Government of Nepal

Ministry of Forest and Environment

Department of Forest and Soil Conservation

Federal Watershed Management Resource Centre

Kulekhani, Makwanpur, Nepal

WATER AND SOIL SAMPLE TEST IN INDRASAROBAR WATERSHED AREA, MAKAWANPUR, NEPAL

(इन्द्रसरोवर जलाशय क्षेत्रमा आउने नदीमा माटो पानीको नमूना परीक्षण)

Submitted by:
Engineering Center Nepal
Chakupat, Lalitpur

2079

Acknowledgement

This study is based on the study experience gained through fieldwork assessment, sample collection and analysis. We are grateful to Federal watershed management resource center, Kulekhani for the financial support that was provided to Engineering Centre Nepal, Kathmandu.We express our gratitude to ***Mr. Shyam Prasad Neupane****, Chief Scientific Officer for his valuable support and guidance. Similarly, we highly acknowledge to* ***Mr. Nikesh kathayat,*** *watershed management officer for his coordination and management. Other supporting staffs of the Federal watershed management resource center, Kulekhani are thankful for their support during fieldworks, Special thanks to* ***Dambar Bahadur Thapa*** *for his valuable time during field work. Engineering center Nepal Pvt. Ltd. is grateful to all the scholars for their valuable time and effort. We acknowledge to* ***Mr. Chetmani Chaudary (Environmentalist and GIS specalist), Mr. Devendra Pandey (Conservation biologist) and Mr. Lekh Prasad Bhatta (Geologist)*** *for their hard effort in this study.*

Abbreviations

BOD: Biological Oxygen Demand
DO: Dissolved Oxygen
DSCWM: Department of Soil Conservation and Watershed Management
ENPHO: Environment and Public Health Organization
ESS: Ecosystem Services
KHEP: Kulekhani Hydroelectric Project
KM: Kilometer
M: Meter
MW: Megawatt
MOPE: Ministry of Population and Environment
MOFE: Misistry of Forest and Environment
SOM: Soil Organic Matter
SMAF: Soil Management Assessment Framework
SWR: Soil and Water Retention
SQI: Soil Quality Index
UNESO: United Nations Educational, Scientific and Cultural Organization
UNEP: United Nations Environment Programme
UNICEF: United Nations International Children's Emergency Fund
WWF: World Wide Fund for Nature
WHO: World Health Organization

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ABSTRACT

Kulekhani Reservoir (Indrasarobar) is one of the first reservoirs made by damming the Kulekhani river and its tributaries at an elevation of 1430 masl in 1982. The Indrasarover watershed was built by the construction of 114 m tall and 10 m wide rock fill (stone and soil mixed dam) dam in Kulekhani with the purpose of generating the electricity which was located in Bagmati province, Makawanpur district. Despite of electricity generation, the reservoir is also famous for cage fish culture, boating and tourism activities. The present study was conducted in Kulekhani reservoir, Makwanpur, with an aim of assessing the quality of water used for aquaculture and protection of fresh water aquatic ecosystem and soil properties for the assessing NPK levels. The data of the study were obtained from two sources, from soil and water samples analysis. Soil samples were taken from depths 0-15 cm and were collected from 3 types of landuse viz: agricultural land, forest land and grassland, in which 5 samples were collected from each sample site and mixed up and then removed foreign materials like roots, stones, pebbles and gravels. After then, mixed sample were comparted into four equal parts, of which two opposite quarters was discarded and the remaining two quarters was remixed. The process was repeated until the desired sample size was obtained and collected in a zipper polythene bag for the lab analysis. Six water samples were collected, five from feeding streams of Kulekhani reservoir (Chitlang khola, Bisenkhel khola, Palung khola, Thado khola, Chalkhu khola) and one from Dam site. The sampled soil and water were analyzed for various parameters viz: pH, conductivity, DO, BOD, turbidity, alkalinity, hardness, chloride, ammonia nitrate, nitrite, calcium, magnesium, Iron, Fe, Mn, and *E.coli* count in water sample and pH, conductivity, nitrogen, phosphorous, organic matter and potassium in soil sample of Kulekhani watershed. The present study concluded that the overall water quality of the study sites is so far natural and their physio-chemical values were within the limits acceptable for aquaculture and protection of fresh water aquatic ecosystem guideline. However, all the water sample was contaminated with *E. coli* bacteria, biological oxygen demand was found at self-cleaning level (<10mg/L) and dissolved oxygen level was found greater than 5mg/L. While, the concentration of ammonia and manganese in all water sample was found lesser than acute effect level (Ammonia: 0.1mg/L, Manganese: 1.3mg/L, GoN-2065) required for protection of fresh water aquatic ecosystem. The present study of soil sample of study sites concluded that organic matter in grassland soil sample was at medium rating level (2.5-5%) but in agricultural land and forest land, the organic matter was at high rating level (>5%). The pH of grassland was neutral while forestland and agricultural land were acidic. The organic matter content in the agricultural land was very high but the content in the forestland was high and medium in grassland. The available nitrogen, available phosphorous and available potassium in the grassland were high (0.26%), very low (3.94 µg/g) and very low (3.2 µg/g) respectively. The available nitrogen, available phosphorous and available potassium in the agricultural land was found to be medium. While, available nitrogen, available phosphorous and available potassium in the forestland were medium (0.14%), low (11 µg/g) and very low (2.51 µg/g) respectively.

Keywords: Kulekhani Reservoir, Water quality, Soil quality, *E.coli*

CHAPTER 1: INTRODUCTION

1.1 Background

An area in which all the water or snowmelt drains to a single streams, river, lake or reservoir is known as watershed or drainage basin (Goodman, 2011). The holistic approach can be applied for the management of watershed by integrating the forestry, agriculture, pasture and water for sustainable management of natural resources (Pandit *et al.*, 2007). In broader sense, the watershed management is an effort for ensuring hydrological, soil as well as biotic regime based on which the water development projects are planned, maintained or even enhanced to prevent it from deterioration. Water and soil regimes of any watershed are mostly affected by the changing in land use pattern of that site (Biswas, 1990). Water and soils are the vital components of the ecosystem that support the production of ecosystem goods and services, such as: food, fibers and energy provision, water storage and purification, irrigation, aquatic environment, neutralization, filtering and buffering of pollutants, natural hazard regulation, bio-geochemical cycle and climate regulation (Biswas, 1990). The sub-watershed is considered as an important unit for the management of watershed, this management approach has been followed by the government of Nepal since ninth five year plan (from 1997/98 to 2001/02) in which the sub-watershed needs to be ranked by erosion severity (DSCWM, 2015).

Reservoirs are essential for storing water and providing necessary head to run turbines for a conventional hydroelectric power (Bodaly *et al.*, 2004). The siltation of reservoirs is one of the most important off-site impacts of soil erosion (Sharma, 1998) that are closely linked to desertification problems like reservoir sedimentation, flooding problems, the loss of fertile foot slopes and floodplains, nutrient loss, eutrophication and the destruction of ecological habitats (Vanmaercke *et al.*, 2011). The crucial ecosystem services (e.g., ecotourism, biodiversity, food production, and sediment retention) would be affected by land-use changes (Liang *et al.*, 2017). The processes of soil erosion, sediment retention, and sediment transport are the key components and functions of the watershed area (Morgan, 2005).

Kulekhani hydro electricity plant (KHEP) is the first reservoir based hydropower plant in Nepal, which was accomplished in 1980s. This reservoir is human made constructed by erecting 114 m tall and 10 m wide rock fill (stone and soil mixed dam) dam in the Kulekhani river which is also the main tributaries of Bagmati basin. Hence, conservation and management of reservoir is crucial. For this, detail investigation of the factors i.e. landuse, soil, rocks, agricultural land, settlements in the upstream of the sub-watershed could provide the details of landslide, soil erosion, soil and water quality. Hence, there will be high probability of landslides, soil erosion, debris flow and floods thereafter increased sedimentation level, the water level of this reservoir to be increased though the precipitation has been observed declining (Ghimire *et al.*, 2019b). Apart from this, the water quality of the reservoir would be affected by the number of households and disposal of household wastes and sanitation, forested area, agricultural land, soil erosion, landslides, mixing of sewages directly to the river body. As a result of consequences, there will be decrease in the dissolved oxygen, increased turbidity, increase the nitrogen and phosphorous content (eutrophication would affect the water quality, reservoir ecosystem, river ecosystem), growth of invasive plants (such as water hyacinth, water lettuce, aliigator weed), decrease in aquatic biodiversity, decrease of endemic fishes and increase of invasive fishes. Hence, physiographical characteristics, biological and socio-economic environment of the river basin should be considered while planning new reservoirs (Shrestha, 2012).

Water is the most vital resource for all kinds of life on this planet. It is essential in every aspect of human beings. A regular and plentiful supply of clean water is essential for the survival and health of most living organisms (Lekhak and Lekhak, 2003). We are all aware of its necessity, for drinking, for producing food, for washing- in essence for maintaining our health and dignity. In addition, water is essential for ensuring the integrity and sustainability of the Earth's ecosystems (UNESCO, 2003). Water pollution is one of the most important problems being faced by both developed and developing countries. A more serious aspect of water pollution is that caused by human activities-urbanization and industrialization. The sources of pollution resulting from these are sewage (decomposable organic matter and pathogenic agents), industrial wastes (toxic metal salts to synthetic organic chemicals), physical pollutants (heat and radioactive substance) and agricultural pollutants (Sharma, 2001). Hydro energy importance also comes from its own source – the water, an essential life resource. Therefore, to maintain the water quality is a main concern from ecological, economical and sustainable development point of view (Bunea *et al.*, 2010).

