically, 63.20% of respondents haven't thought anything for the upliftment of their source of income. Figure 4.15 represents different future adoption strategies for strengthening income.

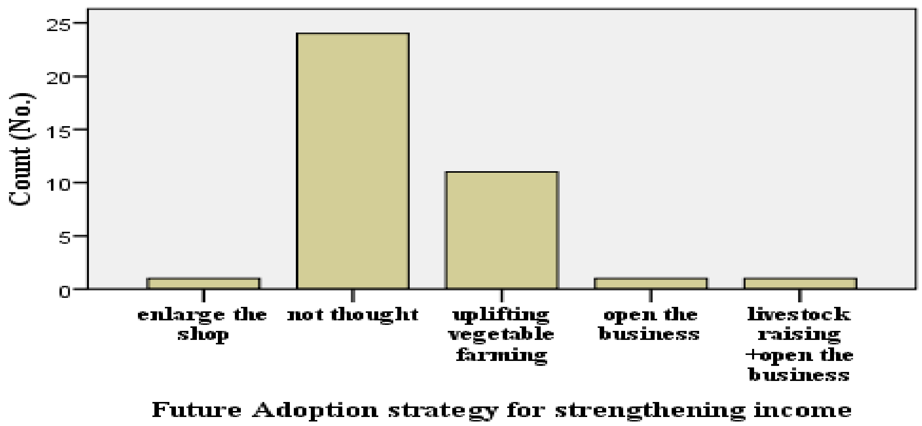


Figure 4.15: Future adoption strategy for strengthening income

4.3.3. Respondent's awareness in wetlands values and services

About 86.80% of respondents were aware of wetland services but 13.20% responded that they don't have knowledge in wetlands services. And 65.80% of respondents told they enjoy benefits, 34.20% said they don't enjoy benefits of wetland values. Among 65.80% of respondents who enjoy wetland benefits, about 21.10% of the respondent's visited the lake area for fuel wood collection and grass collection. About

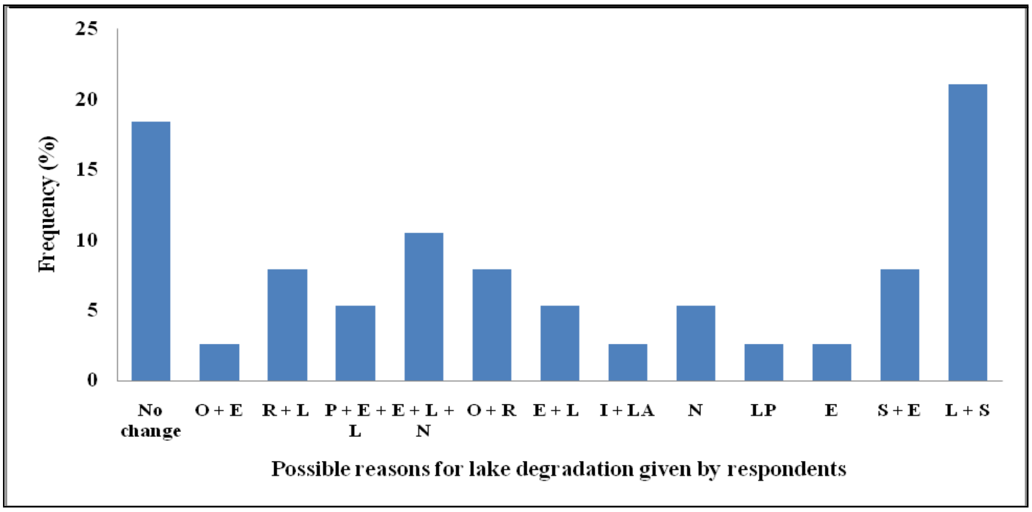
5.30% of respondents visited lake for grass, fuel wood, timber and medicine collection and etc. Table 4.9 represents various engagements in lake by respondents.

Table 4.9: Engagement in lake by respondents

S.No	Engagement	Frequency	Percent (%)
1	Never	13	34.20
2	B	3	7.90
3	F	4	10.50
4	F + G	8	21.10
5	G	2	5.30
6	F + G + M	3	7.90
7	F + T + G	2	5.30
8	F + G + T+ wild fruits	1	2.60
9	F + G + M + B+ reed collection	2	5.30

(**Note:** F=Fuel wood; G=Grass collection; T=Timber; M=Medicine; B=Bamboo

About 81.60% of the respondents agreed with the acceptance of lake degradation with time, whereas about 10.50% responded that the lake is as usual as before and 7.90% totally denied with the degradation of the lakes. Among 81.60% of the respondent, the main reason for the lake degradation was found to be due to landslide and siltation (21.10%). Likewise other different possible reasons for the lake degradation are given in figure 4.16.



(**Note:** O=Opening of lake water; E=Encroachment; R=Road construction; L=Landslide; P=Increase in population; N=No conservation; I=Illiteracy; LA=Lack of awareness; LP=Lake poison; S=Siltation)

Figure 4.16: Possible reasons for lake degradation given by respondents

About 18.40% of respondents responded that the lake is not degrading. But, 81.60% of them shared that there was degradation with time. While categorizing the cause of degradation, 36.80% of them noted due to anthropogenic cause and 31.60% of them told by natural factors. And 13.20% reported both natural and anthropogenic factors. Table 4.10 below represents the categories for the degradation of wetland.

Table 4.10: Categories for the degradation of wetlands

Categories	Frequency	Percent (%)
No change	7	18.4
Natural cause	12	31.6
Artificial cause	14	36.8
Both	5	13.2
Total	38	100

4.3.4. Respondent's willingness to contribute for the wetland conservation

When respondents were asked for the view in lake conservation regardless of its degradation of lake with time or not, all of 38 respondents i.e. 100% agreed for the view that there should be lake conservation. People preferred for the lake conservation for different preference values. About 42.10% of the respondents showed their preference levels of values from bequest, option, direct and indirect values, while 39.50% of them wanted for the bequest, direct, option and indirect values. 15.80% of them wanted for the direct, bequest, option and indirect values and only 2.60% wanted for the direct, option, bequest and indirect values. Table 4.11 represents the various percentages of wetland values preference.

Table 4.11: Wetland values preference and its frequencies and percentage

Wetland values preference	Frequency	Percent (%)
Direct + bequest + option + indirect	6	15.8
Bequest + direct + option + indirect	15	39.5
Bequest + option + direct + indirect	16	42.1
Direct + option + bequest + indirect	1	2.6
Total	38	100

When respondents were asked whether they are willing to pay for lake conservation or not, about 76.30% of the respondents showed WTP. But 13.20% denied paying for the conservation. Likewise, 5.30% wanted to pay but not in the monetary values but only as human labor and 5.30% remained unaffected to the question. Table 4.12 represents the respondent's willingness to pay for conservation.

Table 4.12: Respondents willingness to pay for conservation

Particulars	Frequency	Percent (%)
Yes	29	76.30
No	5	13.20
Yes as labor	2	5.30
Don't know	2	5.30
Total	38	100

About 36.80% of the respondents wanted village government to collect the amount as WTP, 18.40% of the respondents wanted to establish the fund board in the village and collect by themselves. About 10.50% wanted to collect money by the municipality and 7.90% wanted the money to be collected by the national governments. Table 4.13 represents the respondent's collection preference of amount.

Table 4.13: Respondents collection preference of amount as WTP

Preferences	Frequency	Percent (%)
Don't know	7	18.4
Village government	14	36.8
Established fund board in village	7	18.4
Municipality	4	10.5
Women's group	1	2.6
National government	3	7.9
School	1	2.6
Village + municipality + national government	1	2.6
Total	38	100

4.3.5. Respondents aggregate WTP per annum

About 42.10% of respondents were willing to pay around NRs. 1000 per annum. About 15.80% of them were willing to pay NRs. 500 as WTP. The mean amount to be paid by individual household was NRs. 521.05 per annum and shown in fig 4.17.

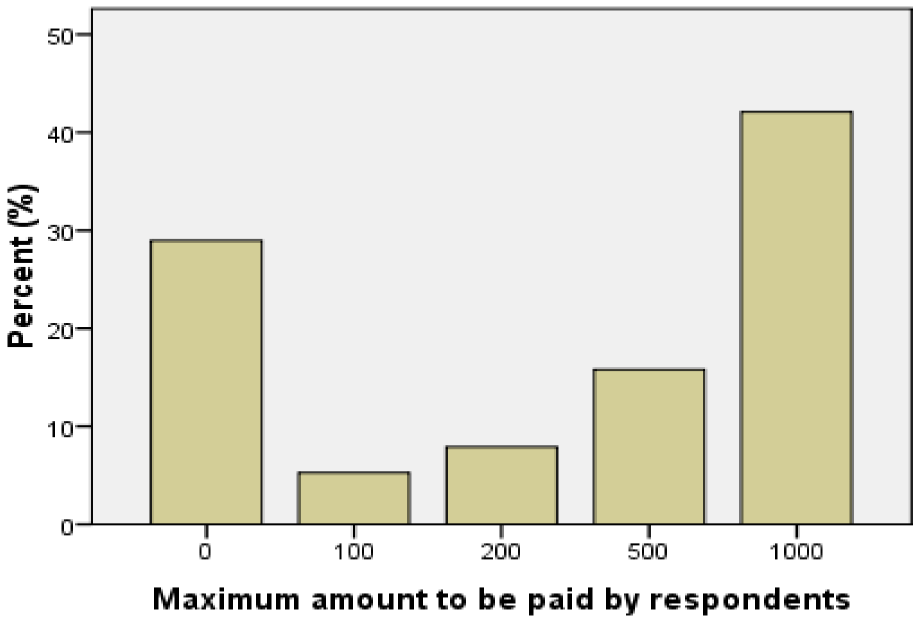


Figure 4.17: Maximum amount to be paid by respondents

WTP rate

Aggregate $WTP_a = \sum i\, [(\Theta i) \times (\eta j) \times (\Theta i\ wtp)]$ ………………………….. (1)

Where: WTP_a = willingness to pay for wetland goods and services per annum

Θi = percentage of the sample in category I (0.763)

ηj = total number of households of the area = 984 (Lekhnath, 2008)

$\Theta i\ wtp$ = mean maximum amount of money individual household is willing to pay for wetland indirect use values, optional use value and bequest value per annum in order for their continuous existence (NRs. 521.05)

= 0.763 × 984 × NRs. 521.05

= NRs. 391, 200.17

Individual household WTP_a = Aggregate $WTP_a / \eta j$ ……………………………. (2)

= NRs. 391, 200.17/984

= NRs. 397.56

Hence, the aggregate WTP per annum was found to be NRs. 391,200 for the lake conservation around the BDLC. This suggested that the individual household WTP per annum was found to be NRs. 397.56 i.e. NRs. 33 per month per household.

The correlation matrix table was constructed using SPSS software version 16.0. Different parameters like age of the respondents, maximum amount to be paid by respondents, time duration of living and total family members of the respondents were used for the construction of correlation matrix table. Age of the respondents was significantly found to be negatively correlated with the maximum amount to be paid as WTP. It was found to be significantly positively correlated with time duration of living in village and total family members in house. Thus maximum WTP was found to be negatively correlated with age, time duration of living and total family members. The correlation matrix table is presented in table 4.14 below.

Table 4.14: Correlation among the variables

		Maximum amount to be paid by respondents	**Time duration of living in the village**	**Total family member of respondents**	**Age of the respondents**
Maximum amount to be paid by respondents	Pearson Correlation	1	-.350*	-0.258	-.612**
	Sig. (2-tailed)		0.031	0.117	0
	N	38	38	38	38
Time duration of living in the village	Pearson Correlation	-.350*	1	.394*	.678**
	Sig. (2-tailed)	0.031		0.014	0
	N	38	38	38	38
Total family member of respondents	Pearson Correlation	-0.258	.394*	1	.417**
	Sig. (2-tailed)	0.117	0.014		0.009
	N	38	38	38	38
Age of the respondents	Pearson Correlation	-.612**	.678**	.417**	1
	Sig. (2-tailed)	0	0	0.009	
	N	38	38	38	38
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).					

CHAPTER 5

5. DISCUSSION

5.1. Analysis of physico-chemical characteristics of lake water

The physico-chemical properties in water bodies vary in composition and concentration on seasonal, diurnal or evenly hourly basis. These variations may be related to patterns of water use and rainfall (Ayoade *et al.*, 2006).

5.1.1. Physico-chemical parameters

It is a well known fact that the maintenance of the healthy aquatic ecosystems is the interaction of the physico-chemical parameters of water and the existing biological diversity. Temperature is one of the most important factors in determining the physiological behavior and the distribution of the organisms in aquatic environment (Singh and Mathur, 2005). The temperature has direct effect on certain chemical and biological activities of the organism in aquatic media (Dwivedi and Pandey, 2002). The surface water temperature of the study sites ranged between 17.60^{o}C to 28.10^{o}C in Gunde lake, 19^{o}C to 30^{o}C in Neureni lake and 26.67^{o}C to 32^{o}C in Khaste lake. The temperature showed a gradual increase from dry season, 2010 A.D. to rainy season, 2011 A.D. Joshi and Singh, 2001 observed that the solubility of oxygen increases when the water temperature decreases. In all the sampling sites in the lakes (annex I), the temperature were also found to be higher in the rainy season than dry season except in outlet of Khaste lake. The difference in sampling time might be one reason in the fluctuation of increase in water temperature. Since the water was sampled in the day time, the clear atmosphere, greater solar radiation and high latent behavior of water could be one of the factors in high water temperature in the three lakes.

Another important parameter in determining the index of pollution is pH. In the present study, the mean values of pH in Gunde lake ranged from 7.27 to 8.02, 7.37 to 7.87 in Neureni lake and from 6.93 to 7.43 in Khaste lake. Hence all the three lakes have the mean pH values from 6.93 to 8.02 which may be high CO_3^{2-} and associated environmental factors. This may also be due to high buffering capacity of the lake system. pH is an important factor in contributing significant formation of algal blooms (Anderson, 1961). The pH value of Khaste in the dry season, 2010 A.D. was found to be 6.93. The temperature at that time was also high. Thus, the high temperature enhances the microbial activity, causing excessive production of CO_2 and thus reduced pH increases algal blooms in lake.

The EC was found to be high in dry season and low in rainy season. The EC ranged from 35 µs/cm to 159 µs/cm in the dry season in all three lakes and from 21.67 µs/cm to 57.8 µs/cm in rainy season. The low EC values in rainy season might be due to rainfall in the catchment area and the successive dilution of water. Pandey and Pandey, 2003 studies also go in conformity with this result. From the analysis of sampling sites (annex I) the values of EC was high in the human interference site in Gunde lake, outlet in Neureni lake and forestland site in Khaste lake.

Oxygen is an important parameter to the metabolism of all aquatic organisms that possess aerobic respiration. Concentration of DO indicates water quality and its relation to the distribution and abundance of various algal species (Sisodia *et al.*, 2004). The DO in the water samples ranged from 4.20 mg/L to 7.50 mg/L. The Gunde lake has DO levels from 4.20 mg/L to 6.42 mg/L, with the lowest at outlet in dry season and highest in inlet in rainy season. The Neureni lake has DO ranged from 4.80 mg/L to 6.30 mg/L, with minimum at outlet in dry season and maximum in inlet in rainy season. Likewise, Khaste lake ranged from 4.90 mg/L to 6.40 mg/L with minimum DO at human disturbance site in dry season and maximum at human disturbances at rainy season. Hence it was found that DO level increased from dry to rainy season. The phenomenon of re-oxygenation of water during the monsoon may be due to circulation and mixing by inflow after monsoon rain (Hannan, 1979). A low content of DO is a sign of organic pollution. Tolerance limit of DO is not less than 6 mg/L (Kudesia, 1985). Concentrations below 5 mg/L may adversely affect the functioning and survival of biological communities and below 2 mg/L may lead to fish mortality (Sisodia, 2006). Occurrence of low DO values has been attributed to the process of decomposition of organic matter involving the utilization of oxygen (Jameel, 1998). Hence, the present study revealed the values of DO below this limits only during the summer season which may be due to higher tropogenic activities as in the study done by Adhikari, 2002. Decomposition of organic matter may be an important factor in consumption of DO, which is vigorous during warm weather (Badge and Verma, 1985).

The free CO_2 contributes to the fitness of natural waters derived from various sources such as atmosphere, respiration by organisms, bacterial decomposition of organic matter *etc*. Unni (1972) emphasized that the rate of changes in free CO_2 concentration is considerable due to decomposition of organic matter at the bottom. In the present study, free CO_2 varied from 11 mg/L to 30.80 mg/L in three lakes. The free CO_2 was found exceeding the WHO guidelines for drinking water in all three lakes.

Total alkalinity as $CaCO_3$ is a measure of buffering capacity of the water and is important for aquatic life in a fresh water system because it equilibrate the pH ranges that occur naturally as a result of photosynthetic activity of aquatic plants (Kaushik and Saksena, 1999). The total alkalinity as $CaCO_3$ values of three lakes ranged from 16.67 mg/L to 76.67 mg/L. It was found to have high values in dry and relatively low in rainy which might be due to dilution due to monsoon rainfall. Bhatia *et al.,* (2004), Bishop (1973) and Jain *et al.*, (1996) also reported similar findings in their studies. Excessive alkalinity may cause eye irritation in humans and chlorosis in plants. Surface water with alkalinity less than 200 mg/L is potentially sensitive to heavy acid deposition. Alkalinity itself is not harmful to human beings; still water supplies with less than 100 mg/L of alkalinity are desirable for domestic use. From WHO guideline values for drinking water, the total alkalinity as $CaCO_3$ ranged within the values in three lakes.

In most fresh waters, total hardness as $CaCO_3$ is mainly imparted by the calcium and magnesium ions, which apart from sulphate, chloride and nitrate are found in combination with carbonates and bicarbonates (Kumar *et al.,* 2011). In the present study the total hardness as $CaCO_3$ was found to be high in dry season in all three lakes which may be due to reduced inflow and evaporation with addition of calcium and magnesium salts and low in rainy season. Hardness values declined during monsoon due to dilution of lake water. Palharya *et al.,* (1993) also recorded similar observation during summer and monsoon in the Narmada river. It was also found that Mg-hardness as $CaCO_3$ was higher than Ca-hardness as $CaCO_3$ in three lakes. This may be attributed to, $MgCO_3$ is partially soluble during these seasons and the magnesium precipitated as $Mg(OH)_3$ (Goher, 2002).

Kannan (1991) has classified water on the basis of hardness values in the following manner: (0-60) mg/L - soft, (61-120) mg/L - moderately hard, (121-160) mg/L - hard and >180 mg/L - very hard. Using these criteria, the water of three lakes was found to be in the soft category. The maximum acceptable level of Mg in drinking water is 50 mg/L (WHO, 1992). The values exceeding 50 mg/L have a laxative and diuretic effect particularly for individuals not accustoms to high dosage (Kumar *et al.*, 2011). But in the present study, the values ranged well within 50 mg/L, so it doesn't pose any harm to human. Mg-hardness exhibits strong positive correlation with Cl^- which revealed that magnesium mainly present as $MgCl_2$ (Bhandari *et al.*, 2008).

Chloride in water influences salinity balance and ion exchange and is contributed by dissolution of salt deposits, sewage discharge, effluents from chemical industries and irrigation drainage to natural waters. In the present study, the chloride value was found to be high in dry season and low in rainy season in Gunde lake and Neureni lake. High values of chloride in summer months may be associated with high temperature which enhances the evaporation, reducing the volume of water thus resulting in the high concentration of salts (Kumar *et al.*, 2011). This result was also found in the Abdel-Satar, 2005. In Khaste lake, the high value of chloride in rainy season is mainly attributed to the dissolution of some ions especially Cl^-, SO_4^{--} from the surrounding rocks and sediment which release into the water of the lakes (Abdo, 2005). Most of the rocks in the catchment areas are phyllite but these rocks contain high amount of muscovite-serite-chlorite. These minerals have very less hardness and it is easily weathered and eroded by geological agents and easily transported downstream (Manandhar *et al.*, 2011). So this could also explain why the chloride values are found high in the rainy season than dry season in Khase lake. The tolerance limit for chloride is 250 mg/L (WHO, 1995). In natural surface water the chloride values are normally found less. So, in the present study all of the sites were found within WHO limits for drinking water. And it infers its presence due to the washing of salts from surrounding catchment area than by any anthropogenic cause.

BOD_5 is the measurement of the amount of biologically oxidizable organic matter present in waste water. The entry of sewage water, industrial effluents and the agricultural runoff might be responsible for the increased levels of BOD_5. The level of BOD_5 ranged from 8.10 mg/L to 31.08 mg/L in three lakes. High content of BOD_5

cause oxygen depletion, which leads to the suffocation of the aquatic life (Verma *et al.*, 1984). High BOD_5 was registered during rainy season in Gunde lake and Khaste lake and could be due to high concentration of dissolved and suspended solids in water (Jameel 1998). In Neureni lake BOD_5 value was found to be high in dry season and could be due to increased biological activities at elevated temperature (Palharya *et al.*, 1993), high input of organic pollutants and reduced rate of flow (Singh and Srivastva, 1988). ENPHO (2006) reported the BOD_5 values in Phewa lake to be in the range of 1.8-9.5 mg/L. Freshwater which is unpolluted normally have less than 2 mg/L of BOD_5. BOD_5 value up to 6 mg/L is the permissible level for fisheries and other aquatic life (ENPHO, 2006). Since the values of BOD_5 in three lakes were recorded much above permissible limits thus indicating presence of decomposable organic matter in the lake.

The COD value ranged from 52 mg/L to 64 mg/L in Gunde lake, 15.60 mg/L to 22 mg/L in Neureni lake and from 64 mg/L to 87.67 mg/L in Khaste lake. It was also found that COD values were higher in dry season than in the rainy season. The increase in COD during hot period is mainly attributed to the increase in the air and water temperatures, facilitating the decomposition and oxidation of organic matter (Abdo, 2002). According to WHO guideline, the permissible limit is < 10 mg/L for unpolluted water. In the present study COD values were found high in all three lakes indicating the organic pollution in the lakes.

The total iron of Gunde lake was found to range from 0.96 mg/L to 1.32 mg/L in dry season and from 0.45 mg/L to 1.02 mg/L in rainy season. The iron concentration was found low in centre and high in the agricultural sites of the lake. In Neureni lake the values ranged from 0.50 mg/L to 1.20 mg/L in dry season and from 0.49 mg/L to 1.45 mg/L in rainy season. Similarly in Khaste lake it was found to range between 1.50 mg/L to 1.70 mg/L in dry season and 0.40 mg/L to 2.40 mg/L in rainy season. The WHO guideline value of total iron is 0.30 mg/L. And all the values were found much higher than the permissible limits in three lakes. The presence of high concentration of iron in lake might be due to the possible geochemistry around its watershed area.