Soil plays a vital role in water quality in terms of non-point source pollution (Gburek and Sharpley, 1998). Soil variability including particle size distribution, slope, and internal drainage within the landscapes of watersheds, large and small, accounts for the difficulty in partitioning downstream water quality data and evaluating sources of non-point source pollution. Soil and water are two key resources that directly or indirectly affect our everyday activities. Until recently, soil has predominantly been perceived in the context of its agricultural production function but healthy soils provide many more goods, services and societal function e.g. for flood protection and maintenance of natural landscapes; and water is necessary for all the provisioning, regulating, supporting and cultural services.

Mismanagement and/or intensive use of soil and water put at risk the maintenance and resilience capacity of our natural capital. Our economies have increasingly relied on technologies and innovations to cope with environmental degradation, rather than on optimizing the ecosystem services (ESS) provided by our environment. For example, in the agricultural sector, irrigation and drainage can be used intensively to cope with the degradation of soil hydrological functions. In the urban environment, storm-water channels and other hydraulic works allow tackling the risks of flooding linked to rainwater runoff on impervious surfaces. When water is applied to the soil surface, water naturally seeps down by gravity provided no physical barriers (such as impermeable layers at the soil surface or within the soil profile) impede this process. The "maximum soil water content" is the maximum amount of water a soil can contain. It informs on how much water can infiltrate in the soil before it reaches saturation (i.e. all available space is occupied by water). Even then, infiltration can continue as water drains downwards to the aquifer or is discharged into any outlets such as ditches or streams. SWR capacity provides multiple ecosystem services, which sustain human needs from an environmental, health and socio-economic perspective. Through its capacity to absorb water and slow down water flows at the soil surface (capture), the soil prevents run off. When soils can absorb less water, more runoff may occur depending on precipitation. They therefore play a key role in the control of land erosion and in the mitigation of flooding events by reducing or postponing peak flows. Through its capacity to store and hold water (storage), the soil acts as a water reservoir where plants extract their water resources, although the water actually available to plants is lower than the maximum soil water content. This capacity ensures a continuous source of water to plants, hence preventing or postponing water deficit during dry periods. In the driest regions, it also helps preventing desertification. By maintaining humid conditions within the soil, this capacity also supports microorganisms and ensures nutrient availability for plants. Through water drainage (release) within the soil and deep percolation, soils contribute to the replenishment of groundwater aquifers. Groundwater has a key ecological function in sustaining river low flows, wetlands and lakes. It is also a major source for agricultural, industrial and domestic water supply.

To enhance the healthy soil and water ecosystem of the reservoir, the study was conducted to test the water and soil quality of Indrasarobar watershed area. Hence, the present study was intended to delineate the sub-watersheds based on drainage basin, identify the most sensitive parameters of sub-watersheds of Kulekhani watershed that could contribute to the watershed manager, policy makers and other similar watersheds for its proper conservation and management.

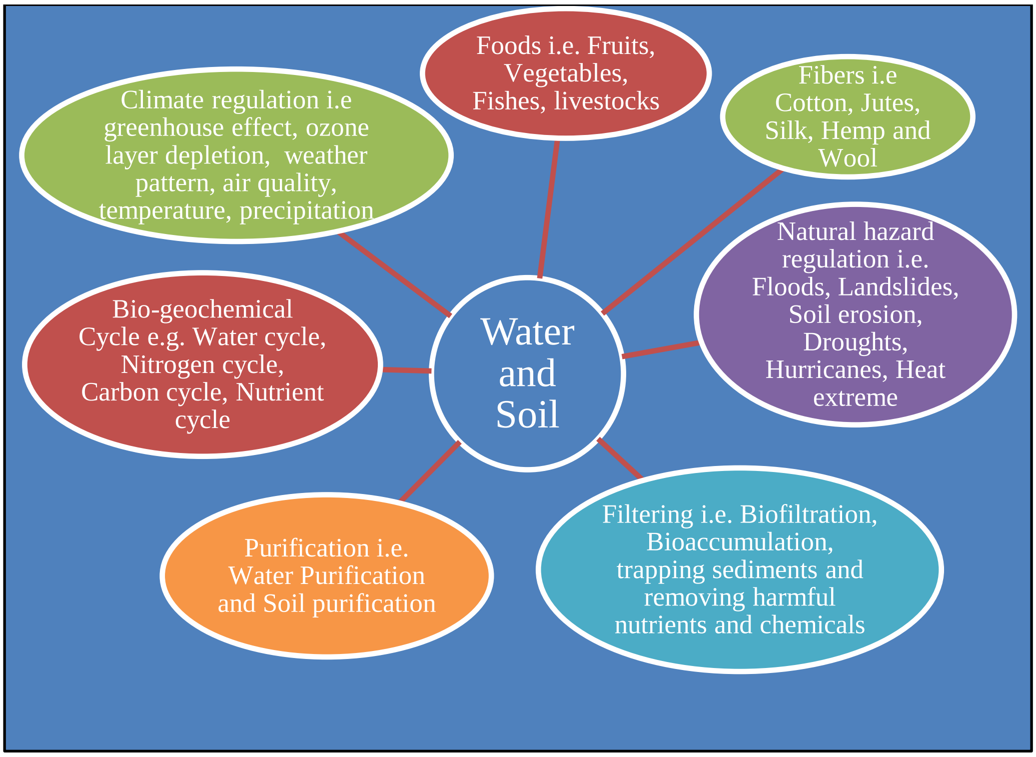


Figure 1: A framework of water and soil in role of Ecosystem Services

1.2 History of Indrasarobar Reservoir

Kulekhani Reservoir (Indrasarobar) is one of the first reservoirs made by damming the Kulekhani river and its tributaries at an elevation of 1430 masl in 1982. The Indrasarover watershed was built by the construction of 114 m tall and 10 m wide rock fill (stone and soil mixed dam) dam in Kulekhani with the purpose of generating the electricity which was located in Bagmati province, Makawanpur district. The total length of the watershed area is 7 km long and 2 km wide reservoir spread from Sisneri to Markhu which stores 85.3 million cubic meters of water. Out of this, only 73.3 million cubic meters of water can be used to generate electricity. The reservoir can store up to 1530 meters of water. The reservoir was built during the reign of the then King Birendra Shah to generate electricity named as Indrasarobar reservoir in the memory of late princess Indra Rajya Laxmi Devi Shah. This reservoir is located 50 km south west of Kathmandu city, Nepal. It is the first large sized reservoir constructed in the hilly region mainly for the generation of electricity. This reservoir accumulates the run-off water from 124 km^2 catchment area during monsoon (June – September) for the peak generation of electricity in the dry season. At present, the first project of 60 MW Kulekhani and the second project of 32 MW are in operation. Also, a 14 MW Kulekhani III is being prepared for operation. Construction started in 2034 BS (1977 BS) and two projects were completed in 2043 BS (1986 BS). Both projects were completed at a cost of about crores 118 million.

This reservoir is also used for the Cage fish culture catching fishes. Cage culture of fish consists of raising fish from the juvenile stage to commercial size in a volume of water enclosed on all sides, including the bottom, while permitting the free circulation of water through the 'cage' (Coche, 1979; Schmitton, 1969). It is a method of farming aquatic organisms in the enclosure placed in a body of water (Beveridge and Stewart, 1998). Cage fish culture is considered to be an old tradition that has developed into a major sector in aquaculture only in the recent past (De Silva and Phillips, 2007; Tacon and Halwart, 2007). Traditionally, subsistence cage farming by use of planktivorous fish species (silver carp *Hypophthalmichthys molitrix* /bighead carp *Aristichthys nobilis*) in nylon cage of 50 m^3 cage volume with bamboo frame have been practiced by farmers and this technology is still popular (Gurung and Bista, 2003; Wagle *et al.*, 2007). Cage fish culture has been practiced since 1985/86. The cages were covered from the top to prevent from escaping as well as predation. The fish were cultured without feeding any supplementary feeds and depend completely on plankton available in the reservoir. Introduction of cage fish farming in the reservoir became successful strategies for an alternative livelihood option and also stimulated the development of a capture fishery, based on escapees and naturally recruited species, all of which have significantly contributed to increasing a fresh affordable animal protein source to the nearby communities (Gurung *et al.*, 2009).

Figure 2: **Fish culture in cages of Kulekhani Reservoir**

Despite of electricity generation, cage fish culture, the reservoir is also famous for boating and tourism activities. The reservoir is visited by large number of tourists for recreational, filming, musical shooting and holiday celebration.

Figure 3: **Boating in Kulekhani Reservoir**

1.3 Objectives

The major objective of the present study is to analyze water and soil quality which plays significant role both in flora and fauna as well as in human health. The specific objectives are:

i. To analyze the physico-chemical characteristics of water and soil.

ii. To analyze microbiological characteristics (coliforms) of water.

1.4 Problem statement and justification

Kulekhani reservoir area is an important source of Kulekhani Hydroelectric project. It is also famous for biodiversity, fishing, boating, scenic beauty and as a recreational place. The tributaries of Kulekhani reservoir are Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola. Due to the urbanization, intense use of fertilizer and pesticides in the agricultural land, disposal of sewage and wastes in the bank of river, the water and soil of the Kulekhani reservoir is deteriorating. So, the water quality of the reservoir and its tributaries and soil quality of the Kulekhani catchment area are directly related with flora and fauna within and surrounding it. Hence, the present study will identify various factors threatening the water quality and soil quality and it will be helpful for planners and user groups to maintain standard water quality by proper management and conservation of the reservoir and its catchments area.

1.5 Limitations

- The major limitation of the present study is that sampling size and sampling number is limited due to budget limit as well as remoteness of the study site from the main road.
- The seasonal collection of water and soil sample could not be performed due to the budget and time limit.
- The study time limit is also limited.
- Documentation of algae could not be performed because of low water level in the reservoir so that security personnel did not allow to spent longer time in the site.

CHAPTER 2: LITERATURE REVIEW

2.1 Water quality

Water is the most vital resource for every living organism including human beings on this planet. Supply of clean water is essential for the survival and health of most living organisms (Lekhak and Lekhak, 2003). Water is used for various purposes e.g. drinking, washing, producing food, irrigation, industry, natural ecosystems, aquatic ecosystem, human health and hydropower generation. In addition, water ensures also the integrity and sustainability of the Earth's ecosystems (UNESCO, 2003).

About 71% of the earth's surface is covered by water of which 97 percent of earth's water is found in oceans (salty water), 2.5 percent is fresh water i.e. unavailable (locked up in glaciers, soil, atmosphere, polar ice caps, highly polluted or lies too far under the earth's surface) and only 0.5 percent fresh water is in available form on the earth (Gleick, 1993). Freshwater is vital to human health, agriculture, industry and natural ecosystems, but is now running scarce in many regions of the world (WWF, 1998).

Water is also related to the health issue or community health in the underdeveloped countries that is caused by drinking non-potable safe drinking water (Park, 1994; UNESCO, 2003). Water pollution is one of the most important issues being faced by both developed and developing countries. Water pollution has been defined as 'any chemical, biological or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired use' (Miller, 2002). Water contains impurities like organic, inorganic, biological or physical foreign substances that are known as polluted water. Water contains impurities of various kinds-both dissolved and suspended particles. These include dissolved gases (H_2S, CO_2, NH_3, N_2), dissolved minerals (Ca, Mg, Na salts), suspended impurities (clay, silt, sand) and even microbes. These are natural impurities derived from atmosphere, catchments area and the soil. A more serious aspect of water pollution is that caused by human activities i.e. urbanization, intensifying of agriculture and industrialization and mixing of sewage and industrial wastes in the water bodies (Sharma, 2001).

Polluted water is a major cause of human disease, misery and death. WHO (1984) has estimated that some 30,000 people die every day from water related disease i.e. chlorea, dysentery, diarrhea, typhoid fever in the less developed countries. About 80 percent of the illness is caused by polluted water. Due to the lack of potable water supply and sanitation, more than 15 million children below five years die each year (UNICEF, 1997). In Nepal, more than 33,000 people die every year due to gastro-enteritis by drinking contaminated water and poor sanitation (Anonymous, 2004). Mixing of sewage and effluents to natural sources of drinking water is a great threat to public health and may cause destruction of plants and animals' life and aesthetic nuisance (Rao, 1994). Surface water and ground water are the major natural sources of water supply in majority of cities of Nepal, including Kathmandu valley. In general, surface water supplies possess a high possibility of organic, bacterial and viral contamination (Joshi *et al.*, 2000). The water quality in Kathmandu valley is very unsatisfactory. While considering microbiological water quality, even chlorinated water of Kathmandu is found heavily contaminated with faecal materials. Over 80 percent of drinking water contains very high count of bacteria (Jha and Lekhak, 1999). The fishes and aquatic ecosystem possess a threat due to the massive use of chemical fertilizer and pesticides in the agricultural land which ultimately seepage to the nearest water bodies.

2.2 Soil quality

Soil is the natural habitat of living bodies. Soil is a living body. It is a medium of plant growth and supports different type of living organisms of the world. It is a natural body consisting of layers (soil horizon) of primarily mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical, and mineralogical characteristics. Soil is essential to plants, not only as a substrate, but also as a reservoir for water and essential minerals including nitrogen and phosphorus, as well as calcium, sulfur, potassium, and other ions.

Soil has a certain distinctive physical, chemical and biological qualities which permit it to support plants growth. Soil quality, thus, may be defined as the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen *et al.,* 1997). It depends on many things such as soil texture, soil pH, nutrients, organic matter, water holding capacity, microorganism, structure, microclimate, irrigation facility, land fragmentations, soil erosion, agricultural system and practices, diseases and insects, consumption of nutrients by crops, leaching of nutrients etc.

Many studies have identified soil nutrient availability to be an important factor controlling net primary productivity (Post *et al*., 1986). Nitrogen, phosphorus and potassium are very important nutrients required for normal growth of plants and for increasing yield. These nutrients are also added manually in agricultural lands. These are the macro nutrients required by the plants in high quantity while other nutrients called micro nutrients like Iron, Manganese, Boron, magnesium, sulphur etc. are required in small quantity and mostly they need not to be manually added. Soil chemical analysis is made to assess the available amounts of major nutrients, nitrogen phosphorus potassium and to assess a few other determinations which are correlated to soil fertility, such as soil texture, soil reaction (pH) and salinity.

Soil organic matter is the solid portion of soil which is formed by the plants debris and dead animals. It increases humus in soil. High organic matter content in soil indicates high capacity to retain moisture in soil. The amount of organic matter in the soil varies according to the ecological zone in which it occurs as well as the land use and management of soil. Area under natural forest has higher organic matter than that used for cultivation.

Ratings for pH and nutrient values (OM, N, P_2O_5, and K_2O) based on standards recommended by Nepal Agricultural Research Council, Nepal (NARC, 2013) and used by Soil Management Directorate are shown below:

pH: Highly acidic <4.5, Acidic = 4.5 to 5.5, Slightly acidic = 5.5 to 6.5, Neutral = 6.5 to 7.5, and Alkaline >7.5

OM: Very high >10, High = 5 to 10, Medium= 2.5 to 5, Low = 1 to 2.5, and Very low <1

N: Very high >0.4, High = 0.2 to 0.4, Medium = 0.1 to 0.2, Low = 0.05 to 0.1, and Very low <0.05

P_2O_5: Very high >110, High = 55 to 110, Medium = 30 to 55, Low = 10 to 30, and Very low <10

K_2O: Very high >500, High = 280 to 500, Medium = 110 to 280, Low = 55 to 110, and Very low <55

2.3 Physico-chemical Characteristics of Water

Various physico-chemical parameters are available for the analysis of water quality to assess the water whether suitable for Aquaculture and Aquatic ecosytem. These methods largely involve standardized procedures and provide useful information. Some of the important parameters under study were temperature, electrical conductivity, pH, alkalinity, turbidity, hardness, dissolved oxygen (DO), biological oxygen demand (BOD), chloride, nitrate, nitrite, calcium, magnesium, manganese, iron etc.

Temperature

Temperature is basically important factor for its effects on chemical and biological reaction in water. A rise in temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and odour, and elevates metabolic activity of organisms (Saxena, 1989). The temperature of freshwater normally varies from 0 to 35^0C, depending on the resources, depth and season. High water temperature enhances the growth of micro-organisms and leads to the speeding up to chemical reaction in water (WHO, 1991).

Conductivity

Conductivity is the measure of the ability of a solution to carry electric current. As this ability is dependent upon the presence of ions in solution, a conductivity measurement is an excellent indicator of the TDS in water. The unit of conductivity is µs/cm. The value of conductivity becomes greater with the increase of dissolved salts and degree of pollution (Twort *et al.*, 1985). Conductivity is a general indicator of productivity (Saxena, 1989). The EC standard for surface water used for potable abstraction is 400 µs/cm (ENPHO, 1997).

pH

pH value or hydrogen ion concentration is a measurement of the acidity or alkalinity of a water. Natural water usually has pH values between 5.0 to 8.5. Many chemical reactions are controlled by pH and the biological activities are usually restricted to fairly narrow pH range of 6.5 to 8.2. Highly acidic or highly alkaline waters are undesirable because of corrosion hazards and possible difficulties in treatment and adverse effects for living organisms

(Anonymous, 2000a). According to Nepal Water quality guidelines for aquaculture 2008, the target water quality for pH ranges from 6.5-9.