5.1.2. Nutrient salt analysis

The cycling of phosphorus within lakes is dynamic and complex, involving adsorption and precipitation reactions, interchange with sediments and uptake by aquatic biota (Borberg and Persson, 1988). In Gunde lake and Khaste lake, orthophosphate was found to be low in dry season and high in rainy season. The human disturbance site reported to have high orthophosphate in rainy season (Annex I). The people in the vicinity of Gunde lake and Khaste lake find easy to wash clothes in the increased volume of lake water in rainy season in outlet and hence this could result in increased orthophosphate contents in lake. In Neureni lake, high orthophosphate value was found in agricultural site in rainy season. High agricultural runoff during monsoon from surrounding area in southern side of lake might have enhanced orthophosphate contents. Lower values of orthophosphate were observed in summer which might be due to utilization of phosphate as nutrients by algae and other aquatic plants (Venkatesharaju, 2010). 0.02 mg/L is considered to be factor for accelerating eutrophication in lake (WHO, 1995). Hence all three lakes were found to have higher orthophosphate contents than WHO values for drinking water and thus contributed in acceleration of eutrophication in lakes.

The ammonia concentration in Gunde lake was found to be high in rainy season and low in dry season. The agricultural site contributed high ammonia concentration in rainy season. In Neureni lake, the values ranged from 0 in dry season and to 0.30 mg/L in rainy season. Similarly, in Khaste lake also there is high ammonia value in rainy season and low in dry season. In contrast the value was found opposite to the result of (Ali, 2002) where there is high ammonia value in hot season. They reported that the ammonia concentrations increase during hot period over cold seasons in oxic condition. The relative decrease in the ammonia concentrations during cold seasons were related to the oxidation of the ammonia by oxygen rich rather than uptake of ammonia by the phytoplankton cells (Shabana, 1999). Likewise, Adhikari, 2002 also noted that there is high ammonia content in summer which may be due to higher microbial activity and excretory products from aquatic animals and low in rainy season due to successive dilution in rainy season.

The nitrate concentration was found to be high in rainy season and low in dry season in three lakes. The minimum and maximum value of nitrate was found to be 0.67

mg/L and 2.89 mg/L respectively. The spatial and temporal variation in nitrates represents the final product of the biochemical oxidation of ammonia (Mahananda *et al.,* 2010). Nitrate showed comparatively higher values in monsoon which might have been because of surface runoff from surrounding catchment areas into the lake during early rain (Razak *et al.,* 2009). The elevated levels of nitrogen can cause eutrophication which is observed in many shallow patches near the bank of lakes (Hasan *et al.,* 2009). Construction of reservoir and dams also contribute to eutrophication as it decreases in flow velocities within the lake body (Deborah, 1996). The lower values recorded during summer season in the present study may be related to the denitrification of NO_3^- into NO_2^- and NH_3 by denitrifying bacteria (Merck, 1980).

5.2. Comparisons of physicochemical parameters with different guideline values in Nepal

Since the studied physicochemical parameters in three lakes didn't cover all the parameters for guideline values for different purposes (like Nepal drinking water quality standards, recreation, protected aquatic ecosystems, aquaculture, livestock watering) (CBS, 2008), the studied parameters which falls within the guideline parameters has only been taken for discussion.

5.2.1. Nepal drinking water quality standards

From Nepal drinking water quality standards (Annex: Table 6.21), pH, EC, total iron, ammonia, chloride, nitrate, total hardness and calcium hardness were taken for discussion. The pH, EC, ammonia, chloride, nitrate and total and calcium hardness of all three lakes were found to be within the permissible limits. Whereas, total iron was found to be far exceeding the Nepal drinking water quality standards. The high level of iron in water could show interferences esp. in aesthetic and daily use but chronic contact of higher level of iron could have negative health impacts in long run.

5.2.2. Nepal water quality guidelines for irrigation water

The parameters for discussion for Nepal water quality guidelines for irrigation water (Annex: Table 6.22) were pH, EC, chloride and total iron. The pH, chloride and total iron of all three lakes were found to be all within permissible limits. The EC of Gunde was found to be exceeded in the year (dry and rainy) 2011 A.D. The EC of Neureni lake was found to be within the permissible limits in dry season, 2010 A.D., but rest of the study period the EC was exceeding the guidelines value. The EC of Khaste lake was however, found to be within Nepal water quality guidelines for irrigation water. This means Gunde lake and Neureni lake was found to be unsuitable for irrigation water from EC parameter point of view.

5.2.3. Nepal water quality guidelines for aquaculture

In the discussion of lake water quality suitability for aquaculture, total alkalinity, ammonia, BOD_5, free CO_2, chloride, COD, DO, total iron, nitrate-N, pH, orthophosphate, temperature and total hardness was taken into consideration. The guidelines value is shown in annex table 6.23. Total alkalinity, ammonia, chloride, nitrate, pH was found well within the permissible limits for aquaculture. BOD_5 was found to be within target values in Gunde lake except in rainy season, 2010 A.D. In Neureni lake, BOD_5 was found to be within limits except in rainy season, 2011 A.D. And BOD_5 exceeded guidelines values throughout study period in Khaste lake. Free CO_2 was found to exceed in Gunde lake and Neureni lake, whereas, Khaste lake also exceeded permissible values except in rainy season, 2011 A.D. The COD value was found to be exceeding in Gunde lake and Khaste lake. Neureni lake has COD value within water quality target value range. The DO was found to be less in year 2010 A.D in Gunde lake. In dry, 2011 A.D. the DO values was found to be less than recommended values in Neureni and Khaste lakes. Total Iron was found to be far exceeding the target values in all three lakes. The orthophosphate was found to be within target range of 0.6 mg/L in Neureni and Khaste lakes but not in Gunde lake. The lake water temperature was found to be suitable for suitable for intermediate and warm fishes for all three lakes. Likewise, the total hardness values were found to be within the limits in all three lakes except in rainy season of 2010 A.D. and 2011 A.D. in Khaste lake.

In general, Gunde lake is not suitable for aquaculture purpose in terms of free CO_2, COD, total iron and orthophosphate parameters in lake water. Neureni lake was found to be unsuitable for aquaculture from free CO_2 and total iron parameters. And in Khaste lake not suitable due to BOD_5, COD, total iron and total hardness parameters. Neureni lake is considered for most suitable for aquaculture among three lakes.

5.2.4. Nepal water quality guidelines for livestock watering

For livestock watering the physicochemical parameters were calcium hardness, EC, pH, total iron, magnesium hardness and nitrate. All the parameters except EC were found to be within the permissible limits of guidelines value for livestock watering in three lakes. Since livestock were seen grazing in and around the lake area in dry season, the lake water might be suitable for watering.

5.2.5. Nepal water quality guidelines for recreation

The analysis for suitability for recreation purpose in lake water, only pH and algae, macrophytes were taken for consideration. pH values was found to be well within the permissible limits in three lakes. But there was luxuriant growth of macrophytes, algae and phyto-planktons in lake area in lake area. This showed interferences in boating, swimming activities in lake. So the lake area might not be suitable for recreation purpose from direct contact in lake. The people may enjoy its beauty merely by sightseeing and bird watching.

5.2.6. Nepal water quality guidelines for the protection of aquatic ecosystem

The physicochemical parameters like ammonia, DO (% saturation), total iron, pH, temperature and phosphorous were taken for analysis of studied parameters. The ammonia concentration was found to be within the target water quality range for protection of aquatic ecosystem. Whereas, % saturation, total iron, pH, temperature and phosphorous were not found to be within the target water quality range for protection of aquatic ecosystem. Since the parameters studied didn’t fall within the guidelines values, which could infer that the studied lakes needs to be protected.

5.3. Water quality index

The WQI was found to be high in dry season and low in rainy season in three lakes. Likewise in the study by Tandel *et al.,* 2011, the water quality was also found to be high in dry season and low in rainy season. In dry season the water quality deteriorates on account of the increase in microbial activity as well as increase in pollutants concentration due water evaporation. In the rainy season the rise in the volume of lake water helped in the dilution of the concentrated pollutants and increases the water quality in lake than in dry season.

From water quality rating table 4.4 the water quality of Gunde lake and Neureni lake was rated from critical pollution to severe pollution. And water quality of Khaste lake was rated as severe pollution throughout the study period. Kumar *et al.*, 2011 conducted NSF-WQI and found decreasing trend of water quality due to anthropogenic causes. Dhakal *et al.*, 2001 reported that the smaller water bodies are more prone to rapid changes in the trophic status in comparison to large water bodies like Phewa, Begnas and Rupa. This could be one of the reasons that Khaste lake (0.64 km^2) is less influenced by natural and anthropogenic activities on its water quality, whereas the Gunde lake and Neureni lake both of area 0.15 km^2 abruptly showed the change from critical pollution to severe pollution. Gunde lake falls in WQ class (II-III) in dry season, 2010 A.D., and rest of the study period in III class. Neureni lake falls in WQ class (II-III) in 2010 A.D. and in III in 2011 A.D. Khaste lake accounted in WQ class III throughout the study period.

From the independent sample t-test calculation, it revealed Gunde lake had significant differences in seasonal variation in physico-chemical parameters but no significant annual variation. The water volume was found to be high in the rainy season and thus dilution of the physico-chemical parameters in lake could have shown significant differences in seasonal variation of WQI in Gunde lake. Likewise no significant changes were found between two years so no significant differences in annual variation of physico-chemical parameters in Gunde lake was found. In Neureni lake, the water volume was found to be somewhat similar in the lake in comparison with two seasons so, no any such significant differences in seasonal variation could have found. In the outlet of Neureni lake, low outflow of water was seen in the year 2010 A.D. but in the next year there was no such outflow in the outlet of Neureni lake. This could have created the significant differences in physico-chemical parameters of Neureni lake annually. In Khaste lake, there was no significant differences in both seasonal and annual basis. Since only three sampling sites were taken i.e. forestland, human disturbance and outlet, this sampling point have the water volume almost similar in both dry and rainy season. This could have thus created no significant differences in WQI of the lake. Likewise, no significant changes in the lake environment were noticed between the two years of sampling period in Khaste lake, so this might showed no significant differences in the annual variation in the lake.

In the secondary benthic faunal data from Manandhar *et al.*, 2011, it was found that all lakes have Chironomus larva which is the indicator tolerant species of the severe organic pollution because it flourishes in the organic enrichment environment. The ovipositing behavior of the females and the multi-voltine life history of chironomids thereby show particularly valuable as an early indicator of pollution (Hellawell, 1986). The communities of these animals respond to various degree of pollution in the aquatic environment. According to Kumari *et al.*, 2008, the presence of pollution indicator species such as *Brachionus* and *Keratella* along with clean water indicator species like *Daphnia, Cyclops* and *Nauplius* indicates a good water quality of lake with presence of some organic pollution. According to Ahmed *et al.,* 2011, zooplanktons *Asplachna, Brachionus, Keratella, Fillina, Cyclops* and *Diaptomus* indicate organic pollution in the ponds studied. Murti C. R., 1991, noted that rotifers, protozoans are usually found in the area of sewage discharge and were found to be useful indicators of organic pollution. According to Lohban *et al.*, 1988, *Euglena*, *Chlamydomonas* genera of algae are the most tolerant species of organic pollution. According to Wu *et al.*, 1998, the dinoflagellates was positively correlated with the concentrations of phosphorus, total organic carbon, bacterial number, and chemical as well as biochemical oxygen demand in the water. Likewise Ryan, 2012 presented the table where different benthic animal's taxa like Hemiptera, Coleoptera, Diptera, Crustacea, Gastropoda, Platyhelminthes represents the tolerant species of organic pollution. Since these taxa of animals are present in three lakes, it thus supported the obtained results of WQI rating of Gunde lake, Neureni lake and Khaste lake.

5.4. Analysis of socio-economic information

The Baral Danda was purposively chosen for the socio-economic study because it served as the common catchment area for Gunde, Neureni and Khaste lakes. As far as to the knowledge till date no baseline estimates for WTP for these three lakes were made. Therefore, it was a difficult task to design a survey instrument or questionnaire which in itself is accused of being responsible for creating biases. However, the questionnaire generated elsewhere (Kasthala *et al.,* 2006) has been referred for the same.

The survey was done in August 2011 and about 40 samples were targeted for the survey but due to absence of the household members, two questions were unfilled.

Likewise, due to time constraints the questionnaire was performed only in nearby areas of the lakes (the vicinity of lake around 5 km).

5.4.1. Socio-economic characteristics

Of total respondents, 26.30% were found male and 73.70% were female. Most of them were found in the age group of (30-40) years, the workable age group. Since those groups of people were the respondents at that time, it can be inferred that people don't have employment opportunities, which could signifies lower economic condition of local people. About 42.10% of respondents in the survey were found to acquire primary education only. These also suggested the lower education status among the people living in study area. Most of the respondent migrated in the village due to marriage. Some people also traveled from upland to lowland to get more facilities and better life style. From the general socioeconomic survey, it was found that the houses were usually made of concrete floor and walls with tin as roofing materials. The respondent's drinking water was found to be mostly from private tap or from village well and also from shared yard tap. In the dry season some respondents went to the nearby spring to fetch water. Most of the respondents didn't perform any water treatment for drinking water. But 15.80% of the respondents boiled the water before drinking and 10.50% did filtration for drinking water. Most of the respondents were found to engage in crop farming and they thus wanted to raise their vegetable farming to strengthen their source of income. People raise livestock in their home and most of people get the firewood from the catchment area of lake and hence fuel wood and biogas was found to be the main fuel type in Baral Danda.

Most of the people get timber, grass, medicine, bamboo, reed from the lake and some people use the wetlands for recreation purpose like sightseeing, fishing, and collection of lotus flowers for medicine. In the southern part of the lake, intensive rice cultivation was done where lake water served as the source of irrigation facilities. About 81.60% of the respondents felt that the lakes are degrading. Among them 36.80% of respondents reported to be due to anthropogenic causes like road construction in the hills surrounding lakes and successive landslide and siltation in the lake. Encroachment, draining away of water from the lake, and very less conservation practices done by the people also accelerated the degradation process in the lake. Additionally, 31.60% of respondents felt that natural factors like landslide due to rainfall, eutrophication and successive encroachment of invasive species must have accelerated the degradation processes. Whereas, 13.20% noted both anthropogenic and natural factors governing the lake degradation.

5.4.2. Willingness to pay (WTP)

About 81.60% of the respondents noticed that the lakes were degrading with time. So they felt that it need to be conserved and for its sake of conservation about 76.30% were willing to pay for its conservation on setting some hypothetical situation. But 23.80% denied paying for its conservation. They had some reasons for the unwillingness. About 45.50% were willing to pay but due to low economic condition they were unable to pay, about 36.40% were able but not willing to pay because they felt that it's the duty of the government to pay for the conservation. And 18.20% were not economically sound and thus felt hard to pay for lake conservation. They can help through human labor not through monetary aspects.

Moreover, the study also revealed that the respondent's willingness in conserving the lake was for the bequest values of the wetlands i.e. to conserve the lake not for its direct goods or benefits but for its availability for their future generations as well. The services and values that wetlands served the respondents through aesthetic or recreational purpose and self pride thus motivate to conserve these lakes for their upcoming generations as well.

From WTP calculation, it was computed that aggregate WTP per annum was around NRs. 391, 200 (US$ 4,400) as of 1$= NRs. 88.90 (5/28/2012) for the lake conservation around the BDLC. This suggested that the individual household WTP per annum to be NRs. 397.56 (US$ 4.47) i.e. NRs. 33 per month per household. Within Nepal, different researchers have also calculated WTP in different wetlands (lakes & ponds). Karki, 2011 studied the WTP in Panchpokhari and reported the WTP per month to be NRs. 50 per month per household. Likewise, Awasthi, 2010 quantified the WTP in Taudaha Lake in Kathmandu and reported to be for user community and non-user community to be NRs. 1,011,200 (US$ 1,349.33) and NRs. 95,200 (US$ 1,269.34) annually.

From the correlation matrix table the maximum amount of WTP was found to be negatively correlated with age, living duration in village and total family members of the respondents. Tognacci *et al.*, 1972 also estimated that younger participants are more concerned about the environment and thus are likely to contribute more WTP. Likewise more number of family members decreases the amount as WTP for lake conservation because more money is invested in meeting their basic needs.

5.5. Relation of water quality index and willingness to pay in lake conservation

The present research was a mere effort to study the connection of lake degradation with the ongoing lake water physicochemical alterations and the local people's attitude or views to conserve their wetlands. The research was divided into two portions; first to know the lake water quality from the water quality index rating by Bach (1980) and second by estimating locales attitude in lake conservation. The result showed poor water quality in three lakes and locals peoples strong willingness to pay for the lake conservation.

The water qualities in the lakes resulted due to high nutrients like ortho-phosphate, BOD, COD, total iron and low DO. These excess parameters in lakes may promote on algal blooms, and increased growth of undesirable macrophytes affecting the drinking water quality, recreational activities and aesthetical purposes. The Bach index rating also revealed that the lakes are of severe pollution categories. These coincides the local people concern in the lake conservation. Locales also felt that the lakes are degrading with time and they need to be conserved. The manifestation of reduced water quality results in reductions of a lake's aesthetic values and decreased recreation benefits and lowering of property prices around lake area (Boyle *et al.*, 1998). Also poor water quality of lakes directly or indirectly affects the human health (Awasthi, 2010), resulting the people concerns for lake conservation. When setting up the hypothetical situation and asked for contributing in lake conservation, the people in Baral Danda Lake Complex showed strong willingness to pay for the conservation.

Likewise the local people are also dependent on these wetlands for a number of wetland ecosystems services and functions. The locals performed different activities in the lake areas like grass collection for their livestock, fodder plants, catching fishes, collection of lotus seeds for medicine, reeds collection for making carpet, etc. The lake water also irrigated the adjoining agricultural lands. The different aesthetical and religious benefits (Jal barahi temple in Khaste Lake) are also prevalent and hence for the sake of these benefits the locals are ready to pay for lake conservation.

From the study and analysis of water quality and willingness to pay aspect for lake conservation, it was found that the water quality and willingness to pay are negatively correlated with each other. Degrading water quality showed the Baral Danda people strong willingness to pay for the lake conservation.

The study thus indicated that the people in the Baral Danda are greatly concerned about their lentic environment and are ready for contributing in solving its possible solutions.

CHAPTER 6

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Seasonal variation of physico-chemical parameters of Gunde lake, Neureni lake and Khaste lake were studied. The study was conducted in dry and rainy season from March, 2010 A.D. to July, 2011 A.D. WQI based on Bach (1980) were used for assessing the water quality of three lakes. The general socio-economic survey was conducted to find WTP for lake conservation in BDLC.

From the analysis of seasonal variation of physico-chemical characteristics, it was found that pH, temperature, total alkalinity as $CaCO_3$, chloride, total hardness as $CaCO_3$, Ca-hardness as $CaCO_3$, Mg-hardness as $CaCO_3$, ammonia and nitrate were found to be within WHO guidelines for drinking water in three lakes but DO, EC, free CO_2, BOD_5, COD, phosphate and iron exceeded WHO values in three lakes. Neureni lake was considered to be suitable for aquaculture than other two lakes. Khaste lake was found to be much suitable for irrigation water. Except EC, all parameters were within the permissible limits for livestock watering of three lakes. The lakes were not considered good for recreation purposes due to dense growth of macrophytes and algal growth in lakes. Also from Nepal Guideline values for protection of aquatic ecosystems, all lakes needs to be protected.

The WQI rating ascertained lake water quality to be degraded from critical to severe pollution in Gunde lake & Neureni lake; Khaste lake accounted severe pollution throughout the study period. Likewise, Gunde lake falls in WQ class from (II-III) in dry, 2010 A.D. to III in rainy 2010 A.D. and dry and rainy season, 2011 A.D. Neureni lake has WQ class (II-III) in 2010 A.D. and III in 2011 A.D. In Khaste lake, WQ class as III in both 2010 A.D. and 2011 A.D.

Likewise, from socio-economic survey it was found that the watershed communities provide their dependency on wetland resources directly or indirectly. It was found that majority of respondents noticed the lakes were degrading gradually and in need of conservation. Local people reported anthropogenic causes to be the main factors for lake degradation like successive landslide in the rainy season by fragile mountain topography, by haphazard construction of road in the uphill and encroachment for agriculture in the lake area. Likewise natural factors also played an important role in the deterioration of lake water quality such as eutrophication and siltation from the nearby catchment slopes.

The people residing in Baral Danda showed strong WTP for lake conservation. From the correlation matrix table, the maximum amount of WTP by respondents was negatively correlated with age, time duration of living and total family size in Baral Danda. From the estimation of WTP per annum, total value for Baral Danda village was computed as NRs. 391,200 (US$ 4,400). The individual household WTP per annum was found to be NRs. 397.56 (US$ 4.47) i.e. NRs. 33 per household per month.

In conclusion, the poor water quality of three lakes calculated through WQI based on Bach (1980) and the local people's strong WTP for the wetland conservation thus definitely signified the need of wetland conservation in BDLC in Lekhnath municipality, Kaski, Nepal.

6.2. Recommendations

6.2.1. For scholars

- The water quality data was not generated in these lake areas before this study hence, regular monitoring of physicochemical data for the availability of data should be done.
- The result of water quality was compared with the macro-invertebrates data to support the data, but not through macrophytes data, hence study on macrophytes could also be done to support the data of WQI.
- More advanced studies of these lakes could be done like using GIS based models or bathymetric surveys to find the actual depth and surface area of the lake which could help in figuring out overall picture of the case of these lakes.

6.2.2. For local peoples

- The money collected as the willingness to pay for lake conservation should be well managed and invested in lake conservation actions.

- Reliable person should be appointed by the villagers for handling the money and the money should be used for lake conservation efforts like promoting fish farming or efforts in minimizing the landslides/siltation or afforestation programmes in upland.
- Since the studied results showed the degrading pattern of water quality of three lakes so the master plans developed by the municipality to make Gunde lake – a potentially a fishing site, Neureni lake and Khaste Lake - a bird watching sites (The Kathmandu post, 2010) should be considered before mobilizing the action. Detail study of these lakes should be done for successful implementation of the plans.
- Awareness and community empowerment programme, income generation activities, health and hygiene education, living environment improvements, women empowerment steps should be mobilized through local level NGOs/INGOs and local government for the wise use of wetlands and tourism development.

REFERENCES

Abdel-Satar, A. M. 2005. On the water quality of Lake Bardawil, Egypt. *Egyptian Jornal of Academic Society of Environment and Develop*ment (D Environmental studies), b (1): 49-73

Abdo, M. H. 2002. *Environmental studies on Rosetta branch and some chemical applications at the area extend from El-Kanater El-Khyria to Kafr-El-Zyat City*. Ph.D. Thesis, Faculty of Science, Ain Shams University, Cairo, Egypt.

Abdo, M. H. 2005. Physico-chemical characteristics of Abu Za'baal ponds, Egypt. *Egyptian Journal of Aquatic Research,* Vol. 31 No. 2: 1-15

Acharya, P. 1997. *Wetland Vegetation and its Utilization in Ghodagodi and Nakhrodi Tal, Kailali, Nepal*. MSc. Thesis, Central Department of Botany, Tribhuvan University, Nepal.

Adhikari, A.R. 2002. *Ecological Study and Environmental Management of Lakes Khaste and Dipang: Wetlands of Pokhara Valley, Nepal,* A dissertation submitted to Central Department of Botany, Tribhuvan University, Kirtipur, Nepal.

Agrawal, S.C. 1999. *Limnology.* A.P.H. Publishing Corporation, New Delhi.

Ahmed, U., Parveen, S., Khan, A. A., Kabir, H. A., Mola, H. R. A. and Ganai, A. H. 2011. Zooplznkton population in relation to physic-chemical factors of a sewage fed pond of Aligarh (UP), India. *Biology and Medicine. Vol 3 (2).* Special Issue: 336-341. http://biolmedonline.com/Articles/MAASCON-1/Vol3_2_336-341.pdf accessed at 4/6/2012 at 12:30 am

Ali, M. H. H. 2002. *Impact of agricultural and sewage effluents on the ecosystem of Lake Qarun, Egypt,* Ph. D. Thesis, Faculty of Science, Al-Azhar University, Egypt.

Anderson, G. C. 1961. Recent changes in the trophic nature of lake Washington – a review. In: *Algae and metropolitan*, Cincinnati, Ohio, TRW. 61(3):27-33.

APHA, AWWA, WEF, 1998. *Standard methods for Examination of Water and Waste Water*, American Public Health Association, Washington DC, 20th Edition.

Aryal, N. 2007. *Biodiversity Assessment of Wetland: a study on the Mardhar Wetland, Rautahat, Nepal.* M Sc. Thesis, Central Department of Environmental Science, Tribhuvan University, Kathmandu.

Aryal 2009. www.koreawetland.org/include/download2.asp?idx=4712&seq=4 *IUCN Nepal Activities on Wetland Conservation and Management.* Accessed on 4:26 pm, 4/5/2010.

Awasthi, M. 2010. *Economic Valuation of Wetland Ecosystem Services (A Case Study of Taudaha Lake, Kathmandu, Nepal).* A dissertation submitted to Central Department of Environmental Science, Tribhuvan University, Kirtipur, Nepal.

Ayoade, A. A., Fagade, S. O., Adebisi, A. A. 2006. Dynamics of limnological features of two manmade lakes in relation to fish production. *African Journal of Biotechnology*, 5:1013-1021.

Bach, E. (1980) in Doetsch, P. 1987. Entwicklung and exemplarische Anwendung eines Verfahrens zur nutzungsadaquaten Quantifizierung von Gewaeeergute. *Hochscbulreihe Aachen, Gewasserchuts- Wasser- Abwasser*, 91.

Badge, U.S. and A.K. Verma, 1985. Limnological studies on J.N.U. Lake, New Delhi, India, *Bulletin of Botanical Society, Sagar*. 32: 16-23.

Bajracharya, S. R. and Maharjun, S.B. and B. R. 2010. Second generation glaciers mapping and inventory of Nepal. *Journal of Nepal Geological Society 41* (abstract volume journal) : 21.

Bajracharya, S. R. and Maharjun, S.B. 2010. *The status of glaciers in Nepal Himalaya*. Unpublished report prepared by ICIMOD, Kathmandu. http://books.icimod.org/index.php/search/publication/750 accessed at 5/27/2012 at 11:41 pm

Ball, R.O., Church, R.L. 1980. Water quality indexing and scoring. *Journal of Environmental Engineering Division, ASCE*, 106(4), 757-771.

Bhandari B. B. 2009. Wise Use of Wetlands in Nepal. In *Banko Janakari Wetlands Special Issue* February 2009. pp. 10-17. http://www.nepjol.info/index.php/BANKO

Bhandari, B, Shrestha, T. B., & Mc Eachern, J. 1994. *Safeguarding wetlands in Nepal*: Proceedings of the National workshop on wetlands management in Nepal 3-5 March, 1993, Kathmandu, IUCN/ Nepal.

Bhandari, B. (ed) 1998. *A study on conservation of Beeshazar Tal.* IUCN/Nepal.

Bhandari, B. 1992. *The current status of wetlands in Nepal*. Country report presented at the Asian Wetland symposium organized by Ramsar Centre, Japan at Otsu, Kushiro, Japan, 14-20 October, IUCN/Nepal.

Bhandari, N. S., and Nayal, K. 2008. "Correlation study on physico-chemical parameters and quality assessment of Koshi river water, Uttarakhand". *Electronic Journal of Chemistry*, 5(2): 342-346.

Bhat, M. M., Yazdani, T., Narain, K., Yunus, M., and Sukla, R. N. 2009. Water Quality Status of Some Urban Ponds of Lucknow, Uttar Pradesh. *Journal of Wetlands Ecology*, 2:67-73.

Bhatia, A. I., Moundiotiya, C., Sisodia, R., & Kulshrestha, M. 2004. A case study of the Jamwa Ramagargh wetland with special reference to Physico-chemcial properties of water and its environs. *Journal of Environmental Hydrology*, 12 (24): 1-7.

Bhattarai, K. K. 1996. *Studies on Physicochemical Environment and Biotic Community of Lami Tal in RCNP*. M. Sc. Thesis, Central Department of Zoology, Tribhuvan University.

Bhuju, U. R., Khadka, M., Neupane, P. K., & Adhikari, R. 2009. *Lakes of Nepal: 5358- Map Based Inventory*. Kathmandu: National Lakes Conservation Development Committee.

Bishop, J. E. 1973. *Limnology of small Malayan river, Sungai Gomback,* Dr. W. Junk Publishers, The Hague.

Broberg, O. and Persson, G. 1988. Particulate and dissolved phosphorus forms in freshwater: Composition and analysis. *Hydrobiology, 170*: 61-90.

Boyle, K. J., Lawson, S. R., Holly J. M. & Bouchard, R. 1998. *Lakefront Property Owner's Economic Demand for Water Clarity in Maine Lakes.* Maine Agriculture and Forest Experiment Station Miscellaneous Report 410. University of Maine

BPP, 1995. *Biodiversity Assessment of Terai Wetlands*. BPP Technical Publication No.1. Department of National Parks and Wildlife Conservation (DNPWC). Ministry of Forest and Soil Conservation (MoFSC- HMGN, Kathmandu)

Brehm, V., 1953. Indische Diapromiden prediaptomides and cladoceran. *OST ZOOL Z.,* 4(3):241 – 345

Burlakoti, C. 2003. *Physico-chemical Characteristics and Macrophytes of Beeshazar Tal, Chitwan.* M Sc. Thesis, Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

CBS, 2008. *Environment Statistics of Nepal, 2008.* Central Bureau of Statistics, Thapathali, Kathmandu, Nepal. Copy 500.

Chand, B. 2011. *Economic Valuation of Wetland Ecosystem Services (A Case Study of Nagdaha Lake, Lalitpur, Nepal).* M.Sc. Thesis submitted to Central Department of Environmental Science, Tribhuvan University, Kirtipur, Nepal.

Chand, P. 2010. *Economic Valuation of wetland, the case study of Ghodaghodi Wetland.* M.Sc. Thesis submitted to Central Department of Environmental Science, Tribhuvan University, Kirtipur, Nepal.

Chaurasia, M & Pandey, G. C. 2007. Study of Physico-chemical characteristics of some water ponds of Ayodhya-Faizabad. *Indian Journal of Environmental Protection* 27(11): 1019-1023

CSUWN. 2009. *Simsar Varnamala*. Conservation and Sustainable Use of Wetlands in Nepal (CSUWN). Kathmandu, Nepal.

Deborah, C. 1996. "*Water quality assessments - A guide to use of biota, sediments and water in Environmental Monitoring*" – 2nd Edition. UNESCO/WHO/UNEP.

Deininger, R.A., & Maciunas, J. J. 1971. *A water quality of environmental and industrial health, school of public health*, University of Michigan, Ann Arbor, Michigan.

Devkota, S. 2005. *Degrading and Disappearing wetlands: a study on natural lake Taudaha of Kathmandu Valley, Kathmandu*. Report on National Workshop Conserving Nepalese Wetlands: Sharing Experiences and Building Partnership, World Wetlands Day 2007.

DFID. 2007. *Biodiversity: A Crucial Issue for the World's Poorest.* London: Environment Policy Department: Department For International Development.

Dhakal, R.P., Bista, J. D. & Gurung, T. B. 2001. *Study on limnology and development of water quality suitable index for cage aqualculture in Lakes of Pokhara Valley.* Annual Technical Report, NARC (Nepal Agriculture Research Council), Agriculture Research Centre (Fisheries), Pokhara, Kaski.

DHM, 2009. *Annual report of hydrological and meteorological data*. Department of Hydrology and Meteorology, Babarmahal, Kathmandu, Nepal.

Dwivedi, B.K. & Pandey, G. C. 2002. Physico-chemical factors and algal diversity of two ponds (Girija Kund and Maqubara Pond), Faizabad. *Pollution Res*earch, 21:361-370.

Emerton, L. 1999. *A Toolkit for valuing wetlands in Eastern Africa*. IUCN, Eastern Africa Regional Office, Nairobi.

ENPHO, 2006. *Report of Water Quality Monitoring of Lake Phewa*. Submitted by Environment and Public Health Organization (ENPHO), September 2006

Ferrow, W. 1978/79 a: Some Limnological and Biological Data from Rara, a Deep Himalayan Lake in Nepal. *Journal of Nepalese Res. Cent.*, T.U., 2/3: 241-261.

Ferrow, W. 1981/82: Limnology of the Pokhara Valley Lakes (Himalayan region Nepal) and its implications for fishery and fish culture. *Journal of Nepalese Res. Cent.*, T.U., V/VI: 27-41.

Ferrow, W. and Swar, D. B., 1978. Bathymetric maps from three lakes in Pokhara Valley. *Nepalese Journal of Inst. Science*, 1: 177-80.

Garrod, G., Willis, K. 1998. Using contingent valuation to estimate the loss of amenity value for inland waterways from public utility service structures. *Environmental and Resources Economics*, 12(2): 241-247.

George, A.V. and M. Koshy, 2008. Water Quality studies of Sasthamkotta Lake of Kerala. *Enviromedia* 27(3):419-424 (2008).

Goher, M. E. M. 2002. *Chemical studies on the precipitation and dissolution of some chemical elements in Lake Qarun*, Ph.D. Thesis. Faculty of Science, Al-Azhar University, Egypt.

GON, 2006, *Nepal Biodiversity Strategy Implementation Plan* 2006-2010. Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Gramlich, F.W. 1977. The demand for clean water, the case of Charles River, *National Tax Journal*, 30(2): 183-194.

Gupta, A.K., Gupta, S. K., & Patil, R. S. 2003. A comparison of Water Quality Indices for Coastal Water. *Journal of Environmental Science and Health*, Part A – Toxic Hazardous Substances & Environmental Engineering, 38(11): 2711-2725.

Gupta, V. & G. M. 2008. *Estimating Intangible Benefits of Improving Water Quality of Powai Lake in India: A Contingent Valuation Approach*

Hamilton, F. B., 1822. An account of the fishes found in the river Gangas and its branches. *Edinburgh*.VII: 405

Hannan, H. 1979. Chemical modification in reservoir regulated streams. In: *The Ecology of Regulated Streams* (eds.) ward, J.W. and J. A. Stanford, J. A. edition plenum corporation publication, pp. 75-94.

Harkins, R.D. 1974. An objective water quality Index, *Journal of the Water Pollution Control Fed*eration, 3: 589-591.

Hasan, I., Rajia, S., Kasi, A. K., & Latifa, G. A. 2009. "Comparative study on the water quality parameters in two rural and urban rivers emphasizing on the pollution level". *Global Journal of Environmental Research* 3 (3): 218-222.

Hellawell, J. M., 1986. *Biological Indicator of Freshwater Pollution and Environmental Management.* (Pollution monitoring series). Elsevier Applied Science Publishers, 1986. The University of California. USA.

Hickel, B., 1973. Limnological investigations in lakes of Pokhara Valley, Nepal. *International Rev. Ges. Hydrobiology*. 58 (5): 659 - 672

HMGN. 1961. *Aquatic Animal Protection Act 1961*. His Majesty's Government of Nepal, Law Books Management Committee, Kathmandu, Nepal.

HMGN. 1973. *National Parks and Wildlife Conservation Act 1973*. His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

HMGN. 1982. *Soil and Watershed Conservation Act 1982.* His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

HMGN. 1988. *National Conservation Strategy: Building on Success*. His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

HMGN. 1989. *Master Plan for the Forestry Sector Nepal (Main Report).* His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal

HMGN. 1992a. *Electricity Act 1992*. His Majesty's Government of Nepal, Kathmandu, Nepal.

HMGN. 1992b. *Water Resources Act 1992*. His Majesty's Government of Nepal, Kathmandu, Nepal.

HMGN. 1993. *Forest Act 1993*. His Majesty's Government of Nepal, Law Books Management Committee, Kathmandu, Nepal.

HMGN. 1993. *Nepal Environmental Policy and Action Plan 1993*. His Majesty's Government of Nepal /Environment Protection Council, Kathmandu, Nepal.

HMGN. 1996. *Environment Protection Act 1996*. His Majesty's Government of Nepal, Ministry of Environment, Science and Technology, Kathmandu, Nepal.

HMGN. 1999. *Local Self Governance Act 1999*. His Majesty's Government of Nepal, Law Books Management Committee, Kathmandu, Nepal.

HMGN. 2000. *Revised Forestry Sector Policy 2000*. His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

HMGN. 2002. *Nepal Biodiversity Strategy 2002*. His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

HMGN. 2003. *National Wetland Policy, 2003.* His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Hokby, S., & Soderqvist, T. 2001. *Elasticities of demand and willingness to pay for environmental services in Sweden*, Paper presented at the 11th Annual Conference of the European Association of Environmental and Resources Economics, Southampton, UK, 28-30 June.

Hollis, G. E.; Hollamd, M. M. & Larson, J.s. 1998. Wise Use of Wetlands. *Nature and Resources*, 24

Hydrology Division/ HMG, 1996. Water Quality Data of Rivers of Kathmandu Valley. Kathmandu Department of Hydrology and Meteorology/ HMG.

IUCN-Nepal, 1996. *An Inventory of Nepal's Wetlands*. IUCN-Nepal, Kathmandu.

Jain, S. M., Sharma, M., & Thakur, R. 1996. Seasonal variations in physicochemical parameters of Halai reservoir of Vidisha district, India. *Indian Journal of Ecobiology,* 8(3), pp. 181-188.

Jameel, A. 1998. Physico-chemical studies in Vyyakondan Channel water of Cauvery, *Pollution Research,* 17:2, 111-114.

Jones, J. R, Knowlton, M. F., & Swar, D. B. 1989. Limnological Reconnaissance of Water bodies in Central & Southern Nepal. *Hydrobiologia.* 184: 171-189.

Kafle, G. and Savillo, I. T. 2009. Present Status of Ramsar Sites in Nepal. In: *International Journal of Biodiversity and Conservation*. Vol. 1(5) pp. 146-150.

Kannan, K. 1991. *Fundamentals of Environmental Pollution*, S. Chand and Company Ltd., New Delhi, India.

Karki, S. 2010. Economic Valuation of Wetlands: A case study in PanchPokhari Wetland, Indrawati Sub-basin. In Proceedings of Graduates' *Workshop on Wetlands* on World Wetlands Day, 2011.

Kasthala, G., Hepelwa, A., Hamiss, H., Kwayu, E., Emerton, L., Springate- Baginski, O., Allen, D. & W. Darwall. 2008. *An integrated assessment of the biodiversity, livelihood and economic values of wetlands in Mtanza- Msona Village, Tanzania.* Tanzania Country Office, International Union for Conservation of Nature, Dar es Salaam.

Kaushik, S. & Saksena, D. N. 1999. Physico-chemical limnology of certain water bodies of central India. In: K Vismayan edited *Fresh Water Ecosystem in India*, Daya Publishing House Delhi: pp 336.

Khanal, S., 2011. Contribution of agroforestry in Biodiversity Conservation and Rural Needs Fulfillment- a study from Lekhnath municipality and Bharatpokhari VDC of Kaski district. Master's thesis submitted to the Tribhuvan University - Institute of Forestry, Nepal.

Khopker, S. M. 2004. *Environmental Pollution*, New Age International Pvt. Ltd., India.

Khorshiddoust, A.M. 2004. *The valuation of environmental quality and formulation of solid waste management strategies for Tehran, Iran.* Ph.D. Thesis, Macquarie University, Sydney, Australia.

Kudesia, V.P. 1985. *Water Pollution*. 2nd ed. Pragati Prakashan, Meerut, India.

Kumar, R. N., Solanki, R., & N.K. J.I. 2011. An assessment of seasonal variation and water quality index of Sabarmati River and Kharicut canal, Ahmadabad, Gujrat.

Electronic Journal of Environmental, Agriculture and Food Chemistry, 10(5): 2248-2261.

Kumari, P., Dhadse, S., Chaudhari, P. R., & Wate, S. R. 2008. A Biomonitoring of Plankton to assess quality of water in the lakes of Nagpur City. *Proceedings of Taal2007: The 12th World Lake Conference: 160-164.* http://wldb.ilec.or.jp/data/ilec/wlc12/A%20-%20Ecology%20&%20Biodiversity/A-28.pdf accessed on 4/5/2012 at 10:19 pm

Lekhnath Municipality, 2008. *Socio-economic Status of Lekhnath Municipality, 2008* published by Lekhnath Municipality, Kaski Nepal.

Loffer, H., 1969. High altitude lakes in the Mount Everest Region. *Verh. Internal. Verein. Limnology.* 17:373 - 385

Lohban, C. S., Chapman, D., & Kremer, B. 1988. *Experimental phycology: a laboratory manual.* Phycological Society of America. CUP Archive, 1988- Science- 295 pp. http://books.google.com.np/books?id=a2o5AAAAIAAJ&dq=chlamydomonas+organic+pollution&source=gbs_navlinks_s accessed at 4/6/2012 at 12: 30 am

Lohman, K., Jones, J. R., Knowlton, M. F., Swar, D. B., Pamperl, M. A., & Brazos, B. J. 1988. Pre and post monsoon limnological characteristics of lakes in the Pokhara Valley, Nepal. *Verhandlungen des Internationalen Verein Limnologie* 23: 558-563.

Mahananda, M.R., Mohanty, B. P., & Behera, N. R. 2010. Physico-chemical analysis of surface and ground water of Bargarh district, Orissa, India. 2 *(3):* 284-295.

Manandhar, R., Sapkota, R. P., Neupane, N., Bastola, R., Adhikari, S., Parajuli, B., & Shrestha, I. 2011. *Status of Degrading and Disappearing Lakes of Lekhnath Municipality*. A mid-term report submitted to the University Grants Commission by Department of Environmental Science, Amrit Science Campus, Thamel, Kathmandu, Nepal.

Merck, E. 1980. "*Complexmetric Assay Methods Titriplex*". Germany.

Ministry of Forests and Soil Conservation, Nepal Biodiversity Action Plan, 2003. Kathmandu, Nepal.

Mool, P., Bajracharya, K., Samjwal, R. and Joshi, S.P. 2001a. *Inventory of Glaciers, Glacial Lakes and Glacial Lake Outburst Flood: Monitoring and Early Warning Systems in the Hindu-Kush- Himalayan Region. Kathmandu: ICIMOD.*

Moss, B. 1998. *Ecology of Fresh waters Man and Medium, Past to Future*, Third Edition, Blackwell Sciences Ltd. United Kingdom.

Muhandiki, V., 2010. *Integrated Lake Basin Management (ILBM) and its Application to Water Quality Management in Lake Victoria Basin.* UNEP-DTIE-IETC-& ILEC, Consultative Meeting on Water and Wastewater management, Kusatsu, Shiga, Japan, 19-20 April, 2010.
http://www.unep.or.jp/Ietc/WS/news-apr10/S6_1_DrVictorMuhandiki.pdf accessed on 4/1/2012 at 10:27 pm

Murti, C. R., 1991. *The Ganga, a scientific study.* Ganga Pariyojana, Nirdesalaya, India, Environment Research Committee. Northern Books Centre, pp- 246.
http://books.google.com.np/books?id=dxpxDSXb9k8C&dq=Rotifers+and+organic+pollutants&source=gbs_navlinks_s accessed on 4/6/2012 at 12:27 am

National Wetlands Policy, 2003. His Majesty's Government of Nepal. Ministry of Forests and Soil Conservation.
http://www.rainwaterharvesting.org/happenings/National_Wetland_Policy_of_Nepal-1.pdf accessed on 3/24/2012 at 7:41 pm

NPC/IUCN. 1991. *Environmental Pollution in Nepal: A review of studies, Kathmandu.* Nepal National Conservation Strategy Implementation Programme, National Planning Commission (NPC), HMG Nepal in collaboration with IUCN- The World Conservation Union. Pp v- xiii, 1-18: 43-57

Oli, K.P. (ed). 1996. *Environmental study of Nepal's Begnas and Rupa Lakes.* NPC and IUCN/Nepal.

Oli, K.P. (ed.). 2000. *Conservation and Development of Lekhnath Municipality.* Vol. I, II. IUCN/ Nepal.

Palharya, J.P., V.K. Siriah, and S. Malviya. 1993. *Environmental impact of Sewage and Effluent Disposal on the river System,* Aashish Publication House, New Delhi.