Alkalinity

Alkalinity of water is its capacity to neutralize a strong acid and is characterized by the presence of hydroxyl (OH^-) ions capable of combining with hydrogen (H^+) ions. In natural waters a number of bases, viz. carbonates, bicarbonates and hydroxides are considered to be the predominant bases. In highly productive water, the alkalinity ought to be over 100 mg/l (Saxena, 1989). Alkalinity can exist in water below the neutral point of pH 7.0 because of the relationship between alkalinity, carbon dioxide and pH value (Twort *et al.* 1985). The target water quality for total hardness as $CaCO_3$ ranges from 20 -100 mg/l as $CaCO_3$ (Nepal Water quality guidelines for aquaculture, 2008)

Hardness

Hardness in water is caused by dissolved calcium and magnesium. Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate in milligram per liter. Hardness is the property of water which prevents the lather formation with soap and increases the boiling point of waters. It is undesirable due to the formation of heat retarding insulating scales in the boilers and other heat exchange equipment (Trively and Goel, 1986). WHO guidelines for hardness is maximum 500 mg/l for drinking-water (ENPHO, 1997). The degree of hardness of drinking –water according to WHO (1991) has been classified in terms of its equivalent $CaCO_3$ concentration as follows:
Soft: 0-60 mg/l
Medium hard: 60-120mg/l
Hard: 120-180 mg/l
Very hard: > 180 mg/l.
According to Nepal Water quality guidelines for aquaculture 2008, the target water quality for total hardness as $CaCO_3$ ranges from 20 -100 mg/l.

Chloride: The presence of chlorides in natural waters can mainly be attributed to dissolution of salt deposits in the form of ions (Cl^-). Otherwise high concentrations may indicate pollution by sewage or some industrial wastes or intrusion of seawater or other saline water. It is the major form of inorganic anions in water for aquatic life. High chloride content has a deleterious effect on metallic pipes and structures, as well as agricultural plants. In natural freshwaters, high concentration of chlorides is regarded as an indicator of pollution due to organic wastes of animal origin (animal excreta have higher chlorides along with nitrogenous wastes). Domestic sewage and industrial effluents also bring chlorides into the water. Chloride content above 250 mg/L makes water salty. However, a level up to 1000 mg/L is safe for human consumption. High level results in corrosion and non-palatability (Ramachandra *et al*., 2012).

Dissolved Oxygen (DO)

Oxygen dissolved in water, often referred to as DO is a very important parameter of water quality and is an index of physical and biological processes going on in water (Saxena, 1989).

The DO of natural water varies with temperature, salinity, photosynthesis and respiration. Cold water can hold more DO than warm water. Low content of DO is a sign of organic pollution. Concentration of DO below 5 mg/l may adversely affect the functioning and survival of biological communities. DO levels of 5 to 6 mg/l are usually required for normal growth and activity. Levels below 3 mg/l stressful to most aquatic organisms and levels below 1 or 2 mg/l will not support fish (Anonymous, 2000a). Nepal Water quality guidelines for aquaculture, 2008 classified the level of dissolved oxygen as follows:
6 -9 mg/l for cold water species
5 -8 mg/l for intermediate water species
5-8 mg/l for warm species

Biochemical oxygen demand (BOD)

BOD is a measure of the dissolved oxygen consumed by microorganisms during the oxidation of reduced substances in waters and wastes. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen aquatic organisms which become stressed, suffocate and die. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, Waste water treatment plants, feedlots and food-processing plants; failing septic systems; and urban storm water runoff. The discharge of wastes with high levels of BOD can cause water quality problems such as severe dissolved oxygen depletion and fish kills in the receiving water bodies (Penn *et al.* 2003). Chlorine can also affect BOD measurement by inhibiting or killing the microorganisms that decompose the organic and inorganic matter in a sample. In chlorinated waters, such as those below the effluent from a sewage treatment plant, it is necessary to neutralize the chlorine with sodium thiosulphate (APHA, 2005).

Calcium

Calcium, in the form of the Ca^{2+} ion, is one of the major inorganic cations, or positive ions, in saltwater and freshwater. It can originate from the dissociation of salts, such as calcium chloride or calcium sulphate, in water. Most calcium in surface water comes from streams flowing over limestone, $CaCO_3$, gypsum, $CaSO_4.2H_2O$ and other calcium- containing rocks and minerals. Calcium carbonate is relatively insoluble in water, but dissolves more readily in water containing significant levels of dissolved carbon dioxide. The concentration of calcium ions (Ca^{2+}) in freshwater is found in a range of 0 to 100 mg/L. A level of 50 mg/L is recommended as the upper limit for drinking water. High levels are not considered a health concern; however, levels above 50 mg/L can be problematic due to formation of excess calcium carbonate deposits in plumbing or in decreased cleansing action of soaps. If the calcium ion concentration in freshwater drops below 5 mg/L, it can support only sparse plant and animal life, a condition known as oligotrophic. Typical seawater contains Ca^{2+} levels of about 400 mg/L.

Nitrate and ammonia

Both nitrate (NO_3-N) and ammonia (NH_4-N) concentrations are highly variable during lake seasonal cycles. For deep stratified lakes, nitrate is higher during mixing events and usually decreases in late summer and fall. For the trophogenic zone of shallow lakes, both concentrations would be lower during periods of water column stability and they will increase during vertical mixing events. NH_4- N is generated by heterotrophic bacteria as the primary nitrogenous end product of decomposition of organic matter and is readily assimilated by plants in the trophogenic zone (Wetzel, 2001). NH_4-N concentrations are usually low in oxygenated waters of oligotrophic to mesotrophic deep lakes because of utilization by plants in the photic zone and nitrification to N oxidized forms. At relatively low dissolved oxygen, nitrification of ammonia ceases, the absorptive capacity of the sediments is reduced and a marked increase of the release of NH_4-N from the sediments then occurs.

Iron (Fe): Iron is found in most raw waters. The element in not harmful but undesirable on aesthetic grounds because it can impart a bitter taste when present in large amounts, causes brown stains on laundry and can give rise to iron bacteria which in turn cause further deterioration in the quality of water by producing slimes or objectionable odours (Twort *et al.*, 1985). Iron ingestion in large quantities results in a condition known as haemchromatosis where in-tissue damage results from iron accumulation (WHO, 1991). The WHO international standards recommended 0.1mg/l Fe as the highest desirable level for total iron with 1.0 mg/l as the maximum permissible level (WHO, 1971).

Manganese (Mn): Manganese is regarded as one of the least toxic elements as there is no evidence that manganese is carcinogenic (WHO, 1984). In Japan, a Mn concentration of 0.75mg/l in a drinking water supply has no apparent adverse effect on the health of its consumers (ENPHO, 1997). The presence of Mn in drinking water supply may be objectionable for a number of reasons unrelated to health. At concentration exceeding 0.15 mg/l Mn imparts an undesirable taste to beverages and stains plumbing fixtures and laundry. The WHO guideline value for drinking water is recommended as 0.1mg/l, based on consideration of the staining properties of Mn (WHO, 1991).

Coliform: Coliform group of bacteria are the normal flora of intestinal tract of human beings and other warm-blooded animals. They have long been recognized as suitable microbial indicator of drinking water quality, largely because these organisms are easy to detect and enumerate in water. They are Gram negative, rod-shaped bacteria characterized broadly by their ability to ferment lactose in culture at 35-37^oC with the production of acid, gas and aldehyde within 24-48 hours, and include *E. coli, Citrobacter, Enterobacter* and *Klebsiella* species. They are also found in botanical environment, vegetation and soil. Of these organisms, only *E. coli* is specifically of faecal pollution (WHO, 1991). The level of coliform organisms present in the drinking water should not exceed the maximum permissible value of less than one cell per 100ml of water set by the WHO (WHO, 1991).

2.4 Physico-chemical parameters of soil

Soil pH is a measurement of how acidic or basic a soil is. Soils with pH values below pH 7 are referred as acid and those with pH values above pH 7 as alkaline. Soils at pH 7 are referred to as neutral. Soils can range from a pH of about 3 to 9. Generally, a soil pH between 6.0 and 7.5 is acceptable for most plants as most nutrients become available in this pH range. However, some plants have soil pH requirements about or below this range. Soil pH affects many aspects of plant growth, including availabilities of nutrients and toxic substances, activities and nature of microbial populations, suppression and enhancement of soil borne diseases, activities of certain pesticides, and soil structure.

Fertilizing with ammonia-based fertilizers may decrease soil pH over time. Adding elemental sulfur (S) can decrease soil pH but it requires 10,000 lb/ac to lower the soil pH from 8 down to 7.5 in a soil with 1.5 percent calcium carbonate ($CaCO_3$).

Soluble Salts or Electric Conductivity (EC) is a measurement of dissolved inorganic solutes. The most common soluble salts in soils are the cations, calcium (Ca^{+2}), magnesium (Mg^{+2}), and sodium (Na^{+}), and the anions chloride (Cl^{-}), sulfate (SO_4^{-2}), and bicarbonate (HCO_3^{-}). Smaller quantities of potassium (K^{+}), ammonium (NH_4^{+}), nitrate (NO_3^{-}), and carbonate (CO_3^{-2}) are also found in most soils. Sources of soluble salts in soils include soil organic matter, commercial fertilizers, animal manures, municipal sewage sludge, runoff from areas where salt or ice-melt products have been used and irrigation water that is high in dissolved salts.

At low levels, soluble salts generally do not harm plants. Excess soluble salts burn foliage, damage roots and lead to problems with water uptake. Wilting, yellowing, and marginal and tip burn of leaves, (scorching), are symptoms of excess soluble salts. Plant species vary markedly in their tolerance to soluble salts. Therefore, the values must be interpreted in relation to a specific plant species.