Pandey, A. K. & Pandey, G. C. 2003. Physicochemical characteristics of city sewage discharge into River Saryu, Faizabad-Ayodhya. *Himalayan Journal of Environmental Zool*ogy, 17: 85-91.

Pant, R. 2008. Wetland Management and Sustainable Livelihood in Pokhara Valley, Nepal. In proceedings: *The roles of lake and wetlands conservation in developing and promoting tourism in Nepal*. 10th Falgun, 2007, Pokhara. Nepal.

Paudel, B. K. 2002. *Quality Analysis and Protection Systems in Rivers of Nepal- A Case of Bagmti River.* An unpublished dissertation, Dept. of Civil engineering, Tribhuvan University, Institute of Engineering, Pulchok Campus, Nepal.

Pokharel, S. 2008. In proceedings: *The roles of lake and wetlands conservation in developing and promoting tourism in Nepal.* 10th Falgun, 2007, Pokhara. Nepal.

Pradhan, B. 1998. *Water Quality Assessment of the Bagmati River and its tributaries, Kathmandu Valley, Nepal.* An unpublished dissertation, Dept. of Hydrobiology, Institute of Water Provision, Water Ecology and Waste Management BOKU-University, Vienna, Austria.

Khatiwada, S. 2008. In proceedings: *The roles of lake and wetlands conservation in developing and promoting tourism in Nepal.* 10th Falgun, 2007, Pokhara. Nepal.

Ramsar Convention on Wetlands, 2012. The Ramsar List of Wetlands of International Importance. http://www.ramsar.org/cda/en/ramsar-documents-list/main/ramsar/1-31-218_4000_0__ accessed on 4/1/2012 at 1:29 pm

Ramsar. 2007. *Economic Valuation of Wetlands: A Guide for Policy*. Retrieved April 29, 2008, from www.ramsar.org

Ramsar-Nepal, 2012. The Annotated Ramsar list of Wetlands of International Importance, Nepal. http://www.ramsar.org/cda/en/ramsar-pubs-notes-annotated-ramsar-16499/main/ramsar/1-30-168%5E16499_4000_0__ accessed on 4/1/2012 at 2:01 pm

Ranga, M. R. 2006. *The Transformation of Costal Wetland Agriculture and Livelihoods in Kerala, India.* Natural Resources Institute. Winnipeg: University of Manitoba.

Razak, A. A, Asiedu, A. B., Entsua-Mensah, R. E. M., & Graft Johnson, de K. A. A. 2009. “Assessment of water quality of the Oti River in Ghana” *West African Journal of Applied Ecology*, Vol.15.

Ryan, M. F. 2002. Biological Indicators of Freshwater Pollution, School of Biology and Environmental Science, National University of Ireland. http://www.aquastress.net/share/img_events_file/128_3BIOLOGICAL%20INDICATORS%20of%20FRESHWATER%20POLLUTION.pdf accessed 4/22/2012 at 2.07.

Sah, J. P. 1993. *Wetland Vegetation and its Management: A Case Study in Koshi Tappu Region, Nepal.* A thesis submitted for M.S. in Asian Institute of Technology, Bangkok, Thailand.

Seenprachawong, U. 2002. *An Economic Analysis of Coral Reefs in the Andaman Sea of Thailand*, a summary of EEPSEA Research Report 2001-RR7, School of Economics, Sukhothai Thammathirat Open University, Thailand.

Shabana, E. E. 1999. *Limnological studies on Lake Bardawil*, M. Sc. Thesis, Faculty of Science, Suez Canal University, Egypt.

Sharma, B. 2007. *Study on Water Quality of Ranipokhari Pond and Nagdaha Lake, Kathmandu Valley and use of benthic invertebrates as biological indicators.* MSc. Thesis submitted to Central Department of Environmental Science, Kirtipur, Nepal.

Sharma, C.K. 1977. *Rivers Systems of Nepal.* Bishal Nagar, Kathmandu: S.Sharma.

Shrestha, G. K. 2007. *Assessment of Water Quality of Manahara River, Kathmandu Valley by using Macro-invertebrates as Biological Indicator.* MSc. Thesis submitted to Central department of Environmental Science, Tribhuvan University, Kirtipur, Nepal.

Shrestha, H. 2005. *Water quality assessment of Bishnumati river downstream with special references to physico-chemical parameters.* M.Sc. Thesis submitted to Central Department of Environmental Science, Tribhuvan University, Kirtipur, Nepal.

Shrestha, R. L., & Nepali, H. S. 1987. *Present Status of Wetlands Distribution and its Preservation in Nepal.* A paper presented at the conference on wetlands and water fowl conservation organized by IWRB and Interweaves at Malacca, Malaysia, 23-28 February, 1987.

Shrestha, U. P. 1995. *Physics Practical Guide,* Trimurti Prakashan, Varanasi. Pp. 286-287.

Shutz, S. D., Lindsay, B. E. 1990. The willingness to pay for groundwater protection. *Water Resources Research,* 20(2): 1869-75.

Singh, R. P. & Mathur, P. 2005. Investigation of variations in physic-chemcial characteristics of a freshwater reservoir of Ajmer city, Rajasthan. *Indian Journal of Environmental Biology,* 19:179-186.

Singh, S., & Srivastava, V. K. 1988. Variations in water quality of Ganga River between Buxar and Ballia, *Pollution Research*, 7: 3-4, 85-92.

Singh, S. P., Sharma, M. C., Sharma, A. P., & Purohit, R. 1984. Limnology of shallow water zones of lake in Kumaon Himalayan *India tropical ecology*, 35: 47-49.

Sisodia, R., Moundiotiya, C., Kulshrestha, M., & Bhatia, A. L. 2004. A case study of Jamwa Ramgargh wetland with special reference to physicochemical properties of water and its environs. *Journal of Environmental Hydrology*, 12(24): 2004.

Sisodia, R., & Moundiotiya, C. 2006. Assessment of water quality index of wetland Kalakho Lake, Rajasthan, India. *Journal of Environmental Hydrology*, 14:23

Siwakoti, M and Tiwari, S. 2002. *Conservation of Wetlands Biodiversity in Nepal: Practices, Problems and Possibilities*. In: Proceedings of the 6th Asia-Pacific NGO's Environmental Conference, Kaohsiung, Taiwan.

Smardon, R. 2011. *Urban & Rural Treatment Wetlands Manual*. A New/Old Green Infrastructure, SUNY-ESF, USA.

Spray, S. L. & McGlothlin, K. L. (Eds). 2004. *Wetlands*. Lanham: Rowman & Littlefield Publishers, Inc.

Swar, D. B. 1980. *Present status of limnological research in Nepal.* Proceeding of First Workshop for the Promotion of Limnology in Developing Countries, Kyoto, Japan

Swar, D. B. & Fernando, C. H. 1980. Some studies on the ecology of limnetic crustacean zooplanktons in lakes Begnas and Rupa, Pokhara Valley, Nepal. Hydrobiology. 70:235

Tandel, N. B., Macwan, J. & Soni, C. K. 2011. *Assessment of Water Quality Index of Small Lake in South Gujarat Region, India.* http://isems.org/images/extraimages/10.pdf accessed on 12/19/2011 at 3:10 pm.

The Kathmandu Post, 2010. Seven vanishing lakes. http://www.ekantipur.com/the-kathmandu-post/2010/04/02/Features/Seven-vanishing-lakes/206810/ accessed at 4/24/2012 at 10:45 pm

Trivedi, R.K. and P.K. Goel. 1986. *Chemical and Biological Methods for Water Pollution Studies*, Environmental Publication, Karad, India.

Tognacci, L. N., Weighel, R. H., Widden, M. F., & Vernon, D. T. A. 1972. Environmental quality: How universal is public concern? *Environmental and behavior*, 4(1): 73-86.

Unni, K. S. 1972. An ecological study of the macrophytic vegetation of Doodhadhari Lake, Raipur (M. P.). *Hydrobiologia*, 40:25-36.

Venkatesharaju, K. P., Ravikumar, R. K., Somashekar, & K. L., Prakash, 2010. Physicochemical and bacteriological investigation on the Cauvery River of Kollegal Stretch in Karnataka. *Journal of Science, Engineering and Technology*, 6 (1): 50-59.

Verma, S. R., Sharma, P., Tyagi, A., Rani, S. S., Gupta, A. K., & Dalela, R. C. 1984. Pollution and saprobic status of Eastern Kalinadi. *Limnology*, 15:1, 69-133.

Wetzel, R. G.1983. *Limnology* 2nd edition. Saunders College Publishing, USA.

WHO, 1995. Guidelines for drinking water standard. World Health Organization, Geneva.

Wu, J. T., Chou, W. T. 1998. Dinoflagellates associations in Feitsui reservoir, Taiwan. *Botanical Bulletin of Academia Sinica*, 39*:* 137-145. http://ejournal.sinica.edu.tw/bbas/content/1998/2/bot92-10.pdf accessed on 4/7/2012 at 10 pm

WWF. 2009. www.hydroweb.com/jeh/jeh2006/sisodia.pdf accessed on 7/24/2010 at 11:45 pm.

ANNEXES

1) **ANNEX I:** Physico-chemical data analysis of Gunde, Neureni and Khaste lakes

a) **PHYSICO-CHEMICAL PARAMETERS OF DRY SEASON, 2010 OF GUNDE LAKE**

Sampling Date: 2066/12/12

Sampling Time: 8:35 am

S. No.	Physico-chemical parameters	Sampling sites					WHO guidelines	Remarks
		Inlet/ Forestland	Centre (lower half)	Outlet	Agricultural land (upper half)	Human disturbance		
1.	Temperature	17	18	18	17	18	-	-
2.	pH	8.10	8.0	7.90	8.20	7.90	6.5-8.5	Falls within the WHO values
3.	Conductivity	032	035	039	032	037	20-30 ms/cm	High than WHO values
4.	Dissolved Oxygen (mg/L)	3.24	6.49	1.62	6.49	3.24	5 mg/L	Below WHO values
5.	Total alkalinity (mg/L)	50	30	30	40	50	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0	0	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	50	30	30	40	50	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	36	10	16	14	20	<75 mg/L	Soft
a)	Ca- hardness as $CaCO_3$ (mg/L)	10	4	6	6	10	-	-
b)	Mg-hardness as $CaCO_3$ (mg/L)	26	6	10	8	10	-	-
7.	Free CO_2 (mg/L)	22	22	19.8	21	22	<10 mg/L	Higher than WHO values
8.	Chloride (mg/L)	14.20	12.78	12.78	14.20	14.20	250 mg/L	Low than WHO values
9.	BOD_5 (mg/L)	141.95	314.40	71.10	314.40	157.20	Acc. to MOEST ,<50 mg/L	Higher than MOEST values
10.	Total solids (mg/L)	1800	600	1200	1000	1400	500 mg/L	Higher than WHO values
11.	Ortho-phosphate (mg/L)	0.14	0.15	0.04	0.03	0.10	0.02 mg/L	HigherWHO values than upper half
12.	Ammonia (mg/L)	0.14	0.01	0.03	0.03	0.01	1.5 mg/L	Less than WHO values
13.	Nitrate (mg/L)	0.67	0.65	0.74	1.15	0.91	50 mg/L	Less than WHO values
14.	Iron (mg/L)	0.87	0.68	0.73	1.95	0.58	0.3 mg/L	Higher than WHO values

b) PHYSICO-CHEMICAL PARAMETERS OF DRY SEASON, 2010 IN NEURENI LAKE

Sampling Date: 2066/12/12

Sampling Time: 12:15 pm

SNo.	Parameters	Sampling sites			WHO guidelines	Remarks
		Inlet/ Forestland	Near agricultural land (southern part)	Outlet		
1.	Temperature	19	20	18	-	-
2.	pH	7.90	7.80	7.90	6.5-8.5	Meets the WHO values
3.	Conductivity (ms/cm)	034	035	037	20-30 ms/cm	More than WHO values
4.	Dissolved Oxygen (mg/L)	4.87	6.49	4.87	5 mg/L	Does not meet WHO values
5.	Total alkalinity (mg/L)	60	50	30	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	60	50	30	-	-
6.	Total hardness as$CaCO_3$ (mg/L)	40	40	120	<75 mg/L	All soft water except outlet
a)	Ca- hardness as $CaCO_3$ (mg/L)	12	14	18	-	-
b)	Mg- hardness as CaCO3 (mg/L)	28	26	102	-	-
7.	Free CO_2 (mg/L)	30.80	44	35.20	<10 mg/L	Greater than WHO values
8.	Chloride (mg/L)	14.20	8.52	14.20	250 mg/L	Lower than WHO values
9.	BOD_5 (mg/L)	202.80	304.40	202.80	<50 mg/L	Higher than MOEST values
10.	Total solids (mg/L)	1400	1200	1400	500 mg/L	Much higher than WHO values
11.	Orthophosphate (mg/L)	0.13	0.07	0.06	0.02 mg/L	Higher than WHO values
12.	Ammonia (mg/L)	0.00	0.07	0.00	1.5 mg/L	Less than WHO values
13.	Nitrate (mg/L)	1.86	0.78	0.44	50 mg/L	Less than WHO values
14.	Iron (mg/L)	0.64	0.49	0.48	0.3 mg/L	Higher WHO

c) PHYSICO-CHEMICAL PARAMETERS OF DRY SEASON, 2010 IN KHASTE LAKE

Sampling Date: 2066/12/12

Sampling Time: 2:45 pm

S. No.	Parameters	Sampling sites			WHO guidelines	Remarks
		Forestland (western)	Human disturbance (southern)	Outlet		
1.	Temperature	28	30	30	-	-
2.	pH	6.90	6.80	7.10	6.5-8.5	Falls within the WHO values
3.	Conductivity	040	036	038	20-30 ms/cm	Higher than WHO values
4.	Dissolved Oxygen (mg/L)	6.49	9.73	6.49	5 mg/L	Meets WHO values
5.	Total alkalinity (mg/L)	30	30	70	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	30	30	70	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	18	12	46	<75 mg/L	Soft
a)	Ca-hardness as $CaCO_3$ (mg/L)	10	6	18	-	-
b)	Mg-hardness as $CaCO_3$ (mg/L)	8	6	28	-	-
7.	Free CO_2 (mg/L)	13.20	13.20	8.80	<10 mg/L	Slightly higher than WHO values except outlet
8.	Chloride (mg/L)	9.94	11.36	11.36	250 mg/L	Lower than WHO values
9.	BOD_5 (mg/L)	314.50	486.60	324.50	<50 mg/L	Much higher than MOEST values
10.	Total solids (mg/L)	400	1000	400	500 mg/L	Below WHO values than HD
11.	Orthophosphate (mg/L)	0.02	0.06	0.04	0.02 mg/L	Slightly higher than WHO values
12.	Ammonia (mg/L)	0.01	0.03	0.02	1.5 mg/L	Less than WHO values
13.	Nitrate (mg/L)	1.05	1.08	1.11	50 mg/L	Less than WHO values
14.	Iron (mg/L)	1.59	1.35	1.56	0.3 mg/L	Much higher than WHO values

d) PHYSICO-CHEMICAL PARAMETERS OF RAINY SEASON, 2010 IN GUNDE LAKE

Sampling Date: 2067/4/18

Sampling Time: 9: 30 am

S. No.	Parameters	Sampling sites			WHO guidelines, 1993	Remarks
		Inlet/ Forestland	Outlet	Human disturbance		
1.	Temperature	24	27	28	-	-
2.	pH	7.23	7.26	7.33	6.5-8.5	Falls within WHO values
3.	Conductivity	027	025	026	20-30 ms/cm	High than WHO values

4.	Dissolved Oxygen (mg/L)	5.27	4.87	3.65	5 mg/L	Below WHO values
5.	Total alkalinity (mg/L)	20	20	10	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	20	20	10	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	20	24	20	<75 mg/L	Soft
a)	Ca-hardness as $CaCO_3$ (mg/L)	4	16	8	-	-
b)	Mg- hardness as $CaCO_3$ (mg/L)	16	8	12	-	-
7.	Free CO_2 (mg/L)	26.40	17.60	22	<10 mg/L	Higher than WHO values
8.	Chloride (mg/L)	39.76	34.08	42.60	<250mg/L	Less than WHO values
9.	BOD_5 (mg/L)	16.20 (Human disturbance)			6 mg/L	High than WHO value
10.	COD (mg/L)	60			10 mg/L	High than WHO value
11.	Total solids (mg/L)	1540	3300	4440	1000 mg/L	Higher than WHO values
12.	Orthophosphate (mg/L)	0.07	0.06	0.05	0.02 mg/L	Higher than WHO value
13.	Ammonia (mg/L)	0.31	0.06	0.90	1.5 mg/L	Less than WHO values
14.	Nitrate (mg/L)	0.55	0.67	0.81	10 mg/L	Less than WHO values
15.	Iron (mg/L)	0.44	0.44	0.48	0.3 mg/L	Higher than WHO value

e) PHYSICO-CHEMICAL PARAMETERS OF RAINY SEASON, 2010 IN NEURENI LAKE

Sampling Date: 2067/4/18

Sampling Time: 12:15 pm

S. No.	Parameters	Sampling sites			WHO guidelines, 1993	Remarks
		Inlet/ Forestland	Near agricultural land (southern part)	Outlet		
1.	Temperature	20	26	26	-	-
2.	pH	7.50	7.33	7.27	6.5-8.5	Meets the WHO values
3.	Conductivity	027	043	067	20-30 ms/cm	More than WHO values
4.	Dissolved Oxygen (mg/L)	6.48	4.86	4.86	5 mg/L	Does not meet WHO values
5.	Total alkalinity (mg/L)	20	20	30	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	20	20	30	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	20	36	40	<75 mg/L	All soft water except outlet
a)	Ca- hardness as $CaCO_3$ (mg/L)	8	10	16	-	-
b)	Mg- hardness as	12	26	24	-	-

	$CaCO_3$ (mg/L)					
7.	Free CO_2 (mg/L)	26.40	13.20	22	<10 mg/L	Greater than WHO values
8.	Chloride (mg/L)	39.76	48.28	39.76	250 mg/L	Lower than WHO
9.	BOD_5 (mg/L)	8.10 (Agricultural)			6 mg/L	More than WHO value
10.	COD (mg/L)	20			10 mg/L	More than WHO value
11.	Total solids (mg/L)	1960	2860	1480	1000 mg/L	Much higher than WHO values
12.	Orthophosphate (mg/L)	0.09	0.07	0.09	0.02 mg/L	Higher than WHO values
13.	Ammonia (mg/L)	0.60	0.10	0.42	1.5 mg/L	Less than WHO values
14.	Nitrate (mg/L)	0.67	0.66	0.68	10 mg/L	Less than WHO values
15.	Iron (mg/L)	0.46	0.54	0.48	0.3 mg/L	Higherthan WHO values

f) PHYSICO-CHEMICAL PARAMETERS OF RAINY SEASON, 2010 IN KHASTE LAKE

Sampling Date: 2067/4/18

Sampling Time: 2:45 pm

S. No.	Parameters	Sampling sites			WHO guidelines, 1993	Remarks
		Forestland (western)	Human disturbance (southern)	Outlet		
1.	Temperature	27	27	26	-	-
2.	pH	7.31	7.34	7.38	6.5-8.5	Falls within the WHO values
3.	Conductivity	035	036	027	20-30 ms/cm	Higher than WHO value
4.	Dissolved Oxygen (mg/L)	5.67	5.27	4.86	5 mg/L	Less than WHO value
5.	Total alkalinity (mg/L)	10	40	10	(20-200) mg/L	Falls within WHO value
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	10	40	10	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	12	32	6	<75 mg/L	Soft
a)	Ca- hardness as $CaCO_3$ (mg/L)	8	16	4	-	-
b)	Mg- hardness as $CaCO_3$ (mg/L)	4	16	2	-	-
7.	Free CO_2 (mg/L)	17.60	30.80	26.40	<10mg/L	Higher than WHO value
8.	Chloride (mg/L)	48.28	39.76	45.44	250mg/L	Low than WHO value
9.	BOD_5 (mg/L)	27.34 (Outlet)			6 mg/L	Much higher than WHO values
10.	COD (mg/L)	80			10 mg/L	Much higher than WHO value
11.	Total solids (mg/L)	860	560	820	1000 mg/L	Below WHO value
12.	Orthophosphate (mg/L)	0.08	0.21	0.10	0.02 mg/L	Slightly higher than WHO values
13.	Ammonia (mg/L)	0.59	0.69	0.67	1.5 mg/L	Less than WHO values

14.	Nitrate (mg/L)	0.60	0.88	0.64	10 mg/L	Less than WHO values
15.	Iron (mg/L)	0.45	0.47	0.46	0.3 mg/L	Higher than WHO value

g) PHYSICO-CHEMICAL PARAMETERS OF DRY SEASON, 2011 IN GUNDE LAKE

S No.	Parameters	Sampling sites				WHO guidelines, 1993	Remarks
		Inlet/ Forestland	Outlet	Agricultural land	Human disturbance		
1.	Temperature	25	27	26	27	-	-
2.	pH	7.60	7.50	7.40	7.70	6.5-8.5	Falls within the WHO values
3.	Conductivity	078	091	081	256	20-30 ms/cm	High than WHO values
4.	Dissolved Oxygen (mg/L)	6.48	5.27	4.87	5.27	5 mg/L	Meets WHO values
5.	Total alkalinity (mg/L)	40	50	30	30	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	40	50	30	30	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	60	63	28	66	<75 mg/L	Soft
a)	Ca- hardness as $CaCO_3$ (mg/L)	2.41	5.61	5.61	2.41	-	-
b)	Mg- hardness as $CaCO_3$ (mg/L)	57.59	57.39	22.39	63.59	-	-
7.	Free CO_2 (mg/L)	15.40	17.60	13.20	11	<10 mg/L	Higher WHO values
8.	Chloride (mg/L)	28.4	22.72	34.08	31.24	250 mg/L	Higher than WHO values
9.	BOD_5 (mg/L)	12.15				<6 mg/L	Higher WHO value
10.	COD (mg/L)	64				<10mg/L	Higher WHO value
11.	Orthophosphate (mg/L)	0.21	0.16	0.02	0.01	0.02 mg/L	Higher WHO value except agri & hd sites
12.	Ammonia (mg/L)	0.08	0.03	0.06	0.00	1.5 mg/L	Less than WHO values
13.	Nitrate (mg/L)	2.68	0.72	3.42	0.25	10 mg/L	Less than WHO values
14.	Iron (mg/L)	1.86	1.47	0.78	0.96	0.3 mg/L	Higher WHO value

h) PHYSICO-CHEMICAL PARAMETERS OF DRY SEASON, 2011 IN NEURENI LAKE

S No.	Parameters	Sampling sites			WHO guidelines, 1993	Remarks
		Inlet/ Forestland	Near agricultural(southern part)	Outlet		
1.	Temperature	27	27.50	28.50	-	-
2.	pH	7.40	7.70	7.30	6.5-8.5	Meets the WHO values
3.	Conductivity	134	058	285	20-30 ms/cm	More than WHO values
4.	Dissolved Oxygen (mg/L)	6.48	4.86	3.27	5 mg/L	Does not meet WHO values except in inlet
5.	Total alkalinity (mg/L)	90	30	110	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	90	30	110	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	80	44	126	<75 mg/L	All soft water except outlet
a)	Ca- hardness as $CaCO_3$ (mg/L)	20.84	9.62	41.68	-	-
b)	Mg- hardness as $CaCO_3$ (mg/L)	59.16	34.38	84.32	-	-
7.	Free CO_2 (mg/L)	19.80	13.20	19.80	<10 mg/L	Greater than WHO values
8.	Chloride (mg/L)	17.04	24.14	26.98	250 mg/L	Lower than WHO values
9.	BOD_5 (mg/L)	10.13 (Agricultural)			<6 mg/L	Higher than WHO value
10.	COD (mg/L)	15.60			<10mg/L	High than WHO
11.	Orthophosphate (mg/L)	0.03	0.08	0.09	0.02 mg/L	High WHO
12.	Ammonia(mg/L)	0	0	0	1.5 mg/L	Low WHO value
13.	Nitrate (mg/L)	0.71	0.23	0.51	10 mg/L	Less than WHO
14.	Iron (mg/L)	0.61	1.27	1.55	0.3 mg/L	High WHO value

i) PHYSICO-CHEMICAL PARAMETERS OF DRY SEASON, 2011 IN KHASTE LAKE

S. No.	Parameters	Sampling sites			WHO guidelines, 1993	Remarks
		Forestland (western)	Human disturbance (southern)	Outlet		
1.	Temperature	28	29	28	-	-
2.	pH	7.70	7.40	7.20	6.5-8.5	Falls within the WHO values
3.	Conductivity	044	030	046	20-30	Higher than WHO value

					ms/cm	
4.	Dissolved Oxygen (mg/L)	4.86	4.86	5.27	5 mg/L	Less than WHO value except in outlet
5.	Total alkalinity (mg/L)	10	35	25	(20-200) mg/L	Falls within WHO value
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	10	35	25	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	86	32	60	<75 mg/L	Soft
a)	Ca- hardness as $CaCO_3$ (mg/L)	5.61	3.21	4.01	-	-
b)	Mg- hardness as $CaCO_3$ (mg/L)	80.39	28.79	55.99	-	-
7.	Free CO_2 (mg/L)	15.40	15.40	6.60	<10 mg/L	Higher than WHO value
8.	Chloride (mg/L)	21.30	14.20	19.88	250 mg/L	Low than WHO value
9.	BOD_5 (mg/L)	16.20 (Outlet)			<6mg/L	Higher WHO values
10.	COD (mg/L)	76			<10mg/L	Higher than WHO
11.	Orthophosphate (mg/L)	0.28	0.08	0.06	0.02 mg/L	Slightly higher than WHO values
12.	Ammonia (mg/L)	0	0.00	0.01	1.5 mg/L	Less than WHO values
13.	Nitrate (mg/L)	1.88	0.43	0.33	10 mg/L	Less than WHO values
14.	Iron (mg/L)	2.09	1.57	1.62	0.3 mg/L	Higher than WHO value

j) PHYSICO-CHEMICAL PARAMETERS OF RAINY SEASON, 2011 IN GUNDE LAKE

S No.	**Parameters**	**Sampling sites**					**WHO guidelines, 1993**	**Remarks**
		Inlet/ Forestland	**Centre**	**Outlet**	**Agricultural land**	**Human disturbance**		
1.	Temperature	26	29.5	29	27	29	-	-
2.	pH	8.20	7.70	7.40	8.50	7.70	6.5-8.5	Falls within the WHO values
3.	Conductivity	32	34	35	150	38	20-30 ms/cm	High than WHO values
4.	Dissolved Oxygen (mg/L)	8.40	5.40	6.50	6	5.80	5 mg/L	Meets WHO values
5.	Total alkalinity (mg/L)	15	15	20	60	20	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0		0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0		0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	15	15	20	60	20	-	-
6.	Total hardness	18	25	22	71	17	<75 mg/L	Soft

	as $CaCO_3$ (mg/L)							
a)	Ca- hardness as $CaCO_3$ (mg/L)	3.31	4.41	4.41	23.25	4.41	-	-
b)	Mg- hardness as $CaCO_3$ (mg/L)	14.79	20.59	17.59	47.75	12.59	-	-
7.	Free CO_2 (mg/L)	35.20	17.60	19.80	11	22	<10 mg/L	Higher than WHO values
8.	Chloride (mg/L)	17.04	25.56	24.14	28.40	19.80	250 mg/L	Lower than WHO values
9.	BOD_5 (mg/L)	14.40					<6 mg/L	Higher than WHO value
10.	COD (mg/L)	56					<10mg/L	Higher than WHO value
11.	Orthophosphate (mg/L)	0.06	0.16	0.11	0.17	0.09	0.02 mg/L	Higher than WHO value
12.	Ammonia (mg/L)	0	0.01	0.18	2.10	2.10	1.5 mg/L	Less than WHO values
13.	Nitrate (mg/L)	2.77	2.84	2.84	3.20	2.77	10 mg/L	Less than WHO values
14.	Iron (mg/L)	0.93	0.93	1.02	1.30	0.93	0.3 mg/L	Higher than WHO value

k) PHYSICO-CHEMICAL PARAMETERS OF RAINY SEASON, 2011 IN NEURENI LAKE

S. No.	Parameters	Sampling sites			WHO guidelines, 1993	Remarks
		Inlet/ Forestland	Near agricultural land (southern part)	Outlet		
1.	Temperature	27	32	31	-	-
2.	pH	7.0	8.40	7.60	6.5-8.5	Meets the WHO values
3.	Conductivity	15	66	64	20-30 ms/cm	More than WHO values except inlet
4.	Dissolved Oxygen (mg/L)	6.60	6.10	6.20	5 mg/L	Meets WHO values
5.	Total alkalinity (mg/L)	5	35	40	(20-200) mg/L	Falls within WHO values
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	5	35	40	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	14	34	35	<75 mg/L	All soft water except outlet
a)	Ca- hardness as $CaCO_3$ (mg/L)	1.60	10.42	9.62	-	-
b)	Mg- hardness	12.40	23.58	25.38	-	-

	as $CaCO_3$ (mg/L)					
7.	Free CO_2 (mg/L)	30.80	11	6.60	<10 mg/L	Greater than WHO values except outlet
8.	Chloride (mg/L)	15.62	18.46	18.46	250 mg/L	Lower than WHO values
9.	BOD_5 (mg/L)	16.40 (Agricultural)			<6 mg/L	Higher than WHO value
10.	COD (mg/L)	19.60			<10mg/L	High than WHO
11.	Orthophosphate (mg/L)	0.02	0.16	0.11	0.02 mg/L	Higher than WHO values
12.	Ammonia (mg/L)	0.15	0.11	0.03	1.5 mg/L	Less WHO values
13.	Nitrate (mg/L)	2.77	2.64	2.84	10 mg/L	Less WHO values
14.	Iron (mg/L)	1.44	1.63	1.35	0.3 mg/L	High WHO values

l) PHYSICO-CHEMICAL PARAMETERS OF RAINY SEASON, 2011 IN KHASTE LAKE

S. No.	Parameters	Sampling sites			WHO guidelines, 1993	Remarks
		Forestland (western)	Human disturbance (southern)	Outlet		
1.	Temperature	34	33	29	-	-
2.	pH	6.70	7.60	7.60	6.5-8.5	Falls within the WHO values
3.	Conductivity	026	021	018	20-30 ms/cm	Higher than WHO value
4.	Dissolved Oxygen (mg/L)	6.50	5.50	7.20	5 mg/L	High than WHO value
5.	Total alkalinity (mg/L)	20	25	20	(20-200) mg/L	Falls within WHO value
a)	Hydroxide alkalinity (mg/L)	0	0	0	-	-
b)	Carbonate alkalinity (mg/L)	0	0	0	-	-
c)	Bicarbonate alkalinity (mg/L)	20	25	20	-	-
6.	Total hardness as $CaCO_3$ (mg/L)	12	13	3	<75 mg/L	Soft
a)	Ca- hardness as $CaCO_3$ (mg/L)	4.41	2.00	0.80	-	-
b)	Mg- hardness as $CaCO_3$ (mg/L)	7.59	11	2.20	-	-
7.	Free CO_2 (mg/L)	8.80	13.20	11	<10 mg/L	Higher than WHO value except forestland
8.	Chloride (mg/L)	34.08	32.66	29.82	250 mg/L	Lower than WHO value
9.	BOD_5 (mg/L)	17.20 (Outlet)			<6mg/L	High than WHO values
10.	COD (mg/L)	64			<10mg/L	Higher than WHO
11.	Orthophosphate (mg/L)	0.06	0.16	0.09	0.02 mg/L	High than WHO values
12.	Ammonia (mg/L)	0.03	0.16	0.12	1.5 mg/L	Less than WHO values
13.	Nitrate (mg/L)	2.77	2.77	3.12	10 mg/L	Less than WHO values
14.	Iron (mg/L)	4.66	1.40	1.28	0.3 mg/L	High than WHO value

2) **ANNEX II:** Average values of physico-chemical parameters at five sampling sites with standard deviation. Values are in mg/l except for pH, conductivity and temperature. (Mean ± standard deviation)

Sr. No.	Lakes name	SNo	Parameters	Seasons (Mean ± S.D)			
				Dry, 2010	**Rainy, 2010**	**Dry, 2011**	**Rainy, 2011**
1.	Gunde Lake	a)	pH	8.02 ± 0.12	7.27 ± 0.04	7.55 ± 0.11	7.90 ± 0.40
		b)	Temperature (^oC)	17.60 ± 0.49	26.33 ± 1.70	26.25 ± 0.83	28.10 ± 1.36
		c)	Conductivity (µs/cm)	35 ± 2.76	26 ± 0.82	126.50 ± 74.92	57.80 ± 46.14
		d)	DO (mg/L)	4.22 ± 1.95	4.59 ± 0.69	5.47 ± 0.60	6.42 ± 1.05
		e)	Free CO_2 (mg/L)	21.36 ± 0.87	22 ± 3.59	14.30 ± 2.46	21.12 ± 7.94
		f)	Total alkalinity (mg/L)	40 ± 8.94	16.67 ± 4.71	37.50 ± 8.29	26 ± 17.15
		g)	Chloride (mg/L)	13.63 ± 0.69	38.81 ± 3.54	29.11 ± 4.20	23.86 ± 3.75
		h)	Total Hardness as $CaCO_3$ (mg/L)	19.20 ± 9.00	21.33 ± 1.89	54.25 ± 15.30	30.60 ± 20.40
		i)	Ca-Hardness as $CaCO_3$ (mg/L)	7.20 ± 2.40	9.33 ± 4.99	4.01 ± 1.60	7.94 ± 7.67
		j)	Mg-Hardness as $CaCO_3$ (mg/L)	12 ± 7.15	12 ± 3.27	50.24 ± 16.27	22.66 ± 12.83
		k)	BOD_5 (mg/L)	12.98 ± 8.66	16.20	12.15	14.40
		l)	COD (mg/L)	52 ± 14.14	60	64	56
		M	O-PO_4^{2-}(mg/L)	0.10 ± 0.05	0.06 ± 0.01	0.10 ± 0.08	0.12 ± 0.04
		n)	Ammonia (mg/L)	0.04 ± 0.05	0.42 ± 0.35	0.04 ± 0.03	0.87 ± 1.00
		o)	Nitrate (mg/L)	0.82 ± 0.19	0.67 ± 0.10	1.77 ± 1.32	2.89 ± 0.16
		p)	Iron (mg/L)	0.96 ± 0.50	0.45 ± 0.02	1.32 ± 0.37	1.02 ± 0.14
2.	Neureni Lake	a)	pH	7.87 ± 0.05	7.37 ± 0.10	7.47 ± 0.17	7.67 ± 0.57
		b)	Temperature (^oC)	19 ± 0.82	24 ± 2.83	27.67 ± 0.62	30 ± 2.16
		c)	Conductivity (µs/cm)	35.33 ± 1.25	45.67 ± 16.44	159 ± 94.34	48.33 ± 23.58
		d)	DO (mg/L)	5.41 ± 0.77	5.40 ± 0.76	4.87 ± 1.31	6.30 ± 0.22
		e)	Free CO_2 (mg/L)	36.67 ± 5.49	20.53 ± 5.49	17.60 ± 3.11	16.13 ± 10.52
		f)	Chloride (mg/L)	12.31 ± 2.68	42.60 ± 4.02	22.72 ± 4.18	17.51 ± 1.34
		g)	Total alkalinity (mg/L)	46.67 ± 12.47	23.33 ± 4.71	76.67 ± 33.99	26.67 ± 15.46
		h)	Total Hardness as $CaCO_3$ (mg/L)	66.67 ± 37.71	32 ± 8.64	83.33 ± 33.56	27.67 ± 9.67
		i)	Ca- Hardness as $CaCO_3$ (mg/L)	14.67 ± 2.49	11.33 ± 3.40	24.05 ± 13.28	7.21 ± 3.98
		j)	Mg- Hardness as $CaCO_3$ (mg/L)	52 ± 35.37	20.67± 6.18	59.28 ± 20.39	20.45 ± 5.74
		k)	BOD_5 (mg/L)	13.52 ± 7.65	8.10	10.12	16.40
		l)	COD (mg/L)	22 ± 1.63	20	15.60	19.60

		M	$O\text{-}PO_4^{--}$(mg/L)	0.08 ± 0.03	0.08 ± 0.01	0.07 ± 0.03	0.97 ± 0.06
		n)	Ammonia (mg/L)	0.02 ± 0.03	0.37 ± 0.21	0.00 ± 0.00	0.10 ± 0.05
		o)	NO_3^- (mg/L)	1.03 ± 0.61	0.67 ± 0.01	0.49 ± 0.20	2.75 ± 0.09
		p)	Iron (mg/L)	0.53 ± 0.07	0.49 ± 0.03	1.14 ± 0.39	1.47 ± 0.12
3	Khaste Lake	a)	pH	6.93 ± 0.12	7.34 ± 0.03	7.43 ± 0.21	7.30 ± 0.42
		b)	Temperature (^oC)	29.33 ± 0.94	26.67 ± 0.47	28.33 ± 0.47	32 ± 2.16
		c)	Conductivity(µs/cm)	38 ± 1.63	32.67 ±4.03	40 ± 7.12	21.67 ± 3.30
		d)	DO (mg/L)	7.57 ± 1.53	5.27 ± 0.33	4.99 ± 0.19	6.40 ± 0.70
		e)	Free CO_2 (mg/L)	11.73 ± 2.07	24.93 ± 5.49	12.47 ± 4.15	11 ± 1.80
		f)	Total alkalinity (mg/L)	43.33 ± 18.86	20 ± 14.14	23.33 ± 10.27	21.67 ± 2.36
		g)	Chloride (mg/L)	10.89 ± 0.67	44.50 ± 3.54	18.46 ± 3.07	32.17 ± 1.77
		h)	Total Hardness as $CaCO_3$ (mg/L)	25.33 ± 14.82	16.67 ± 11.12	59.33 ± 22.05	9.33 ± 4.50
		i)	Ca- Hardness as $CaCO_3$ (mg/L)	11.33 ± 4.99	9.33 ± 4.99	4.27 ± 1.00	2.41 ± 1.50
		j)	Mg- Hardness as $CaCO_3$ (mg/L)	14 ± 9.93	7.33 ± 6.18	55.06 ± 21.07	6.93 ± 3.62
		k)	BOD_5 (mg/L)	31.09±13.38	27.34	16.20	17.20
		l)	COD (mg/L)	87.67 ± 2.05	80	76	64
		M	$O\text{-}PO_4^{2-}$ (mg/L)	0.04 ± 0.01	0.13 ± 0.05	0.14 ± 0.10	0.10 ± 0.04
		n)	Ammonia (mg/L)	0.02 ± 0.01	0.65 ± 0.04	0.00 ± 0.00	0.10 ± 0.05
		o)	NO_3^- (mg/L)	1.08 ± 0.02	0.71 ± 0.12	0.88 ± 0.71	2.89 ± 0.16
		p)	Iron (mg/L)	1.50 ± 0.11	0.46 ± 0.01	1.76 ± 0.23	2.44 ± 1.56

3) **ANNEX III:** Questionnaire for Baral Danda Lake Complex, Lekhnath Municipality

Household questionnaire for Baral Dada Complex in Lekhnath Municipality

Questionnaire No.: ____
Name of Respondent: ____________________
Name of Interviewer: ____________________ Date: ______________

SECTION A: GENERAL HOUSEHOLD INFORMATION

1. Are you the head of the household? (Respondent) 01 Yes____ 02 No_____
2. Sex- 01 Male ____, 02 Female______
3. How many persons are there in your household (i.e. persons that live here with you and share these households' resources?
   Male ____, Female______
4. How old are you? (i.e. age of the respondent): ___________ years.
5. Where were you born? *Check appropriate*
01 Same village [ ]
02 Same ward different village [ ]
03 Same district different ward [ ]
04 Same region different district [ ]
05 Other regions [ ]
6. If not born in this village when did you start living in this village? (Year)_________
7. How many household members left home to seek for employment elsewhere?
Male _____, Female _____

8. Please provide a list of all members of the households and relevant information on each from the table below:

No.	Name of household member	Relation to household head A1	Sex; 1 male, 2 female	Age	Place of birth-A2	Years lived in the village	Reason moving village-A3	Marital Status-A4	Religion A5	Education A6
1										
2										
3										
4										

9. Reasons for incomplete primary or secondary education of respondents.
____

10. Types of housing and flooring materials: (from observation)
01= all mud; 02= floor mud and wood walls; 03 = mud floor and brick walls; 04 = stone floor and brick walls; 05 = concrete type
11. Types of roofing materials: (from observation)
01 = straw; 02 = wood; 03 = tin; 04 = concrete flat
12. Throughout the year, what is your household member's main economic activity? Tick for the appropriate answer.

Activity	Tick	Activity	Tick
01 Crop Farming		08 Livestock Keeping	
Cash Crops		Dairy Cattle	
Food Crops		Local Cattle	
02 Mining/Quarrying		Sheep/goats	
03 Business/shop		Poultry	
04 Hunting		09 Firewood Selling	
05 Paid Employee		10 Logging Timber	
Government		11 Tailoring	
NGO		12 Fishing	
INGO		13 Tourism	
06 Plants Products Harvested		14 Not Active	
Reeds		Too old	
Grasses		Disabled	
Medicinal plants		Sick	
Wild food plants			
07 Animals harvested			

13What options do you think will be adopted by your household to increase level of income?
01…………………………………………
02………………………………………..
03……………………………………….
14. What kind(s) of fuel do you use for cooking?