Electrical conductivity (EC) is a measure of soil salinity and can also be used to estimate soluble nutrients present (Rhoades, 1996). Microbial and plant activity responds to soil electrical conductivity of the soil. Highly saline soils cause considerable stress and constraint to plant growth and development.

Soil Organic Matter (SOM) is composed of materials containing carbon. These materials include plant and animal remains (including bacteria and fungi) in various stages of decomposition, root and microbial exudates and humus. Soil OM is affected by several factors such as soil texture, tillage, parent material, crop productivity, drainage, and other management factor. Soil OM is important for water and nutrient holding capacity.

Nitrogen (N) is an essential nutrient for plant growth and development. There are two forms of plant available N, nitrate (NO_3^{-}) and ammonium (NH_4^{+}). Nitrate-N is the only N form reported as ammonium-N (NH_4-N) levels are typically significantly lower than NO_3-N levels. Nitrate-N values reported are in part per million (ppm). The value reflects what is immediately and not what will be available from mineralization or decomposition of OM or lost from leaching and denitrification.

Nitrogen recommendations are based on crop requirements and expected yields, with the assumption that very small amounts of available N remain in the soil after a growing season. . Nitrate, the mobile form of nitrogen, is primarily used to identify plant-available soil nitrogen.

Phosphorous (P) is involved in many vital plant growth processes. The most essential function is in energy storage and transfer. Phosphorous soil test is an index of availability and is reported in parts per millions (ppm). The quantity of total P in the soil has little or no relation to the availability of P to plants as it is relatively immobile in soil. The phosphorus application rate necessary to correct P deficiencies varies depending on soil properties and crop grown. Phosphorus availability decreases in cool, wet soils. Phosphorus applications are not recommended when test results are high or excessive.

Potassium (K) is taken up by plants in large amounts compared to any other nutrient except nitrogen. Although total soil K content exceeds plant uptake during a growing season, in most cases only a small fraction of it is available to plants. Potassium is involved in water relations. It is important in many crop quality characteristics due to its involvement in synthesis and transport of photosynthesis to plant reproductive and storage organs (grains, fruits, tubers, etc.). In fruits and vegetables adequate K enhance fruit size, color, and taste.

2.5 Water and Soil quality studies conducted in Nepal

Various investigations have been carried out in the past by many scientists and researchers regarding physico-chemical and microbial characteristics of water and NPK test of soil.

Physico-chemical characteristics of water

Upadhyaya and Ray (1982) carried out chemical analysis of water from six river locations of the Kathmandu valley. They found that Bishnumati and Bagmati had high specific conductivity, TDS, and concentration of Na+, K+ and Cl-. While, sample of Monohara river water was found to be comparatively clean but Dhobikhola contained high level of sodium and potassium compounds. Yadav et al. (1984) analyzed water quality of Bagmati, Nagmati, Shyalmati and Sundarijal reservoir in Shivapuri area for various parameters like pH, alkalinity, TDS, hardness, iron, manganese and phosphorus and showed that these water bodies were not polluted.

RONAST (1987) reported the effluent impact of Bhrikuti Paper Mill and the Everest Paper Mill in the Narayani river and Orahi river was highest polluted at the initial area of mixing of effluent. The condition was severe in the Orahi river since the river’s dilution rate was low.

Shrestha (1990) studied physico-chemical, microbiological and biological parameters of the Bagmati river in Kathmandu and found that pollution increased downstream from Sundarijal to Sundarighat and again slightly decreased from Chovar to Khokana.

Shrestha *et al*. (1991) performed water quality study of two rivers (Madri Khola and Bhote Khola), which showed that all the tested physicochemical parameters were under WHO guidelines values with absence of iron and manganese in all samples.

ENPHO (1992) carried out water quality testing activity for installing shallow tube wells and gravity flow systems in some areas in Terai in 1990. Some tested physico-chemical parameters were pH, conductivity, Mn, Fe etc and the result showed that concentration of most of the chemical constituents in the analyzed samples were found to be within WHO permissible limit. Mn and Fe were found in excess of WHO upper limit in 57% and 49% of the samples, respectively.

HMG/MOHPP (1994) while preparing report on the Bagmati basin water management strategy and investment programme (BBWMSIP) analyzed water quality of different parts of the river, industrial and domestic sewage. It categorized the sources of pollution on the Bagmati river as domestic waste water, storm water, industrial waste water and agricultural runoff. The key findings of its analysis were (i) maximum organic pollution, (ii) mostly low DO (iii) heavy metal concentration within acceptable limits and (iv) extremely high coliform bacteria counts.

Poudel and Upadhyaya (1995) analyzed surface water quality of different three sections of the Bagmati and Monohara river for 34 parameters ranging from physical, chemical to biological. The study concluded that most pollution in the Bagmati river and its tributaries was of organic wastes, and heavy metal concentration was found to be at the marginally acceptable limits. The river water had become unfit for many uses viz. drinking, aquatic life, recreation, cleaning and agricultural purpose due to direct discharge of domestic and industrial waste. ENPHO (1996) monitored Shivapuri watershed regions by assessing water quality at sources of Bagmati, Nagmati and Shyalmati Khola. It concluded that chemical characteristics of the water were all within the WHO standard for drinking and the standard within the European Community for raw water sources for potable water abstraction. The research concluded that this kind of water could be supplied by only a simple physical treatment with disinfection.

Sharma (1996) studied the ecology of the Koshi river in Nepal and India (North Bihar). He studied the physico-chemical characteristics of the river and found that river water was quite suitable and possessed a high degree of ecological efficiency and enormous potential for biotic development. During the study, he observed the alkaline pH, low free CO2, high DO (5.88 to 7.33mg/l), total alkalinity 50 mg/l.

ENPHO (1997) again assessed water quality of Shivapuri Watershed. This study also concluded that overall water quality within the watershed area was normal. Most of the values obtained during the period of study were within the WHO and EC guideline. The temporal and spatial variations of parameters had been significantly low in most of the sample sources. The value of electrical conductivity, turbidity, total hardness, $N\text{-}NH_3$, $N\text{-}NH_4$, $P\text{-}PO_4$ were found slightly higher at Shyalmati than Nagmati.

Ghimire (1999) evaluated water quality of the Bagmati river of Kathmandu by investigating different physico-chemical and heavy metal parameters. According to him, most of the pollution parameters were found to be increased towards downstreams. Most of the heavy metals in the river water were well within threshold limits but Fe and Mn were present in significant amount. In this study the water quality in terms of heavy metals was also assessed by examining macrophytic plants of the river.

Nanoty *et al.* (2001) studied water quality of Morna river at Akola district (Maharastra), India and observed that the river water showed high concentration of sulfates and nitrates. The physico-chemical examination of river water was alkaline with pH 7.2 to 7.9, total dissolved solid ranged from 220-6,000mg/l and Nitrate-N ranged from 2.0mg/l-8.9mg/l during this studied period.

Das and Jha (2002) analyzed drinking water quality of Janakpur town with Physical, chemical and bacteriological parameters (pH, temperature, EC, turbidity, hardness, iron and MPN). Result showed that in tube-well water iron was highest and most of the tube-well water samples exhibited more than its permissible limit (0.3mg/l).

Srivastava et al. (2003) studied physico-chemical characteristics (pH, temperature, DO, free CO2, alkalinity and hardness) and zinc concentration in water bodies in and around Jaipur, India. Reuslts revealed that the water of Jalmahal lake is most polluted due to high pH, hardness, alkalinity, free CO2, zinc content and a low level of DO. Contrarily, Ramgarh lake was least polluted as it had high DO and low pH, hardness, free CO2 and zinc content.

Microbiological characteristics of water

Sharma (1977) determined the quality of drinking water supplied to the households of Kathmandu valley. Coliform tests were performed on water samples from 39 localities and results showed that all the working samples had some degree of faecal contamination. The number of coliform cells per 100ml of water ranged from 4 to 460. Yadav et al. (1984) analyzed water from Sundarijal (Sundarijal reservoir, Bagmati, Shyalmati and Nagmati) on July 1982. They reported that reservoir had the lowest E. coli count (10MPN/100ml) and Bagmati had the highest (180MPN/100ml). However, all the sources contained equal number of total coliform (180MPN/100ml).

Sharma (1986) studied the quality of water samples from different sources of Kathmandu and Lalitpur area. He found that the coliform concentration had significantly increased in nine years. Water samples were taken in dry summer, rainy and winter seasons. The coliform bacteria count ranged from 0 to 4800 during the rainy season, 0 to 75 in winter season and 0 to 460 per 100ml in the summer season.

Joshi (1986) carried out bacteriological tests of drinking water sources of two villages of central Nepal: Chaubas (Shivapuri area) and Saibu (Langtang N.P.area). He reported that pollution of drinking water was a problem in these villages. The coliform count ranged from

5-100 cells/100ml of water. In Chaubas, contamination range was within 5-10 cells/100ml whereas in Saibu, it was within 20-100cells/100ml.

Sharma and Rijal (1988) carried out a study of microbial and chemical pollution of Bagmati, Bishnumati and Dhobikhola rivers. All sources contained more than 4800 cells of total coliform (TC) and faecal coliform (FC) per 100ml of water. Bottino and Sharma (1989) analyzed 472 different water samples from treatment plant and reservoirs, hospital storage tanks and public water taps. Their result showed that the bacteriological contamination increased as the water travels from the water treatment plant to the distribution systems. It also reported that all the water samples had coliform count far exceeding WHO standard.

Shrestha *et al.* (1991) reported FC in Madrikhola, Bhotekhola and Amalabisauni reservoir of Pokhara. Of these, Madrikhola had lowest FC (55/100ml) and the reservoir had highest (120 organism/100ml). Sharma (1993) carried out microbial examination of water samples from different cities of Nepal. He found that the highest coliform count was 2,400 cells per 100ml in Kathmandu, 4800 cells per 100 ml in Biratnagar and Pokhara each.

Poudel and Upadhyaya (1995) studied river water quality of Bagmati at Chovar and Shankhamul, and Manohara Khola. The number of coliforms detected were 38138 cells/100ml, 1602 cells/100ml and 7627 cell/100ml for these sites, respectively. ENPHO (1996) analyzed microbial water quality of different streams of Shivapuri watershed area including Bagmati, Nagmati, Shyalmati and Sundarijal reservoir. The result showed that in all the water sources of Shivapuri faecal contamination was found. The average total coliform densities found ranges from 600 to 2850 col/100ml in the streams and 1175 to 3800col/100ml in the water from reservoirs. The average faecal coliform densities were at the range of 8 to 169col/100ml and 35 to 160col/100ml in the water from streams and reservoirs, respectively.

Shrestha and Sharma (1996) carried out water analysis in Lalitpur. Out of 49 samples from nine different sites, 24 (49%) samples were found to be bacterial contamination. ENPHO (1997) on monitoring and assessment of water quality in the Shivapuri watershed from August 1996 to August 1997, found that among Bagmati, Shyalmati, Nagmati and Sundarijal reservoir, Shyalmati had F.C. count 2 to 1,200 col/100ml, Nagmati had 4 to 390 col/100ml, Bagmati had 96 to 3,800 cells/100ml and Sundarijal reservoir had 144 to 10, 900 col/100ml.

ENPHO (2001) carried out water quality analysis in Kavre, Parsa and Chitwan. The bacteriological water quality in Kavre indicated that about 76% water samples at Mahadevsthan, 86% in Kusadevi, 82% in Dhumkharku, 82% in Sathighar and 64% in Shyampati were contaminated by faecal matter and unsafe for consumption. In Parsa, about 36% in Sakhuwa Parsami, 13% in Bageshwori Titrauna, 14% in Pancharuhhi, 55% in Belwa and 7% in Amarpati water samples were contaminated by faecal matter and unsafe for consumption. In Chitwan, about 71% in Dibya Nagar, 63% in Geetanagar, 93% in Jutpani, 88% in Pithuwa and 79% in Kabilas water samples were contaminated by faecal matter and unsafe for consumption.

Pradhan (2001) analyzed the water quality situation of the Bagmati river and its tributaries using bacteriological and saprobic measures. The water quality was determined for different uses on the basis of the enumerated bacteria according to different standards given by WHO, PESCOD and EC. According to this study, the headwater regions were found within the standard of potable raw water abstraction with simple to extensive treatment.

Das and Jha (2002) analyzed MPN of coliform in drinking water samples of handpumps, taps and ponds at Janakpur. The MPN of coliform bacteria varied from 10 to 1060per100ml. Tube well water samples contained 10 to 54 coliforms per 100ml of sample, corporation water contained 15 to 180 coliforms per 100ml of sample while the pond water samples contained 120 to 1060 coliforms per 100ml of sample. The study showed that all the fifteen water samples were found to contain total coliform bacteria exceeding the WHO water quality standard.

Khatib *et al*. (2003) studied on quantitative and qualitative determinants of drinking water in the Tulkarem district in Palestine. Five hundred drinking water samples were collected from different sources in the district for the year 1999. Out of these samples, 34% and 92% were contaminated with total coliforms and faecal coliforms, respectively.

Physico-chemical characteristics of Soil

Regmi and Zoebisch (2004) studied on soil fertility of Bari and Khet land in a small watershed of middle hill region of Nepal and found that Soil fertility status of nitrogen (N), phosphorous (P), potassium (K) and organic matter (OM) was found 0.13%, 14.38 kg/ha and 305.86 kg/ha respectively in *Bari* while o.14%, 54.53 kh/ha and 648.90 kg/ha respectively in *Khet* land. The pH was found to be slightly low, more acidic in *Khet* than in *Bari* land.

Ghimire *et.al*. (2018) carried out assessment of soil quality for different land uses in the chure region of central Nepal indicated that OM was found higher in forest soil (2.56%) and lower in degraded land soil (0.86%), Total nitrogen was found higher in the forest soil (0.27%) while it is found lower in degraded land (0.07%), Available phosphorous for all the land use fell in low level among them highest amount was found in bari soil 24.16kg/ha followed by khet 15.91kg/ha, Forest 9.77kg/ha and degraded land 1.22kg/ha.

Buddhathoki (2012) carried out A case study of soil nutrient analysis of Pauwa VDC and found that soil of Pauwa VDC contained medium levels of nitrogen (0.126%- 0.42%) and organic matter content (3-5.5%) while the potassium availability in soil was found to be high (118-339.52 kg/ha). Phosphorus was found to be low and pH value ranged from slighly acidic to medium acidic soil (19.98-44.49%).

Bajracharya *et al*. (2006) carried out assessment of soil quality using physiochemical and biological indicators in a mid-hill watershed of Nepal and concluded that Soil organic carbon (SOC- 2.4 to 2.6%) and total nitrogen (TN:-0.10 to 0.16%) were similar for the soils of khet, bari, forest and grazing, while available phosphorus (P:-10 to 29 ppm) varied highly even within khet, bari, forest and grazing land uses.

CHAPTER 3: METHODOLOGY

3.1 Site selection and sampling

Kulekhani area was selected as the study site. The sub-watersheds of the Kulekhani reservoir were selected for the sampling of water. The water samples were collected from Chitlang khola, Bisenkhel khola, Palung khola, Thado khola, Chalkhu khola and dam site. Soil samples were collected from forest, grassland and agricultural land. The samples were taken by digging a V shaped pit of 15 cm from surface. Soil from each site was mixed properly and then analyses were performed.

3.2 Description of the Study area

The Kulekhani Watershed area of the Kulekhani Reservoir was selected for the study area. It is located in the Makwanpur district of Bagmati Province. The reservoir (also known as Indrasarbar) synonymously known as Kulekhani Hydropower. The total area of the watershed is 124.67 km^2. Geographically it is extended from 27^0 34' 54" N to 27^0 40' 59" N and 85^0 01' 21" E to 85^0 12' 20" E.

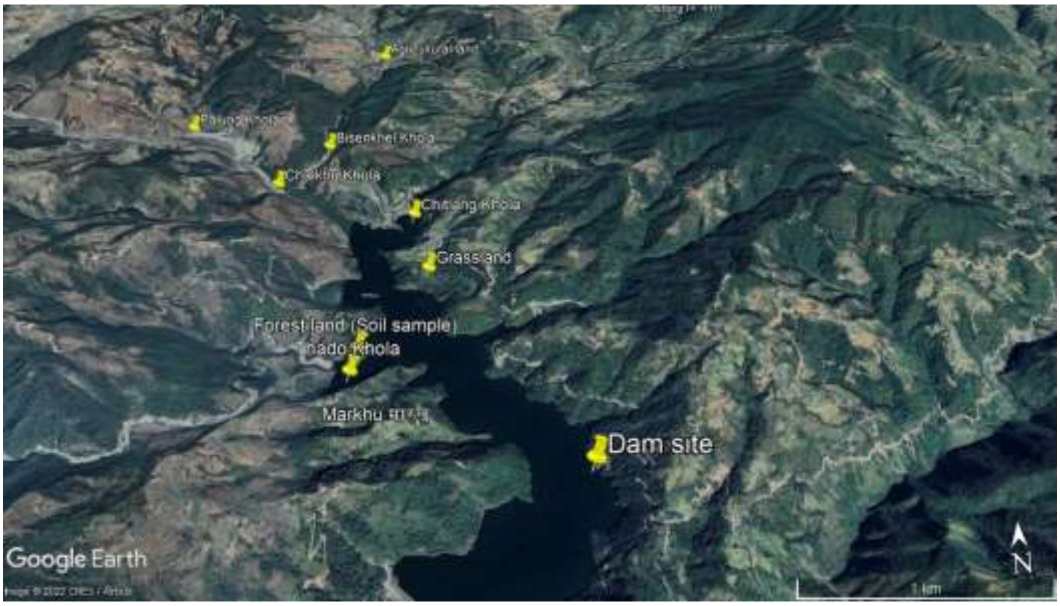


Figure 4: Sampling sites of water and soil sample

Geology

Geology of the study area comprises the Lesser Himalayan rocks of the Kulekhani Formation, Markhu Formation and the Tistung Formation (Figure 4). Granitic intrusion is found in the south-western region and Quaternary deposits are distributed as major stream valley-filled deposits. Palung valley consists of granite and phyllite whereas Markhu area is dominated by marble. In general, phyllite, schists and quartzite are mostly found in the Kulekhani watershed.