Type	Firewood	Kerosene	Electricity	Biogas plant	Others
Rank					

CODE: Rank: 1= most used, then 2, 3 etc.
19. Now I would like to ask you some questions about water use in your household:

Sources / Questions	1) Private connections to piped water in House	2) Yard tap (shared connection)	3) Own source (specify) (well, borehole)	4) Village well	5) Water Vendors (specify) __ tanker, handcart, other)	6) Rivers or streams	7) Springs	8) Others Specify	Total
Which source of									

water do you use?									
What is the distance from water sources?									
Amount of water used from each source (no. of Gagri per day (Rs/gagri)									
Total amount spend on water: Pay nothing (0),Rs/day									
Time spend in collecting water: (mins/day) walking waiting, filling									

20. In the above table, you indicated that your household typically uses about _____________ gagri per day. Does this include all uses such as drinking, cooking, washing clothes and dishes, toilet use etc.? ____ (01) Yes, _____ (02) No

21. If no, How much does your household consume for all uses ___________L.
[1 big gagri = 20l, small gagri = 15 l]

22. What is the primary method you use to treat your water?
_________________ (01) None
_________________ (02) Boiling
_________________ (03) Filtering
_________________ (04) Setting
_________________ (05) Chemical treatment
_________________ (06) other, specify____________

SECTION B: EXTRACTION OF NATURAL RESOURCES FROM THE WETLANDS

24. Now, I would like to ask you some questions about your household's collection of natural products in and around the wetland area:

1		2	3	4	5		6		7	
On the last year, any collection […]from the village Com mons/ forest lands?1=Yes 2=No		Frequency of trip to collect […] in the last year	Duration to reach that area on average	Duration to collect once you reach?	How many […] did your hh collect?		On average, how much […] did your hh sell of the total collected from wetland?		How much […] did you buy from other households in the village or from the market?	
		Trip no. per month	Mins	Mins	Quantity	Value (Rs)	Quantity	Value (Rs)	Quantity	Value (Rs)
Firewood										
Grasses livestock										
Wood for timber/lg										
medicinal plants										
Reeds										
Thatching grasses										

SECTION C: CVM QUESTIONNAIRE FOR WETLAND CONSERVATION AT BARAL DANDA

Qn. 1) Are you aware of these benefits?
1) Yes
2) No
Qn.2) Do you enjoy these benefits from these three wetlands?
1) Yes
2) No
Despite all these benefits, the environmental integrity and status of these wetlands are increasingly threatened by indiscriminate use and sometimes abuse leading to their degradation, something that may result into these benefits disappearing forever.
Qn.3) Do you agree with this observations?
1) Yes
2) No
Bearing in mind that the wetlands are important to you in your everyday needs, its disappearance together with the goods and services it provides will have a negative impact on your household's livelihoods.
Qn.4) If Yes, what could be the reason behind the degradation in your opinion?..
Qn.5) As a stakeholder and a beneficiary of goods and services supplied by these wetlands, do you think the wetlands are worth conserving?
1) Yes
2) No
If the plan to stop degradation and enhance conservation is established involving the local government in collaboration with villagers, relevant government departments as well as some active local NGOs to manage the wetlands and carry out activities such as
1. Conservation of the wetland so that it continues to provide its important goods and services
2. Monitoring and planning for the sustainable utilization of the wetland
3. Rehabilitation of the wetland by carrying out various activities including tree planting. The wetlands will continue providing goods and services from which we enjoy. These benefits could be direct or indirect as mentioned above.
Qn.6) In order to facilitate conservation of these wetlands so as to sustain the services and benefits they offer to you, would you be willing to contribute toward this goal?
01) Yes 02) No
Qn.7) Whom would you prefer to collect your contribution?
1). The local government (District officers)
2). The village government.
3). Established fund board at the village
4). Other, (specify)____
5). Don't know
Qn.8) Where would you like the collection to be done?
1) In the village
2) Go to pay at the district
3) Others……………………………………………………………………………………………

A. Direct Benefits

1) For the direct benefits of wetlands that do not have market price, would you be willing to contribute some amount of money per year for conservation and implementing the above plans/activities?
a). Yes (Go to question 2)
b). No (Go to question 6)
c). Don't Know (Go to question 6)
2) If yes would you be willing to contribute Rs 500/ per year?
a. Yes (Go to question 3)
b. No (Go to Question 4)
c. Don't know (Go to Question 4)
3) Suppose your household would have to contribute Rs 1,000/= per year, would you be willing to contribute this amount?

a). Yes (Go to Question 5)
b). No (Go to question 5)
c). don't know (Go to question 5)
4) Suppose your household would have to contribute Rs 1/= per year for conservation, would you be willing to contribute this amount?
a). Yes
b). No (Go to 5)
c). Don't know (Go to 5)
5) What is the maximum amount that you are willing to contribute for conservation of wetlands for its direct benefits per year?
Rs _________
6) Which of these best describes your household unwillingness to pay decision?
a) Willing to pay, but not able
b) Able, but not willing to pay
c) Not able, not willing to pay
d) Others (specify) ______________________
Likewise, for other three values, the willingness to pay for wetland conservation is summarized below:

Values	Definitions	Willing to contribute? 01 Yes 02 No 03 don't know	Rs 1,000	Rs 5,000	Rs 500	Maximum amount	Reason for unwillingness	House hold decision
Indirect value	The benefits people derives indirectly from wetlands							
Option use value	Conservation of wetland resources for future use of the present generation							
Bequest value	The benefits we enjoy can be made available to the coming generation							

ANNEXES IV: Methodologies in physico-chemical characteristics of water

1. Temperature
The thermometer was dipped into the water sample and noted the reading. To minimize error, a care was made to calibrate the thermometer with another thermometer of known accuracy (Trivedi and Goel, 1987).
2. Conductivity
The conductivity meter was first calibrated with standard potassium chloride solution of 0.01N. The temperature was adjusted at 25ºC. Then the electrode was washed and rinsed a few times with distilled water and then dipped in the beaker containing the sample. The conductivity reading was noted down after the reading stabilized at the certain point.
3. pH (Potential Hydrogen)
The electrode rod is rinsed with distilled water and placed in buffer solution and set the pH meter with pH of buffer solution of different pH (pH 4 and 9.2). Beaker was filled with sample water then the dried electrode was dipped into the sample. Equilibrium between electrodes and sample was established by stirring sample to ensure homogeneity. Then the reading of pH meter was noted (APHA, 1995).
4. Free CO_2
100 ml of water sample was taken in a conical flask and added few drops of phenolphthalein indicator. If the color turns pink, free CO_2 is absent. When the water sample remained colorless, it was titrated against 0.05N sodium hydroxide till pink color appeared at the end point. It is calculated by the following equation (APHA, 1995).
Calculation

$$\text{Free CO2 (mg/L)} = \frac{\text{(ml x N) of NaOH x 1000}}{\text{Volume of sample t}}$$

Where, N = Normality of NaOH

5. DO

300ml of sample was taken in BOD bottle. Then, 2ml of Manganous sulphate solution was added followed by the addition of 2ml of alkaline KI solution. The formed precipitate was allowed to settle for 10 minute and 2ml conc. Sulphuric acid was added by the side of the bottle. It was thoroughly mixed and 50ml of the sample was titrated with 0.025N Sodium thiosulphate using 2 drops of starch as an indicator by the use of pipette until concurrent reading was obtained.

Calculation:

$$\text{Dissolved Oxygen (mg/L)} = \frac{\text{(ml x N) of titrant x 8 x 1000}}{V_2 (V_1 - V)/ V_1}$$

Where,

V_1 = volume of sample bottle after placing the stopper
V_2 = volume of the part of the contents titrated
V = volume of $MnSO_4$ and KI added
N = normality

6. BOD_5

Dilution water was prepared in a container by aerating with air in distilled water for about 30 minutes. 1 ml of each phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride solution for each liter of dilution water and mixed thoroughly. The water sample was neutralized to pH by using NaOH or H_2SO4. Two sets of the BOD bottles were filled with the diluted water sample. One set of bottles was stopped tightly, water sealed and incubated for 5 days at 20ºC in BOD incubator and DO was determined immediately for another set. DO was determined in the sample bottles immediately after the completion of 5 days of incubation. The BOD_5 is calculated by the following equation (APHA, 1995)

BOD_5 (mg/L) = ($DO-DO_5$) * Dilution factor. Where, DO = Initial DO & DO_5 = DO after 5 days

7. COD

It was determined in the lab by taking 20ml of sample in the reflux flask and 10ml of 0.25N Potassium Dichromate (K_2Cro_4) solution was added. Then a pinch of silver sulphate and 30ml sulphuric acid (H_2SO_4) was also added. Adding some anti-bumping agent it was reflux for 2 hrs. After 2 hrs it was cooled and the volume was made to 140ml by adding distilled water. Finally, it was titrated against 0.1N Ferrous Ammonium Sulphate solution in the presence of 2-3 drops of Ferroin indicator. Similar process was followed for the blank taking distilled water instead of sample.

Calculation:-

$$\text{COD (mg/L)} = \frac{\text{(B-A)} \times \text{Normality of Ferrous Ammonium Sulphate} \times 8}{\text{Volume of sample}} \times 1000$$

Where, A = sample titrated value
B = Blank titrated value

8. Chloride

50 ml of sample was taken in cleaned distilled water rinsed conical flask and added 2 ml of potassium chromate (K_2CrO_4) solution. Then it was titrated against 0.02N silver nitrate until a persistent red tinge appeared (Trivedi and Goel, 1987).

$$\text{Chloride (mg/L)} = \frac{\text{(A-B) x N x 100}}{\text{Volume of sample}} \qquad \text{(APHA, 1995)}$$

Where, A = ml titration for sample
B = ml titration for blank
N = normality of $AgNO_3$

9. Alkalinity as $CaCO_3$

For the determination of phenolphthalein alkalinity (PA), 100 ml of sample was taken in a conical flask and titrated against 0.1N hydrochloric acid (HCl) for 2 drops of phenolphthalein indicator till the disappearance of pink colour and the result was calculated as follows (APHA, 1995; Trivedi and Goel, 1987).

$$\text{PA as } CaCO_3 \text{ (mg/L)} = \frac{\text{(A x normality of HCl) x 1000 x 50}}{\text{Volume of sample taken}}$$

Where, A = volume of HCl used only with phenolphthalein

When the taken sample remained colourless after the addition of phenolphthalein indicator, PA = 0. Then total alkalinity (TA) was determined by adding 2-3 drops of methyl orange to the same sample and continued the titration further until the yellow colour changed into pink at end point. This is total alkalinity which is calculated as follows (APHA, 1995; Trivedi and Goel, 1987).

$$\text{TA as } CaCO_3 \text{ (mg/L)} = \frac{\text{(B x normality of HCl) x 1000 x 50}}{\text{Volume of sample taken}}$$

Where, B = total volume of HCl used with phenolphthalein and methyl orange

10. Total Hardness as $CaCO_3$

50 ml of water sample was taken in a clean conical flask. 2 ml of ammonia buffer solution was added and stirred through mixing. After this 200 mg of Eriochrome Black T indicator was added and shaken well, the solution becomes wine red. Then the sample was titrated against standard EDTA solution of 0.01M till the colour changed from wine red to blue marking the end point.

$$\text{Total Hardness as } CaCO_3 \text{ (mg/L)} = \frac{\text{ml of EDTA used x B x 1000}}{\text{Volume of sample taken}}$$

Where, B = mg $CaCO_3$ equivalent to 1.00 ml of 0.01M EDTA = 1

11. Calcium Hardness

50 ml of sample was taken in a clean distilled water rinsed conical flask and 2 ml of sodium hydroxide was added to adjust the pH to about 12-13. Then 200 mg of murexide (ammonium purpurate) indicator was added and the solution stirred on a magnetic stirrer. This treated sample was titrated with EDTA solution of 0.01M immediately until the pink colour changed to purple. The purple end point was also compared with the distilled water blank titration at the end point.

$$\text{Calcium Hardness as } CaCO_3 \text{ (mg/L)} = \frac{\text{ml of EDTA x B x 1000}}{\text{ml sample}}$$

Where, B = mg $CaCO_3$ equivalent to 1.00 ml EDTA of 0.01M

Magnesium Hardness (mg/L) = Total Hardness (as mg $CaCO_3$/L) – Calcium Hardness (as mg $CaCO_3$/L) x 0.243

12. Orthophosphate

50 ml of filtered water sample was taken in a volumetric flask. If water sample contains color & colloidal impurities, they can be removed by adding a spoonful of activated charcoal and then filtering the water sample. 2 ml of ammonium molybdate was added to water sample which was followed by 5 drops of stannous chloride solution. A blue color appeared. Reading was taken at 690 nm in spectrophotometer. The readings were taken after 10 minutes but before 12 minutes of the addition of the latest reagent using the same specific interval for all determinations.

13. Ammonia

25 ml sample was taken in a conical flask, 1 ml phenol solution, 1 ml sodium nitroprusside, and 2.5 ml of oxidizing solution were added to it thoroughly mixing after each addition. The mouth of conical flask was covered with plastic wraps and kept in dark for at least 1 hrs at r.t. to develop blue color. The absorbance of the color was measured using spectrophotometer at 635 nm using distilled water blank with same chemicals

14. Nitrate

50 ml of water sample containing not more than 1 mg/L of NO_3-N was taken in a conical flask. Then an equivalent amount of silver sulphate solution was added to remove chlorides. It was then heated slightly and the precipitate of silver chloride was filtered. Then the filtrate in the porcelain basin was evaporated to dryness. It was then cooled and the residue was dissolved in 2 ml phenol disulphonic acid and diluted to 50 ml. Then 6 ml of liquid ammonia was added which developed yellow colour. Similar process was done for blank distilled water. Then the absorbance was noted in spectrophotometer at 410 nm.

15. Total Iron

50 ml of filtered sample in conical flask, 2 ml of conc. HCl and 1 ml of hydeoxylamine was added. Also glass beads were added in same conical flask for the heat absorption. Then the content was boiled to half of the volume for dissolution of all the iron where iron reduced to ferrous state. This content was cooled & transferred to 100 ml volumetric flask after which 10 ml ammonium acetate buffer & 2 ml phenonthroline solution was added . Finally that volume was diluted up to 100 ml with distilled water, which was left for 10 minute to develop color. Same procedure was followed for blank also. Then absorbance of reagent blank and the sample was measured at wave length 510 nm by spectrophotometer reading after 10 minute.

ANNEX V

Table 1: Correlation matrix of Gunde lake

Gunde lake	pH	Temperature	EC	DO	Free CO_2	Total alkalinity as $CaCO_3$	Chloride	TH as $CaCO_3$	CaH as $CaCO_3$	MgH as $CaCO_3$	BOD_5	COD	OPO_4^{2-} - P	NH_4-N	NO_3^-	Fe
pH	1															
Temperature	-0.52	1														
EC	-0.08	0.34	1													
DO	0.15	0.76	0.45	1												
Free CO_2	0.17	-0.23	**-0.98**	-0.26	1											
Total alkalinity as $CaCO_3$	0.63	-0.62	0.48	-0.14	-0.51	1										
Chloride	**-0.96**	0.72	0.06	0.08	-0.10	-0.77	1									
TH as $CaCO_3$	-0.19	0.45	**0.99**	0.49	**-0.96**	0.36	0.19	1								
CaH as $CaCO_3$	-0.12	0.04	**-0.93**	-0.18	**0.95**	-0.76	0.22	-0.87	1							
MgH as $CaCO_3$	-0.15	0.40	**0.99**	0.46	**-0.98**	0.41	0.14	**0.99**	**-0.90**	1						
BOD_5	-0.51	0.37	-0.71	-0.07	0.72	**-0.96**	0.61	-0.61	**0.90**	-0.66	1					
COD	-0.77	0.66	0.69	0.25	-0.72	-0.20	0.76	0.77	-0.47	0.74	-0.05	1				
O-PO_4^{2-}-P	0.73	0.12	0.46	0.73	-0.30	0.50	-0.60	0.40	-0.44	0.41	-0.59	-0.20	1			
NH_4-N	0.05	0.64	-0.30	0.70	0.48	-0.66	0.22	-0.23	0.58	-0.28	0.60	-0.14	0.30	1		
NO_3^-	0.36	0.59	0.43	**0.97**	-0.23	0.02	-0.14	0.44	-0.22	0.42	-0.19	0.08	**0.86**	0.65	1	
Fe	0.48	-0.02	**0.83**	0.45	-0.77	0.79	-0.49	0.76	**-0.89**	0.79	**-0.92**	0.18	**0.80**	-0.27	0.55	1

Table 2: Correlation matrix of Neureni lake

Neureni lake	pH	Temperature	EC	DO	Free CO_2	Total alkalinity as $CaCO_3$	Chloride	TH as $CaCO_3$	CaH as $CaCO_3$	MgH as $CaCO_3$	BOD_5	COD	O-PO_4^{2-}P	NH_4-N	NO_3^-	Fe
pH	1															
Temperature	-0.43	1														
EC	-0.43	0.43	1													
DO	0.35	0.35	-0.65	1												
Free CO_2	0.71	**-0.94**	-0.45	-0.18	1											
Total alkalinity as $CaCO_3$	-0.00	0.02	**0.86**	-0.75	0.04	1										
Chloride	**-0.88**	0.08	-0.01	-0.22	-0.41	-0.35	1									
TH as $CaCO_3$	0.15	-0.27	0.70	**-0.80**	0.32	**0.96**	-0.40	1								
CaH as $CaCO_3$	-0.21	-0.08	**0.86**	**-0.90**	0.04	**0.96**	-0.09	**0.93**	1							
MgH as $CaCO_3$	0.27	-0.33	0.62	-0.74	0.41	**0.93**	-0.50	**0.99**	**0.88**	1						
BOD_5	0.77	0.22	-0.34	0.76	0.10	-0.20	**-0.80**	-0.22	-0.47	-0.12	1					
COD	0.60	-0.65	**-0.95**	0.47	0.70	-0.68	-0.15	-0.45	-0.68	-0.35	0.33	1				
O-PO_4^{2-}P	0.24	0.66	-0.29	**0.91**	-0.45	-0.46	-0.31	-0.62	-0.67	-0.58	**0.80**	0.09	1			
NH_4-N	-0.61	-0.05	-0.44	0.13	-0.23	-0.71	**0.90**	-0.70	-0.49	-0.75	-0.53	0.26	-0.10	1		
NO_3^-	0.41	0.49	-0.43	**0.95**	-0.26	-0.52	-0.41	-0.62	-0.74	-0.56	**0.87**	0.27	**0.98**	-0.13	1	
Fe	-0.08	**0.86**	0.62	0.18	-0.68	0.41	-0.36	0.15	0.22	0.13	0.42	-0.72	0.57	-0.54	0.44	1

Table 3: Correlation matrix of Khaste lake

Khaste lake	pH	Temp.	EC	DO	Free CO_2	Total alkalinity as $CaCO_3$	Chloride	TH as $CaCO_3$	Ca H as $CaCO_3$	Mg Has $CaCO_3$	BOD_5	COD	O-PO_4^{2-}-P	NH_4-N	NO_3^-	Fe
pH	1															
Temp.	-0.20	1														
EC	-0.17	-0.66	1													
DO	**-0.94**	0.52	-0.12	1												
Free CO_2	0.30	-0.78	0.049	-0.49	1											
Total alkalinity as $CaCO_3$	**-0.94**	0.11	0.44	**0.84**	-0.42	1										
Chloride	0.55	-0.25	-0.56	-0.52	0.77	-0.78	1									
TH as $CaCO_3$	0.31	-0.35	0.77	-0.44	-0.25	0.03	-0.53	1								
Ca H as $CaCO_3$	0.43	-0.37	0.72	-0.55	-0.18	-0.09	-0.42	**0.99**	1							
Mg H as $CaCO_3$	0.42	-0.23	0.65	-0.50	-0.31	-0.09	-0.48	**0.98**	**0.99**	1						
BOD_5	-0.76	-0.41	0.31	0.54	0.39	0.65	-0.08	-0.36	-0.43	-0.52	1					
COD	-0.60	-0.63	0.79	0.30	0.25	0.70	-0.40	0.23	0.15	0.05	**0.83**	1				
O-PO_4^{2-}-P	**0.99**	-0.36	-0.05	**-0.98**	0.41	**-0.91**	0.57	0.36	0.47	0.45	-0.65	-0.47	1			
NH_4-N	0.29	-0.61	-0.18	-0.42	**0.97**	-0.49	**0.87**	-0.44	-0.37	-0.48	0.35	0.09	0.38	1		
NO_3^-	0.02	**0.93**	**-0.88**	0.31	-0.52	-0.19	0.11	-0.53	-0.51	-0.38	-0.48	**-0.81**	-0.13	-0.32	1	
Fe	-0.00	**0.92**	-0.42	0.30	**-0.90**	0.05	-0.42	0.04	0.02	0.17	-0.64	-0.64	-0.16	**-0.80**	**0.80**	1

Annex VI: Photos

Plate 1: Luxuriant growth of macrophytes in rainy season in Khaste lake

Plate 2: Luxriant growth of macrophytes in rainy season in Neureni lake

Plate 3: Water sample collection in outlet of Gunde lake

Plate 4: Collection of Gastropod from the lake

Plate 5: Analysis of physico-chemical parameters in the study site by researcher

Plate 6: Analysis of physico-chemical parameters in CDES lab by researcher

Plate 7: Questionnaire survey

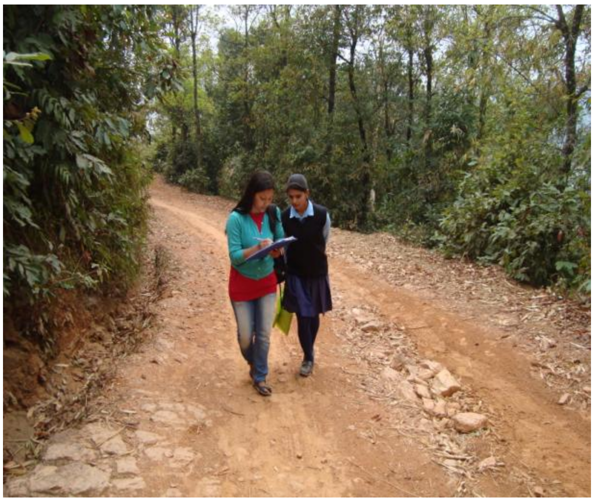


Plate 8: Interviewing school girl in BDLC

Plate 9: Local people getting ready for fishing in Khaste lake

Plate 10: A boy in Neureni lake

Plate 11: A boy catching fish from the lake

ANNEX VII: List of names of the respondents interviewed during questionnaire survey in Baral Danda Lake Complex

Date: 2067/12/4

Location: Baral Danda Lake Complex (Catchment areas of Gunde, Neureni and Khaste Lakes), Lekhnath Municipality, Kaski, Nepal.

S. No.	Names of respondents	Sex	Age
1.	Sabita Bastakoti	Female	14
2.	Pooja Poudel	Female	18
3.	Bam Dev Bastakoti	Male	73
4.	Sushmita Gahatraj	Female	13
5.	Kamala Dhungana	Female	30
6.	Nandakali Dhungana	Female	67
7.	Dhankumari Dhungana	Female	58
8.	Sunita Adhikari	Female	35
9.	Narayani Baral	Female	50
10.	Saraswati Dhungana	Female	33
11.	Bindeswari Baral	Female	32
12.	Geeta Adhikari	Female	38
13.	Gokarna Dahal	Male	39
14.	Thakur Prasad Bastakoti	Male	42
15.	Parbati Bastakoti	Female	44
16.	Laxmi Bastakoti	Female	26
17.	Hari Raj Adhikari	Male	43
18.	Hem Baral	Male	42
19.	Kalawati Lamichhane	Female	63
20.	Kabita Bastakoti	Female	14
21.	Meena Devi Dhungana	Female	38
22.	Nilkumari Timilsina	Female	65
23.	Ishwari Dhungana	Female	30
24.	Shusri Bhola Baral	Female	52
25.	Madhav Prasad Bhandari	Male	79
26.	Sumitra Biswakarma	Female	40
27.	Bishnu Lamichhane	Female	23
28.	Bhagawati Adhikari	Female	30
29.	Sita Biswakarma	Female	23
30.	Madhav Prasad Baral	Male	73
31.	Sita Tiwari	Female	46
32.	Purnakala Dhungana	Female	41
33.	Rajkumari Dhungana	Female	35
34.	Ramchandra Dhungana	Male	45
35.	Keshav Dhungana	Male	44
36.	Laxmi Baral	Female	38
37.	Tulsiram Lamichhane	Male	70
38.	Goma Lamichhane	Female	34

ANNEX VIII: Independent sample t-test

1) Gunde lake

a) Season wise

Group Statistics					
WQI	Season	N	Mean	Std. Deviation	Std. Error Mean
	1	8	42.2413	3.72776	1.31796
	2	7	32.1014	6.7644	2.5567

Independent Samples Test										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper
WQI	Equal variances assumed	7.903	0.015	3.663	13	0.003	10.13982	2.76786	4.16022	16.11942
	Equal variances not assumed			3.525	9.064	0.006	10.13982	2.87641	3.6399	16.63974

b) Year wise

Group Statistics					
WQI	**Year**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
	1	7	39.32	8.31085	3.14121
	2	8	35.925	6.52699	2.30764

Independent Samples Test										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper

WQI	Equal variances assumed	0.483	0.499	0.886	13	0.392	3.395	3.83189	-4.88329	11.67329
	Equal variances not assumed			0.871	11.382	0.402	3.395	3.89774	-5.14885	11.93885

2) Khaste lake

a) Season wise

Group Statistics					
WQI	**Season**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
	1	6	32.5217	3.05191	1.24594
	2	6	30.1383	2.93785	1.19937

Independent Samples Test										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
WQI	Equal variances assumed	0.002	0.97	1.378	10	0.198	2.38333	1.72941	-1.47002	6.23669
	Equal variances not assumed			1.378	9.986	0.198	2.38333	1.72941	-1.47078	6.23745

b) Year wise

Group Statistics					
WQI	**Year**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
	1	6	32.1167	2.83006	1.15537
	2	6	30.5433	3.44365	1.40587

Independent Samples Test										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
WQI	Equal variances assumed	0.563	0.47	0.865	10	0.408	1.57333	1.81971	-2.48123	5.62789
	Equal variances not assumed			0.865	9.638	0.408	1.57333	1.81971	-2.50195	5.64862

3) Neureni lake

a) Season wise

Group Statistics					
WQI	**Season**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
	1	6	45.2683	7.72602	3.15413
	2	6	40.7233	9.99482	4.08037

Independent Samples Test									
	Levene's Test for Equality of Variances		**t-test for Equality of Means**						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper

WQI	Equal variances assumed	0.955	0.351	0.881	10	0.399	4.545	5.15732	-6.94622	16.03622
	Equal variances not assumed			0.881	9.403	0.4	4.545	5.15732	-7.04586	16.13586

b) Year wise

Group Statistics					
WQI	**Year**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
	1	6	49.4733	4.59997	1.87793
	2	6	36.5183	7.07976	2.8903

Independent Samples Test										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
WQI	Equal variances assumed	0.784	0.397	3.759	10	0.004	12.955	3.4468	5.27505	20.63495
	Equal variances not assumed			3.759	8.583	0.005	12.955	3.4468	5.09966	20.81034

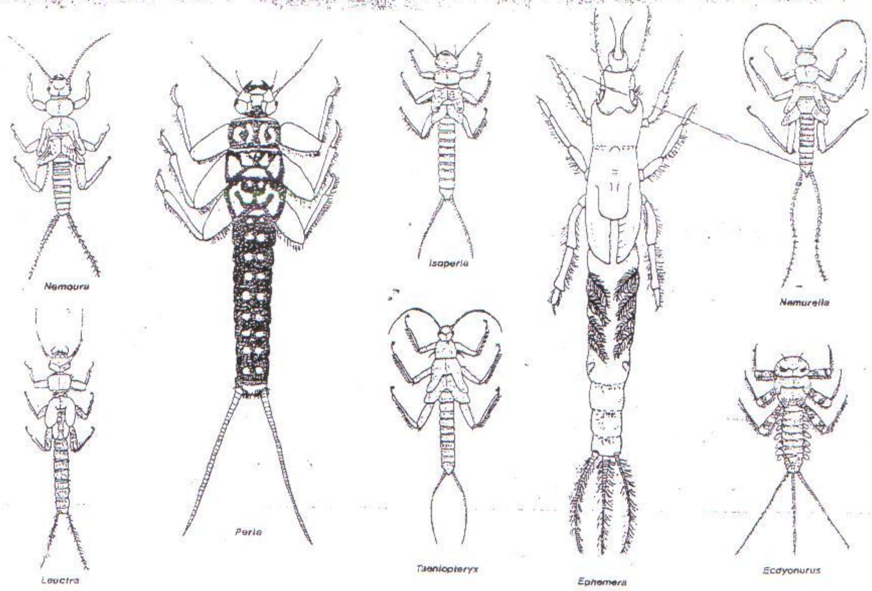


FIG. 6.10 Microinvertebrate animals commonly associated with various degrees of organic pollution. (A) Clean-water (sensitive) forms: (B) mild-pollution (less sensitive) forms: (C) moderate-pollution (relatively tolerant) forms: (D) severe-pollution (tolerant) forms.

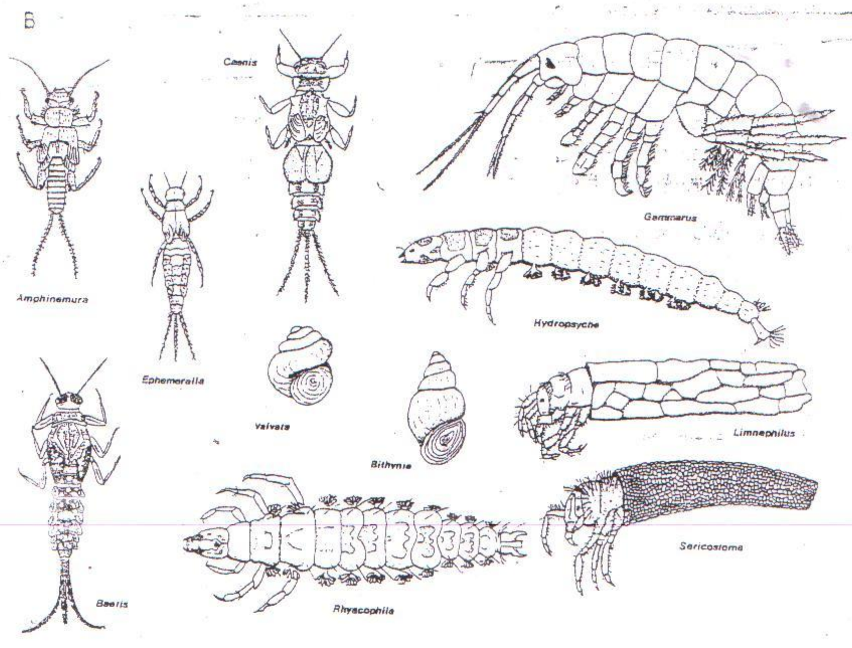


FIG. 6.10—*contd.*

polluted waters and *Helobdella stagnalis*. Tolerant molluscs include *Lymnaea peregra*, *Physa fontinalis* and *Sphaerium* spp.

Beyond the *Asellus*-zone, with further recovery, is the *Gammarus*-zone which may be regarded as the first stage in the return of a normal cleanwater fauna. Hawkes and Davies (1971) have observed that *Gammarus* is particularly sensitive to short periods of low oxygen (5 hr LC_{50} was 1 mg O_2 litre^{-1} at 20 °C), particularly at night when plant respiration may depress dissolved oxygen levels, and so may not become established even though oxygen levels, as indicated by daytime measurements, appear to be adequate. The *Gammarus* zone is characterised by an even greater diversity of macroinvertebrates than the *Asellus*-zone. The most important group along with *Gammarus* are the Trichoptera (caddis flies), followed, as the zone merges with the next, by Ephemeroptera (mayflies). Some species of Ephemeroptera are well adapted to coping with silty conditions (e.g. *Ephemera* and *Caenis*) and so can also survive the deposition of materials in organic effluents provided that oxygen levels are not too depressed.

The extent to which other groups, for example Plecoptera and some Coleoptera, will return depends on the type of river or stream. In upland eroding substrates these groups are part of the normal community but are less likely to occur in lowland streams and rivers, even when they are unaffected by pollution.

The responses of European invertebrates to degrees of organic enrichment, determined largely in terms of the Saprobien system, are indicated in Table 6.7. Similar tables, based on North American species (Table 6.8) and on the limited published data for other regions (Table 6.9) have also been compiled. It should be remembered that the limitations of 'indicator species', discussed in Section 3.2, apply to these compilations.

6.4.7 Fish

As with most of the other organisms considered above, the existence of fish populations below discharges of organic matter depends to a large extent on dissolved oxygen levels. However, the presence of ammonia in many effluents, especially sewage, may have a greater influence on the survival of viable fish populations since most fish are extremely sensitive to undissociated ammonia. When oxygen is adequate, coarse fish populations are able to survive even in undiluted sewage effluent (Allan *et al.* 1958, Alabaster 1959) ... substances present in sewage effluent which contain industrial ... domestic components, for example phen...

(4) cond.

	0	10	20	30	40	50	60	70	80	90
0	1.346	1.356	1.363	1.368	1.371	1.373	1.375	1.376	1.377	1.378
100	1.379	1.379	1.380	1.380	1.380	1.380	1.380	1.380	1.380	1.379
200	1.379	1.378	1.378	1.377	1.376	1.375	1.374	1.373	1.372	1.371
300	1.370	1.369	1.367	1.366	1.365	1.363	1.362	1.360	1.359	1.357
400	1.355	1.354	1.352	1.350	1.348	1.346	1.344	1.342	1.341	1.339
500	1.336	1.334	1.332	1.330	1.328	1.326	1.324	1.322	1.319	1.317
600	1.315	1.313	1.311	1.308	1.306	1.304	1.301	1.299	1.297	1.295
700	1.292	1.290	1.288	1.285	1.283	1.281	1.278	1.276	1.274	1.272
800	1.270	1.267	1.265	1.263	1.261	1.259	1.257	1.255	1.253	1.250
900	1.248	1.247	1.245	1.243	1.241	1.239	1.237	1.235	1.234	1.232
1000	1.230	1.228	1.227	1.225	1.224	1.222	1.220	1.219	1.217	1.216
1100	1.214	1.213	1.212	1.210	1.209	1.207	1.206	1.205	1.203	1.202
1200	1.201	1.199	1.198	1.197	1.195	1.194	1.193	1.192	1.191	1.189
1300	1.188	1.187	1.186	1.185	1.184	1.183	1.182	1.181	1.180	1.179
1400	1.178	1.178	1.177	1.176	1.176	1.175	1.175	1.175	1.175	1.175
1500	1.175									

(4) pH

	0.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3	0.0	0.930	1.006	1.042	1.073	1.100	1.124	1.147	1.168	1.189
4	1.208	1.226	1.244	1.261	1.278	1.294	1.309	1.325	1.339	1.354
5	1.368	1.382	1.396	1.409	1.422	1.435	1.447	1.460	1.472	1.484
6	1.495	1.507	1.518	1.529	1.540	1.550	1.560	1.568	1.574	1.579
7	1.583	1.585	1.585	1.585	1.584	1.581	1.576	1.571	1.563	1.554
8	1.543	1.531	1.518	1.505	1.492	1.479	1.466	1.452	1.438	1.424
9	1.409	1.395	1.380	1.364	1.349	1.333	1.317	1.300	1.283	1.266
10	1.249	1.231	1.213	1.195	1.176	1.157	1.138	1.119	1.099	1.078
11	1.057	1.034	1.009	0.988	0.943	0.887	0.85	0.79	0.7	0.6
12	0.0									

XIV

(5) NO_3-N

	0.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	1.585	1.583	1.581	1.578	1.576	1.574	1.572	1.570	1.567	1.565
1	1.563	1.560	1.558	1.555	1.553	1.550	1.548	1.545	1.542	1.540
2	1.537	1.534	1.531	1.528	1.525	1.522	1.519	1.516	1.513	1.510
3	1.507	1.503	1.500	1.497	1.493	1.489	1.486	1.482	1.477	1.473
4	1.469	1.465	1.461	1.456	1.452	1.448	1.443	1.439	1.435	1.430
5	1.426	1.422	1.417	1.413	1.408	1.404	1.400	1.395	1.391	1.387
6	1.382	1.378	1.374	1.370	1.366	1.361	1.357	1.354	1.350	1.346
7	1.342	1.339	1.335	1.332	1.329	1.326	1.323	1.320	1.318	1.315
8	1.313									

(6) o-PO_4-P

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	1.585	1.583	1.580	1.577	1.573	1.568	1.562	1.556	1.549	1.541
0.1	1.533	1.524	1.514	1.503	1.493	1.484	1.474	1.464	1.454	1.444
0.2	1.434	1.425	1.415	1.405	1.395	1.386	1.376	1.366	1.357	1.348
0.3	1.338	1.329	1.920	1.312	1.303	1.295	1.286	1.278	1.271	1.263
0.4	1.256	1.249	1.243	1.236	1.230	1.225	1.220	1.215	1.210	1.206
0.5	1.202	1.199	1.196	1.193	1.190	1.187	1.185	1.183	1.181	1.179
0.6	1.178	1.176	1.175	1.173	1.172	1.171	1.170	1.168	1.167	1.166
0.7	1.164	1.163	1.162	1.160	1.159	1.157	1.155	1.153	1.152	1.150
0.8	1.148	1.146	1.144	1.142	1.140	1.138	1.136	1.134	1.132	1.130
0.9	1.128	1.126	1.124	1.123	1.121	1.120	1.119	1.118	1.117	1.116
1.0	1.114	1.112	1.110	1.109	1.107	1.106	1.104	1.103	1.102	1.100
1.1	1.098	1.097	1.095	1.094	1.092	1.090	1.088	1.086	1.084	1.082
1.2	1.080	1.078	1.076	1.074	1.071	1.068	1.066	1.063	1.061	1.059
1.3	1.056	1.053	1.051	1.050	1.049	1.047	1.045	1.044	1.042	1.040

Appendix I: q_i^w value for each chemical parameter

(2)

[illegible]	[illegible]	1.130	1.152	1.158	1.167	1.181	1.199	1.219	1.241	1.263
10	1.286	1.308	1.330	1.351	1.371	1.391	1.410	1.429	1.446	1.464
20	1.480	1.497	1.513	1.528	1.544	1.559	1.574	1.589	1.604	1.620
30	1.635	1.650	1.666	1.681	1.697	1.713	1.729	1.745	1.762	1.779
40	1.796	1.813	1.830	1.847	1.865	1.882	1.900	1.918	1.935	1.953
50	1.971	1.988	2.006	2.023	2.041	2.050	2.075	2.092	2.109	2.125
60	2.141	2.157	2.173	2.189	2.204	2.219	2.234	2.248	2.262	2.276
70	2.290	2.303	2.315	2.328	2.340	2.351	2.363	2.374	2.384	2.394
80	2.404	2.413	2.422	2.431	2.439	2.447	2.455	2.462	2.469	2.476
90	2.482	2.489	2.495	2.500	2.506	2.512	2.512	2.512	2.512	2.512
100	2.512	2.512	2.512	2.512	2.512	2.512	2.510	2.507	2.505	2.502
110	2.500	2.497	2.494	2.491	2.488	2.485	2.482	2.479	2.475	2.472
120	2.468	2.465	2.461	2.457	2.453	2.449	2.444	2.440	2.436	2.431
130	2.426	2.421	2.417	2.412	2.406	2.401	2.396	2.391	2.386	2.380
140	2.374	2.369	2.363	2.358	2.352	2.346	2.341	2.335	2.329	2.324
150	2.318	2.312	2.307	2.302	2.296	2.291	2.286	2.281	2.276	2.272
160	2.267	2.263	2.259	2.255	2.252	2.249	2.246	2.243	2.241	2.239
170	2.237									

(1)

Temp. WT

	0.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	1.445									
10	1.445									
14	1.445	1.445	1.445	1.445	1.445	1.445	1.445	1.445	1.445	1.445
15	1.444	1.444	1.444	1.444	1.444	1.444	1.444	1.444	1.443	1.443
16	1.443	1.442	1.442	1.442	1.441	1.441	1.441	1.440	1.440	1.439
17	1.439	1.438	1.438	1.437	1.436	1.436	1.435	1.434	1.433	1.432
18	1.432	1.430	1.429	1.427	1.426	1.424	1.422	1.421	1.419	1.418
19	1.416	1.414	1.412	1.411	1.409	1.407	1.405	1.404	1.402	1.400
20	1.398	1.396	1.394	1.392	1.390	1.388	1.386	1.383	1.381	1.379
21	1.377	1.374	1.372	1.369	1.367	1.364	1.362	1.359	1.356	1.354
22	1.351	1.348	1.345	1.342	1.339	1.335	1.332	1.329	1.325	1.321
23	1.318	1.314	1.310	1.305	1.301	1.297	1.292	1.287	1.282	1.276
24	1.271	1.267	1.263	1.259	1.256	1.252	1.248	1.244	1.240	1.236
25	1.232	1.228	1.223	1.219	1.215	1.211	1.206	1.202	1.198	1.193
26	1.189	1.184	1.180	1.175	1.170	1.166	1.161	1.156	1.151	1.146
27	1.141	1.136	1.131	1.126	1.121	1.116	1.110	1.105	1.100	1.094
28	1.089	1.083	1.077	1.072	1.066	1.060	1.054	1.048	1.042	1.036
29	1.030	1.023	1.017	1.011	1.004	0.998	0.991	0.984	0.977	0.970
30	0.963	0.956	0.949	0.942	0.935	0.926	0.918	0.909	0.901	0.891
31	0.881	0.870	0.857	0.843	0.825	0.802	0.768	0.691		
32	0.0									

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.5	.6	.7	.8	.9
0	2.512	2.512	2.512	2.512	2.511	2.511	2.510	2.509	2.507	2.504
1	2.502	2.498	2.495	2.491	2.487	2.482	2.477	2.472	2.466	2.460
2	2.454	2.447	2.440	2.433	2.426	2.418	2.411	2.403	2.394	2.386
3	2.377	2.368	2.359	2.350	2.340	2.330	2.321	2.311	2.300	2.290
4	2.280	2.269	2.258	2.247	2.236	2.225	2.214	2.202	2.191	2.179
5	2.168	2.156	2.144	2.132	2.120	2.108	2.096	2.083	2.071	2.059
6	2.047	2.034	2.022	2.010	1.997	1.985	1.973	1.960	1.948	1.936
7	1.923	1.911	1.899	1.887	1.875	1.863	1.851	1.840	1.828	1.817
8	1.805	1.794	1.783	1.772	1.761	1.750	1.740	1.729	1.719	1.709
9	1.699	1.690	1.680	1.671	1.662	1.653	1.644	1.636	1.628	1.619
10	1.611	1.604	1.596	1.588	1.581	1.574	1.567	1.560	1.553	1.547
11	1.540	1.534	1.527	1.521	1.515	1.509	1.502	1.496	1.490	1.484
12	1.478	1.472	1.466	1.460	1.453	1.447	1.441	1.434	1.428	1.421
13	1.415	1.408	1.402	1.395	1.388	1.381	1.375	1.368	1.361	1.355
14	1.348	1.342	1.336	1.330	1.325	1.320	1.315	1.311	1.308	1.306
15	1.304									

(7)

NH_4-R

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.1	1.995	1.995	1.995	1.984	1.976	1.968	1.960	1.952	1.945	1.938
0.2	1.930	1.923	1.916	1.910	1.903	1.897	1.891	1.884	1.879	1.873
0.3	1.867	1.862	1.857	1.852	1.847	1.843	1.838	1.834	1.830	1.826
0.4	1.822	1.819	1.815	1.812	1.809	1.806	1.803	1.800	1.797	1.795
0.5	1.792	1.790	1.787	1.785	1.782	1.780	1.778	1.776	1.773	1.771
0.6	1.769	1.766	1.764	1.761	1.759	1.756	1.753	1.750	1.747	1.743
0.7	1.740	1.736	1.732	1.727	1.722	1.717	1.712	1.706	1.702	1.701
0.8	1.700	1.699	1.698	1.697	1.696	1.695	1.694	1.693	1.692	1.692
0.9	1.691	1.690	1.689	1.688	1.687	1.686	1.685	1.684	1.683	1.682

	0.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1	1.681	1.672	1.663	1.654	1.645	1.636	1.626	1.617	1.608	1.599
2	1.589	1.580	1.571	1.562	1.553	1.544	1.535	1.526	1.517	1.508
3	1.499	1.490	1.481	1.473	1.464	1.456	1.447	1.439	1.431	1.423
4	1.415	1.408	1.400	1.393	1.386	1.380	1.373	1.367	1.361	1.355
5	1.350	1.345	1.340	1.335	1.331	1.327	1.324	1.320	1.317	1.315
6	1.313	1.310	1.307	1.304	1.301	1.298	1.294	1.291	1.288	1.285
7	1.282	1.279	1.277	1.274	1.272	1.269	1.267	1.264	1.262	1.259
8	1.257	1.255	1.253	1.251	1.249	1.247	1.244	1.242	1.240	1.238
9	1.236	.	.	.	.	.	.	.	.	.