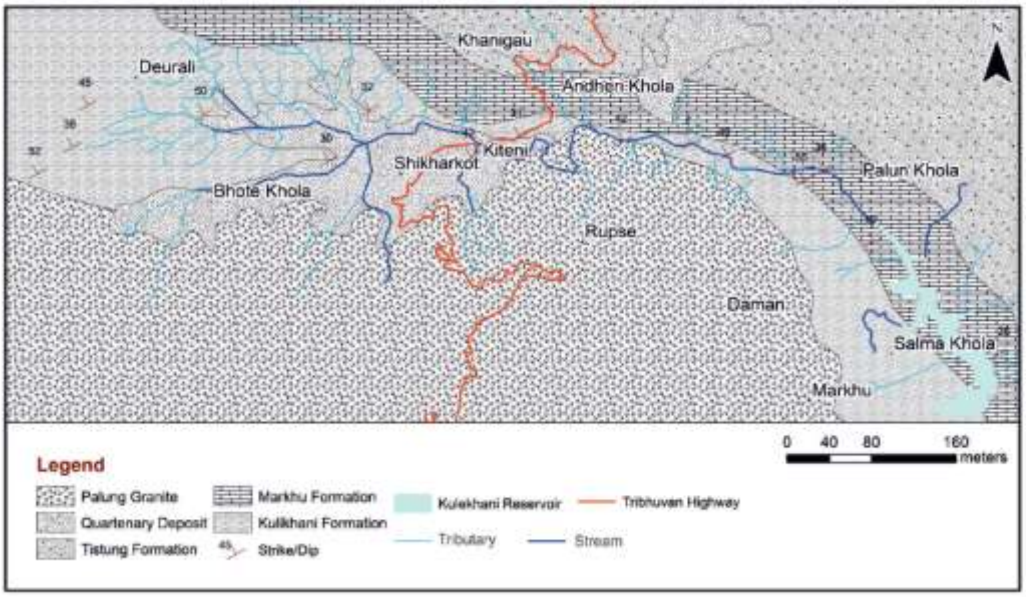


Figure 5: **Geological map of the study area (modified after Stöcklin and Bhattarai, 1977; Stöcklin, 1980)**

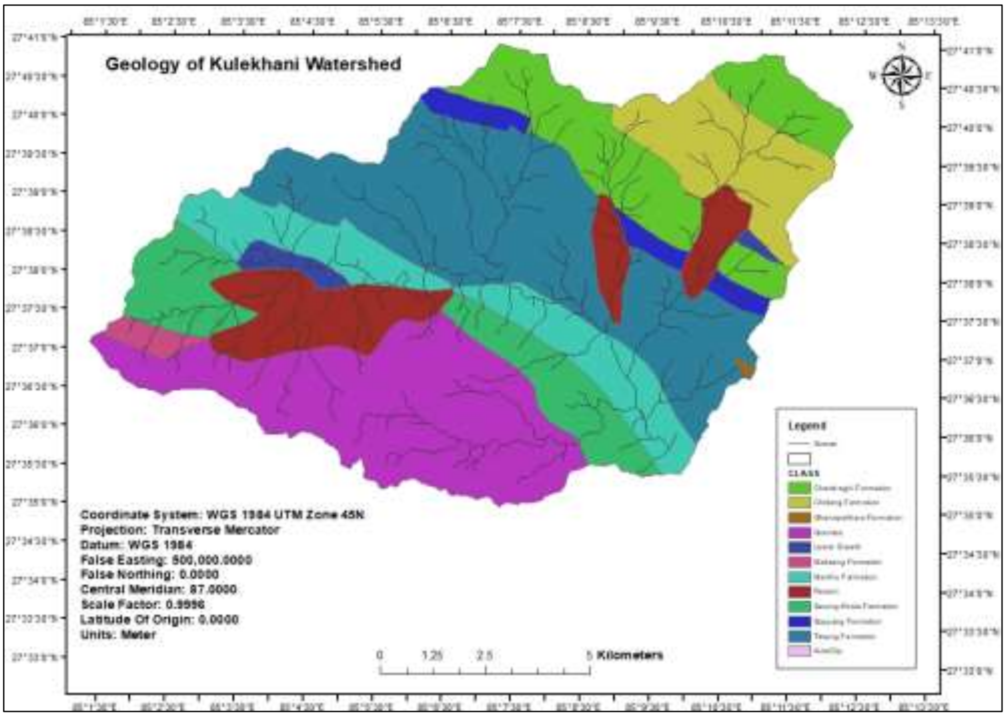


Figure 6: Geology of Kulekhani Catchment area

Rocks

The rocks of the Kulekhani area belong to the Bhimphedi Group and the Phulchauki Group of the Kathmandu Complex (Stöcklin, 1980). The Bhimphedi Group is represented by the Chisapani Quartzite (fine-grained quartzite), the Kulikhani Formation (alternating quartzite and schist), and the Markhu Formation (alternating marble and schist). The overlying Phulchauki Group is represented by the Tistung Formation (slate and phyllite), the Sopyang Formation (slate and limestone), and the Chandragiri Limestone. There are from three to five sets of joints in the rock. In the study area, the Palung Granite is intruded in the Kathmandu

Complex and crops out on the right bank of the Palung Khola in the southern part of the watershed. Generally the granite is highly weathered and changed into yellow-brown soil. As a result, a large amount (more than 60%) of sand and gravel in the Kulekhani reservoir was derived from the Palung Granite. The steep rocky cliffs and gentle soil terraces indicate the control of lithology in the development of landforms. The Chandragiri Limestone and the Palung Granite form high peaks whereas the soft rocks (i.e. slate and phyllite) constitute moderate slopes.

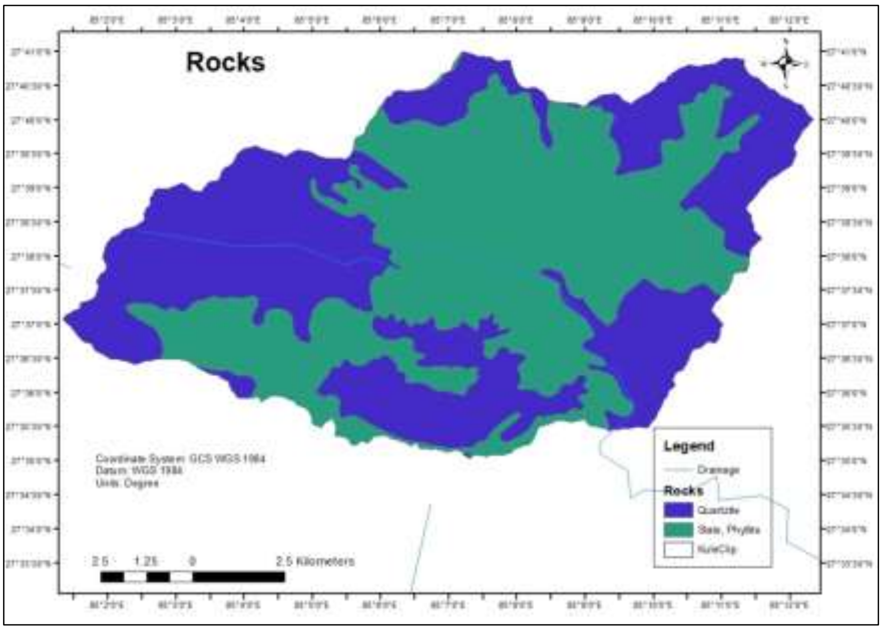


Figure 7: Rocks in the Kulekhani Catchment area

Soils

Soils cover about 3/4 of the watershed area and are exposed along the roads and riverbanks. Alluvial terraces are developed mainly along the Palung Khola, Chuliprang Khola, Tistung Khola, Bisingkhel Khola and Chitlang Khola (Fig.1). The dominant soil colour is yellowish brown and the depth of soil varies from 1 to >6 m. In the Kulekhani watershed, several alluvial and debris fans exist, and the major ones are located at the mouths of the Palung Khola, Kiteni Khola, Bisingkhel Khola, and the Thado Khola.

The residual soils are commonly developed on gentle hill slopes. They are found on hilltops, spurs, and ridges, generally at an altitude of more than 1600 m. The residual soil over granite occupies the southern part of the watershed and its thickness varies from 1 to 6 m. The colluvial soils are present on the valley slopes. The colluvial soils, deposited by landslides, are mainly on the foothills. An extensive area (about 6000 m^2) covered by coarse colluvial soil occurs along the right bank of the Palung *Khola,* near Tasar. At Phedigaun, colluvial soil is frequently observed at an altitude of 1900 to 2500 m.