Appendix H: O_2 Saturation Value with reference to respective temperature

t^{0}C	0.0	0.1	0.2	0.3	0.4 mg O_2/l	0.5	0.6	0.7	0.8	0.9
0	14.15	14.12	14.08	14.04	14.00	13.97	13.93	13.89	13.85	13.81
1	13	13.74	13.70	13.66	13.63	13.59	13.55	13.51	13.48	13.44
2	13.40	13.37	13.33	13.30	13.26	13.22	13.19	13.15	13.12	13.08
3	13.05	13.01	12.98	12.94	12.91	12.87	12.84	12.81	12.77	12.74
4	12.70	12.57	12.64	12.60	12.57	12.54	12.51	12.47	12.44	12.41
5	12.37	12.34	12.31	12.28	12.25	12.22	12.18	12.15	12.12	12.09
6	12.06	12.03	12.00	11.97	11.94	11.91	11.88	11.85	11.82	11.79
7	11.76	11.73	11.70	11.67	11.64	11.61	11.58	11.55	11.52	11.50
8	11.47	11.44	11.41	11.38	11.36	11.33	11.30	11.27	11.25	11.22
9	11.19	11.16	11.14	11.11	11.08	11.06	11.03	11.00	10.98	10.95
10	10.92	10.90	10.87	10.85	10.82	10.80	10.77	10.75	10.72	10.70
11	10.67	10.65	10.62	10.60	10.57	10.55	10.53	10.50	10.48	10.45
12	10.43	10.40	10.38	10.36	10.34	10.31	10.29	10.27	10.24	10.22
13	10.20	10.17	10.15	10.13	10.11	10.09	10.06	10.04	10.02	10.00
14	9.98	9.95	9.93	9.91	9.89	9.87	9.85	9.83	9.81	9.78
15	9.76	9.74	9.72	9.70	9.68	9.66	9.64	9.62	9.60	9.58
16	9.56	9.54	9.52	9.50	9.48	9.46	9.45	9.43	9.41	9.39
17	9.37	9.35	9.33	9.31	9.30	9.28	9.26	9.24	9.22	9.20
18	9.18	9.17	9.15	9.13	9.12	9.10	9.08	9.06	9.04	9.03
19	9.01	8.99	8.98	8.96	8.94	8.98	8.91	8.89	8.88	8.86
20	8.84	8.83	8.81	8.79	8.78	8.76	8.75	8.73	8.71	8.70
21	8.68	8.67	8.65	8.64	8.62	8.61	8.59	8.58	8.56	8.55
22	8.53	8.52	8.50	8.49	8.47	8.46	8.44	8.43	8.41	8.40
23	8.38	8.37	8.36	8.34	8.33	8.32	8.30	8.29	8.27	8.26
24	8.25	8.23	8.22	8.21	8.19	8.18	8.17	8.15	8.14	8.13
25	8.11	8.10	8.09	8.07	8.06	8.05	8.04	8.02	8.01	8.00
26	7.99	7.97	7.96	7.95	7.94	7.92	7.91	7.90	7.89	7.88
27	7.86	7.85	7.84	7.83	7.82	7.81	7.79	7.78	7.77	7.76
28	7.75	7.74	7.72	7.71	7.70	7.69	7.68	7.67	7.66	7.65
29	7.64	7.62	7.61	7.60	7.59	7.58	7.57	7.56	7.55	7.54
30	7.53	7.52	7.51	7.50	7.48	7.47	7.46	7.45	7.44	7.43
31	7.42	7.41	7.40	7.39	7.38	7.37	7.36	7.35	7.34	7.33
32	7.32	7.31	7.30	7.29	7.28	7.27	7.26	7.25	7.24	7.23
33	7.22	7.21	7.20	7.20	7.19	7.18	7.17	7.16	7.15	7.14
34	7.13	7.12	7.11	7.10	7.09	7.08	7.07	7.06	7.05	7.05
35	7.04	7.03	7.02	7.01	7.00	6.99	6.98	6.97	6.96	6.95
36	6.94	6.94	6.93	6.92	6.91	6.90	6.89	6.88	6.87	6.86
37	6.86	6.85	6.84	6.83	6.82	6.81	6.80	6.79	6.78	6.77
38	6.76	6.76	6.75	6.74	6.73	6.72	6.71	6.70	6.70	6.69
39	6.68	6.67	6.66	6.65	6.64	6.63	6.63	6.62	6.61	6.60
40	6.59	6.58	6.57	6.56	6.56	6.55	6.54	6.53	6.52	6.51

Table 6.21 : Nepal's Drinking Water Quality Standards

Group	Parameter	Unit	Maximum Concentration Limits
Physical	Turbidity	NTU	5 (10)**
	pH		6.5-8.5*
	Color	TCU	5 (15)**
	Taste & Odor		Would not be objectionable
	Total Dissolved Solids	mg/l	1000
	Electrical Conductivity	µc/cm	1500
	Iron	mg/l	0.3 (3)**
	Manganese	mg/l	0.2
	Arsenic	mg/l	0.05
	Cadmium	mg/l	0.003
	Chromium	mg/l	0.05
	Cyanide	mg/l	0.07
	Fluoride	mg/l	0.5-1.5*
	Lead	mg/l	0.01
	Ammonia	mg/l	1.5
Chemical	Chloride	mg/l	250
	Sulphate	mg/l	250
	Nitrate	mg/l	50
	Copper	mg/l	1
	Total Hardness	mg/l	500
	Calcium	mg/l	200
	Zinc	mg/l	3
	Mercury	mg/l	0.001
	Aluminum	mg/l	0.2
	Residual Chlorine	mg/l	0.1-0.2*
Micro Germs	E-Coli	MPN/100ml	0
	Total Coli form	MPN/100ml	95 % in sample

Note : * These standards indicate the maximum and minimum limits.

** Figures in parenthesis are upper range of the standards recommended.

Source : Ministry of Physical Planning (Nepal Gazette (B.S. 2063/03/12)).

Table 6.22 : Nepal Water Quality Guidelines for Irrigation Water

Microbiological constituents:

S.N.	Parameter name	Target Water Quality Range	Remarks
1.	Coliforms(faecal)	< 1 count /100 ml	1 – 1000 count / 100 ml could be used for plants for which edible parts are not wetted.

Physical Constituents:

S.N.	Parameter name	Target Water Quality Range	Remarks
1	pH	6.5 – 8.5	Adverse effect on plants outside this range
2.	Suspended Solids	< 50 mg/l	Above the limit problem with sedimentation and irrigation system
3.	Electrical Conductivity	< 40 mS/m	Upto 540 mS/m depending upon sensitivity of crops.

Chemical Constituents:

S.N.	Parameter name	Target Water Quality Range	Remarks
1.	Aluminium	< 5 mg/l	Upto 20 mg/l max. acceptable conc.
2.	Arsenic	< 0.1 mg/l	> 2 mg/l creates severe problem
3.	Beryllium	< 0.1 mg/l	0.1 – 0.5 mg/l max. acceptable conc.
4.	Boron	< 0.5 mg/l	Upto 15 mg/l depending upon species.
5.	Cadmium	< 0.01 mg/l	0.01 – 0.05 mg/l max. acceptable conc.
6.	Chloride	< 100 mg/l	Upto 700 mg/l depending upon species
7.	Chromium	< 0.1 mg/l	Upto 1.0 mg/l max. acceptable conc.
8.	Cobalt	< 0.05 mg/l	Upto 5.0 mg/l max. acceptable conc.
9.	Copper	< 0.2 mg/l	Upto 5.0 mg/l max. acceptable conc.
10.	Fluoride	< 2.0 mg/l	Upto 15 mg/l max. acceptable conc.
11.	Iron	< 5.0 mg/l (non-toxic)	> 1.5 mg/l creates problem in drip irrigation system
12.	Lead	< 0.2 mg/l	Upto 2.0 mg/l max. acceptable conc.
13.	Lithium	< 2.5 mg/l	For citrus < 0.75 mg/l
14.	Manganese	< 0.02 mg/l	Upto 10 mg/l max. acceptable conc.
15.	Molybdenum	< 0.01 mg/l	Upto 0.05 mg/l max. acceptable conc.
16.	Nickel	< 0.2 mg/l	Upto 2.0 mg/l max. acceptable conc.
17.	Nitrogen (inorganic)	< 5 mg/l	Higher concentration may affect sensitive plants and may contaminate ground water
18.	Selenium	< 0.02 mg/l	Upto 0.05 mg/l max. acceptable conc.
19.	Sodium Adsorption Ratio (SAR)	< 2.0	Upto 10 depending upon sensitivity of crops.
20.	Sodium	< 70 mg/l	Upto 460 depending upon sensitivity of crops
21.	Total Dissolved Solids (as EC)	< 40 mS/m	Upto 540 mS/m depending upon sensitivity of crops
22	Uranium	< 0.01 mg/l	Upto 0.1 mg/l max. acceptable conc.
23.	Vanadium	< 0.1 mg/l	Upto 1.0 mg/l max. acceptable conc.
24.	Zinc	< 1.0 mg/l	Upto 5 mg/l max. acceptable conc.

Source : Department of Irrigation, Ground Water Project (Nepal Gazette (Number 10, B.S., 2065-03-02)).

Table 6.23 : Nepal Water Quality Guidelines for Aquaculture

S. N.	Constituents	Target Water Quality Range		Remarks
1	Algae	No criteria		
2	Alkalinity	20 – 100 mg/l as $CaCO_3$		High alkalinity reduces natural food production in ponds below optimal production
3	Aluminium	< 30µg/L (pH >6.5),		Highly toxic to trouts (1.5 µg/l is fatal to brown trout)
		< 10 µg/L (pH < 6.5)		
4	Ammonia (for cold water fish)	0 – 25 µg/L		
5	Ammonia (for warm water fish)	0 – 30 µg/L		
6	Arsenic	0 – 0.05 mg/l		
7	Bacteria (E. Coli)	< 10 counts of E.coli /g of fish flesh		
8	BOD_5	< 15 mg/l		
9	Cadmium	Hardness: 0– 60 mg/l	< 0.2 mg/l	Cadmium toxicity depends upon hardness of water
		Hardness: 60–120 mg/l	< 0.8 mg/l	
		Hardness: 120–180mg/l	< 1.3 mg/l	
		Hardness: >180 mg/l	< 1.8 mg/l	
10	Carbon dioxide	< 12 mg/l, upto 75 mg/l for warm water fish		
11	Chloride	Value not recommended (fish can survive at < 600 mg/l Chloride but the production is not optimum)		
12	Chlorine	< 2 µg HOCl /L for cold water fish		
		< 10 µg HOCl/L for warm water fish		
13	Chromium (VI)	< 20 µg/L		
14	COD	< 40 mg/l		
15	Colour	< 100 Pt-Co unit		
16	Copper	< 5 µg/L		0.006 and 0.03 µg/L are upper limits for hard and soft water
17	Cyanides	< 20 µg/L as HCN		LC_{50} starts from 100 µg/L upwards
18	Dissolved oxygen	6 – 9 mg/l for cold water species		
		5 – 8 for intermediate water species,		
		5 – 8 for warm water species.		
19	Fluoride	< 20 µg/l		
20	Iron	< 10 µg/l		0.2 - 1.75 general lethal threshold for fish
21	Lead	< 10 µg/l		30 µg/L max. conc. limit for brook trout
22	Magnesium	< 15 mg/l		
23	Manganese	< 100 µg/l		Above 500 µg/L increasing risk of lethal effect
24	Mercury	< 1 µg/l		Bioaccumulation and biomagnification occurs
25	Nickel	< 100 µg/l		
26	Nitrate-N	< 300 mg/l		1000 mg/l is below the 96-hour LC_{50} values for most fish
27	Nitrite-N	0 – 0.05 mg/l for cold water fish		> 7 mg/l is LC_{50} for many fish species
		0.06 - .25 mg/l for warm water fish		

Table 6.23 : Nepal Water Quality Guidelines for Aquaculture (contd…)

<table>
<tr><th>S. N.</th><th>Constituents</th><th colspan="2">Target Water Quality Range</th><th colspan="2">Remarks</th></tr>
<tr><td>28</td><td>Nuisance plants</td><td colspan="2">Less than 10 % of the fish pond should be covered by aquatic plants.</td><td colspan="2"></td></tr>
<tr><td>29</td><td>Oils and Greese (including Petrochemicals)</td><td colspan="2">< 300 µg/L</td><td colspan="2"></td></tr>
<tr><td>30</td><td>PCBs</td><td colspan="2">No quantitative guidelines, should not be detected in fish</td><td colspan="2"></td></tr>
<tr><td>31</td><td>pH</td><td colspan="2">6.5 – 9.0</td><td colspan="2">Outside this range the health of fish is adversely affected</td></tr>
<tr><td>32</td><td>Phenols</td><td colspan="2">< 1 mg/l</td><td colspan="2">> 7.5 mg/l 24 hr. LC_{50} starts for most fish</td></tr>
<tr><td>33</td><td>Phosphorus</td><td colspan="2">< 0.6 mg/l as orthophosphate</td><td colspan="2" rowspan="2">> 12.5 mg/l 96 hr. LC_{50} starts for most fish</td></tr>
<tr><td>34</td><td>Selenium (VI)</td><td colspan="2">< 0.3 mg/l</td></tr>
<tr><td>35</td><td>Sulphide as H_2S</td><td colspan="2">< 0.001 mg/l</td><td colspan="2">> 0.002 mg/l long term health hazard for fish</td></tr>
<tr><td rowspan="3">36</td><td rowspan="3">Temperature</td><td colspan="2">4 – 18 for cold water fish</td><td colspan="2" rowspan="5">Mortality increases with increasing TGP</td></tr>
<tr><td colspan="2">16 – 32 for intermediate species</td></tr>
<tr><td colspan="2">24 – 30 for warm water fish</td></tr>
<tr><td rowspan="2">37</td><td rowspan="2">Total Dissolved Gases as Total Gas Pressure (TGP)</td><td colspan="2">< 100 % for cold water fish</td></tr>
<tr><td colspan="2">< 105 % for warm water fish</td></tr>
<tr><td>38</td><td>Total Dissolved Solids</td><td colspan="2">< 2000 mg/l</td><td colspan="2"></td></tr>
<tr><td>39</td><td>Total Hardness as $CaCO_3$</td><td colspan="2">20 – 100 mg/l ,</td><td colspan="2">In > 175 mg/l osmoregulation of fish is affected.</td></tr>
<tr><td rowspan="2">40</td><td rowspan="2">Total Suspended Matter.</td><td colspan="2">< 20000 mg/l for turbid water species,</td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="2">< 25 NTU for clear water species</td></tr>
<tr><td>41</td><td>Zinc, depends upon water hardness: mg/l dissolved Zn</td><td>Hardness:</td><td>Coldwater</td><td>Warm water</td><td rowspan="5">Warm water fish are more tolerant</td></tr>
<tr><td rowspan="4"></td><td rowspan="4"></td><td>10 mg/l</td><td>0.03</td><td>0.3</td></tr>
<tr><td>50 mg/l</td><td>0.2</td><td>0.7</td></tr>
<tr><td>100 mg/l</td><td>0.3</td><td>1</td></tr>
<tr><td>500 mg/l</td><td>0.5</td><td>2</td></tr>
</table>

Pesticides: No guideline values provided.

Source : Department of Irrigation, Ground Water Project (Nepal Gazette (Number 10, B.S., 2065-03-02)).

Table 6.24 : Nepal Water Quality Guidelines for Livestock Watering

S.N.	Constituent	Proposed concentration
1.	Algae	No visible blue-green scum
2.	Aluminium	< 5 mg/l
3.	Arsenic	< 0.2 mg/l
4.	Beryllium	< 0.1 mg/l
5.	Boron	< 5 mg/l
6.	Cadmium	< 0.01 mg/l
7.	Calcium	< 1000 mg/l
8.	Chloride	
9.	Chromium (VI)	< 1 mg/l
10.	Cobalt	< 1 mg/l
11.	Copper	< 0.5 mg/l
12	Electrical Conductivity	< 1.5 dS/m
13.	Fluoride	< 2 mg/l
14.	pH	6.5 – 8.5
15.	Iron	Not Toxic
16.	Lead	< 0.1 mg/l
17.	Magnesium	< 500 mg/l
18.	Manganese	< 10 mg/l
19.	Mercury	< 10 µg/L
20.	Molybdenum	< 0.01 mg/l
21.	Nickel	< 1 mg/l
22.	Nitrate/Nitrite	< 100 mg/l as nitrate
23.	Nitrite – N	< 10 mg/l
24.	Selenium	< 0.05 mg/l
25.	Sodium	< 2000 mg/l
26.	Sulphate	< 1000 mg/l
27.	Total Dissolved Solids	
	Dairy Cattle	< 7100 mg/l
	Sheep	<12800 mg/l
	Horse	< 6400 mg/l
	Pigs	< 4300 mg/l
	Poultry	< 2800 mg/l
28.	Vanadium	< 0.1 mg/l (FAO)
29.	Zinc	< 24 mg/l (FAO)
Pathogens:		
1.	Faecal coliform count	< 200 count /100ml < 1000 counts for < 20 % of the samples
Pesticides: Guidelines applicable for human beings.		
Chlorinated Hydrocarbons: Guidelines for human beings apply.		

Source : Department of Irrigation, Ground Water Project (Nepal Gazette (Number 10, B.S., 2065-03-02))

Table 6.25 : Nepal Water Quality Guidelines for Recreation

Biological Parameters:

S.N.	**Parameter Name:**	**Full contact**	**Partial contact**	**Non contact**
1	Algae, macrophytes, phytoplankton scum, etc.	Should not be present in excessive amount		
Indicator Organism				
	Total coliform Bacteria			
	Faecal coliform	<130 count/100 ml	<1000 count/100ml	No target value
	Escherichia coli	<130 count/100 ml	No target value	No target value
	Entero cocci Faecal Streptococci	<30 count/100 ml	0 – 230 count/100 ml	No target value
	Coliphage	< 20 count/100 ml	No target value	No target value
	Schistosoma/ Bilharzia	No snails capable of acting as the intermediate host of the bilharzia parasite	No snails capable of acting as the intermediate host of the bilharzia parasite	No target value
Nuisance plants				
		Swimmer should not be entangled	Boats should not be entangled.	
Chemical Irritant				
The criteria are qualitative and no specific irritant and quantitative measures are given				
Chemical Parameters:				
	pH	6.5 – 8.5	6.5 – 8.5	No target value
Physical Parameters:				
1.	Clarity	> 1.6 (Sechchi disc depth Metres)	No target value	No target value
2.	Colour	100 Pt-Co units	100 Pt-Co units	No Target value
3.	Floating Matter and refuse	Free of floating or submerged debris	No target value	No target value
4.	Odour	No objectionable or unpleasant odour	No objectionable or unpleasant odour	No objectionable or unpleasant odour
5.	Residual Chlorine	0.1 mg/l	No target value	No target value
6.	Surface films	Should not be noticeable	Should not be noticeable	Should not be noticeable
7.	Turbidity	0.5 NTU		

Source : Department of Irrigation, Ground Water Project (Nepal Gazette (Number 10, B.S., 2065-03-02)).

Table 6.26 : Nepal Water Quality Guidelines for Industries

S. N.	Parameter Name:	Recommended value			
		Category 1	**Category 2**	**Category 3**	**Category 4**
1	Alkalinity	<50 mg/l	< 120 mg/l	< 300 mg/l	< 1200 mg/l
2	COD	< 10 mg/l	< 15 mg/l	< 30 mg/l	< 75 mg/l
3	Chloride	< 20 mg/l	< 40 mg/l	< 100 mg/l	< 500 mg/l
4	Iron	< 0.1 mg/l	< 0.2 mg/l	< 0.3 mg/l	< 10 mg/l
5	Manganese	< 0.05 mg/l	< 0.1 mg/l	< 0.2 mg/l	< 10 mg/l
6	pH	7.0 - 8.0	6.5 - 8.0	6.5 - 8.0	5 - 10
7	Silica	< 5 mg/l	0 - 10 mg/l	< 20 mg/l	< 150 mg/l
8	Sulphate	< 30 mg/l	< 80 mg/l	< 200 mg/l	< 500 mg/l
9	Suspended solids	< 3 mg/l	< 5 mg/l	< 5 mg/l	< 25 mg/l
10	Total dissolved solids	TDS: < 100 mg/l EC: < 15 mS/m	TDS: < 200 EC: < 30	TDS: < 450 EC: < 70	TDS: < 1600 EC: < 250
11	Total Hardness	< 50 mg/l as $CaCO_3$	< 100 mg/l as $CaCO_3$	< 250 mg/l as $CaCO_3$	< 1000 mg/l as $CaCO_3$

Source : Department of Irrigation, Ground Water Project (Nepal Gazette (Number 10, B.S., 2065-03-02)).

Table 6.27 : Nepal Water Quality Guidelines for the Protection of Aquatic Ecosystem

S.N.	Parameter name		Target Water Quality Range	Chronic Effect Value	Acute Effect Value
1.	Aluminium (mg/l)		At pH <6.5: 5	10	100
			At pH >6.5:10	20	150
2.	Ammonia (µg/L)		< 7	< 15	< 100
3.	Arsenic (µg/L)		< 10	< 20	< 130
4.	Atrazine (µg/L)		< 10	< 19	< 100
5.	Cadmium				
	Soft water	(60 mg/l $CaCO_3$)	< 0.15	0.3	3
	Medium water	(60 – 119 mg/l)	< 0.25	0.5	6
	Hard water	120 – 180 mg/l	< 0.35	0.7	10
	Very Hard	> 180 mg/l	< 0.40	0.8	13
6.	Chlorine (Residual) µg/L		< 0.2	0.35	5
7.	Chromium (VI) µg/L		7	10	200
8.	Chromium (III) µg/L		< 12	24	340
9.	Copper µg/L				
	Soft water	(60 mg/l $CaCO_3$)	< 0.3	0.53	1.6
	Medium water	(60 – 119 mg/l)	< 0.8	1.5	4.6
	Hard water	120 – 180 mg/l	< 1.2	2.4	7.5
	Very Hard	> 180 mg/l	< 1.40	2.8	12
10.	Cyanide µg/L		1	4	110
11.	Dissolved Oxygen (% saturation)		80 – 120	> 60	> 40

Table 6.27 : Nepal Water Quality Guidelines for the Protection of Aquatic Ecosystem (contd…)

S.N.	Parameter name		Target Water Quality Range	Chronic Effect Value	Acute Effect Value
12.	Endosulphan (µg/L)		< 0.01	0.02	0.2
13.	Fluoride (µg/L)		< 750	1500	2540
14.	Iron		The iron concentration should not be allowed to vary by more than 10 % of the background dissolved iron concentration for a particular site or case, at a specific time.		
15.	Lead µg/L				
	Soft water	(60 mg/l $CaCO_3$)	< 0.2	0.5	4
	Medium water	(60 – 119 mg/l)	< 0.5	1.0	7
	Hard water	120 – 180 mg/l	< 1.0	2.0	13
	Very Hard	> 180 mg/l	< 1.2	2.4	16
16.	Manganese (µg/L)		< 180	370	1300
17.	Mercury (µg/L)		< 0.04	0.08	1.7
18.	Nitrogen (inorganic)		Inorganic nitrogen concentrations should not be changed by more than 15 % from that of the water body under local unimpacted conditions at any time of the year; The trophic status of the water body should not increase above its present level, though a decrease in trophic status is permissible (see Effects); The amplitude and frequency of natural cycles in inorganic nitrogen concentrations should not be changed.		
19.	pH				
	All aquatic ecosystems		pH values should not be allowed to vary from the range of the background pH values for a specific site and time of day, by > 0.5 of a pH unit, orby > 5 %, and should be assessed by whichever estimate is more conservative.		
20.	Phenols (µg/l)		<30	60	500
21.	Phosphorus (inorganic) All surface waters		Inorganic phosphorus concentrations should not be changed by > 15 % from that of the water body under local, unimpacted conditions at any time of the year;		
			The trophic status of the water body should not increase above its present level, though a *decrease* in trophic status is permissible (see *Effects*);		
			The amplitude and frequency of natural cycles in inorganic phosphorus concentrations should not be changed.		
22.	Selenium (µg/l)		< 2	5	30
23.	Temperature (All aquatic ecosystems)		Water temperature should not be allowed to vary from the background average daily water temperature considered to be normal for that specific site and time of day, by > 2 ^{o}C, or by > 10 %, whichever estimate is the more conservative.		
24.	Total Dissolved Solids (All inland waters)		• TDS concentrations should not be changed by > 15 % from the normal cycles of the water body under un impacted conditions at any time of the year; • The amplitude and frequency of natural cycles in TDS concentrations should not be changed.		
25.	Total Suspended Solids (All inland waters)		Any increase in TSS concentrations must be limited to < 10 % of the background TSS concentrations at a specific site and time.		
26.	Zinc (µg/l)		< 2	3.6	36

Source: Department of Irrigation, Ground Water Project (Nepal Gazette (Number 10, B.S., 2065-03-02))