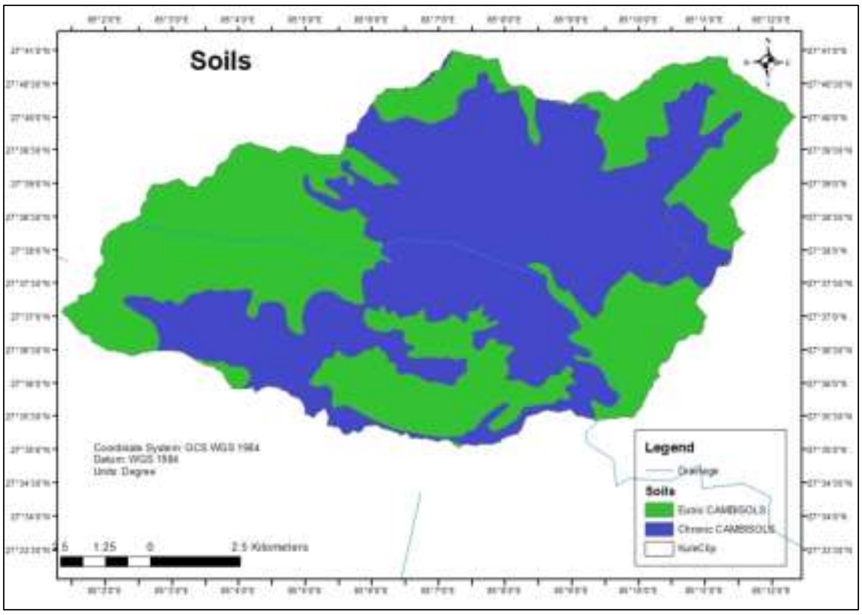


Figure 8: Soils of Kulekhani Catchments area

Geomorphology and Topology

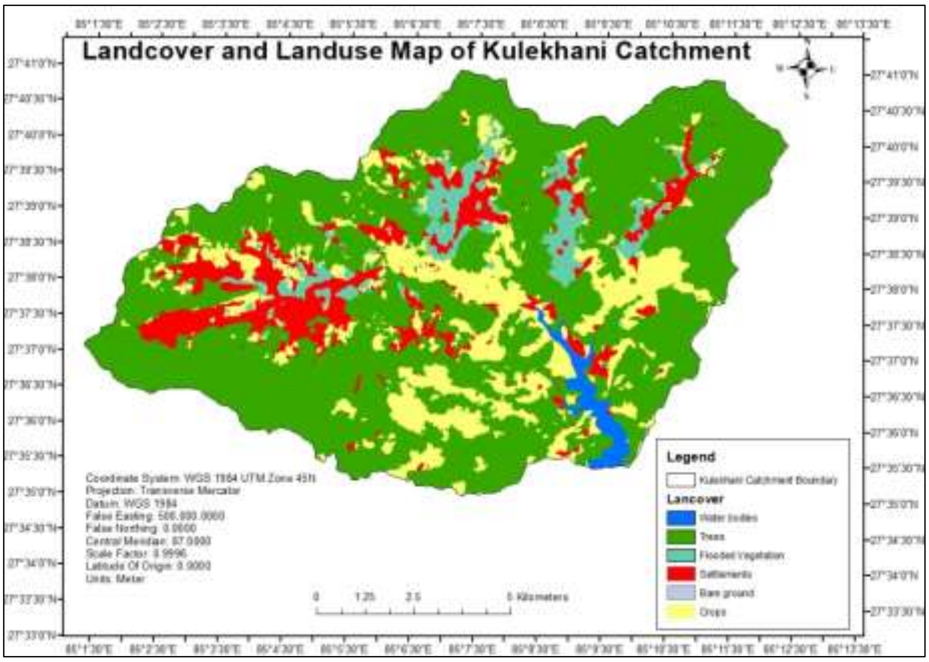
The Kulekhani river basin is composed of rugged mountains together with valleys, alluvial fans, river terraces and flood plains. Geomorphology of this area can be divided into the Mahabharat range and the midlands valley. The Mahabharat range is characterized by steep topology whereas the midland valleys are relatively flat. The dominant feature of the Kulekhani watershed is the high variation in altitudes. Terrains elevation varies from 1534 m at dam site to 2621 m at peak of Simbhanjyang over the southern part of the watershed.

Wide flat land spreads throughout the middle part of the watershed mainly Palung, Tistung and Chitlang. The geology of the Kulekhani area consists of Precambrian to Cambrian metamorphic rocks of the Markhu formation, Kulekhani formation, Chisapani formation, Kalitar formation and granites (Stocklin and Bhattarai, 1977) metamorphic rocks.

Soil and Land use

Forest occupies about 44% of the entire watershed and the sloping agricultural land is about 34%. The remaining 22% of watershed consist of grazing lands, rock fields, landslides, reservoirs and others (DOSC). Major landslides were observed in the southern part of the watershed. The mountain soils are derived from the parent rock consisting mostly of phyllite, granite and quartzite. Soils are poorly developed in the Mahabharata range, with forest podsols of relatively low fertility and high readability. In most places phyllite being susceptible to weathering gives rise to ferruginous soil. In quartzite zone, there is very little development of soil. In places where granite rocks are exposed the feldspar is highly weathered and gives kaolin-bearing soil. The climate also works differently in the soil formation in the mountainous part.

The midland region is composed of phyllitic shicsts, limestone, sandstones and states. Most slopes are under 250 and weathering horizons are deeper than in Mahabharata range. The soils in the lowlands of midland region are deep, rich alluvial or in situ soils and very suitable for cultivation. Northward, on the ridge slopes are thinner and erodible.



Source: ICIMOD, 2020

Figure 9: Landuse map of Kulekhani Watershed

Table 1: Landuse area of Kulekhani Catchment area

S.N	Landuse	Area (ha)
1	Water bodies	197.68
2	Trees	8047.25
3	Flooded vegetation	704.61
4	Settlements	1322.74
5	Bare ground	1.31
6	Crops	2121.31

General climate

Due to the variation in topography, the climate of Kulekhani watershed varies from subtropical at low lands to temperate at higher elevations. As the watershed is affected by monsoon it has four distinct seasons viz., pre-monsoon (March to May), monsoon (June to September), post monsoon (October to November) and winter (December to February).

It is under the influence of two major climatic zones namely warm temperate humid zone and cool temperate humid zone, which are mostly found in between the altitude 1500 to 2000m and above 2000m respectively. The average annual precipitation over the watershed is about 1500 mm. May to September is the wettest period whereas the winter is distinctively dry period. During winter seasons, the higher elevation such as Simbhanjyang and Daman receive precipitation as snowfall.

River System

The Kulekhani river system is the tributary of the Bagmati river and falls in the second category as it originates in the Middle Mountains. It is further divided into eight divisions based on the drainage system. Each system is known by the name of the major river that catches all the incoming water drained towards it. They are: Palung Khola, Sankhmool, Tistung Khola, Bisingkhel Khola, Chitlang Khola, Reservoir, Simbhanjyang Khola and Tasar Khola. Each river system represents separate watershed and they are Palung, Kitini, Kunchhal, Bisingkhel, Tubikhel, Simlang, Nalibang, and Tasar respectively.

The tributaries originating from southern mountains have relatively steeper river gradient than those originating from northern mountains. Kulekhani river joins the Bagmati river at about 9 km to southeast of dam. Total length of the rivers in the Kulekhani Watershed is 625 km and the area is 124.97. The average density is 4.96 km/km^2.

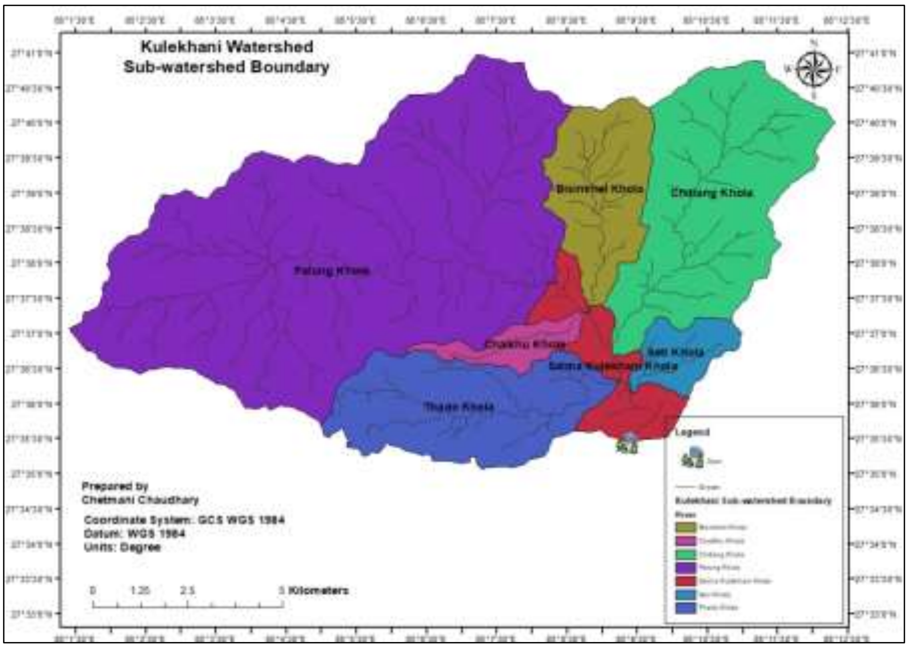


Figure 10: Kulekhani Sub-Watershed map

Table 2: Details of Sub-watershed of Kulekhani Catchments area

S.N	River	Area (km^2)	Stream_density
1	Bisinkhel Khola	9.654	19.648
2	Chitlang Khola	22.639	8.378
3	Chalkhu Khola	2.681	70.756
4	Seti Khola	3.356	56.525
5	Palung Khola	62.622	3.029
6	Salma Kulekhani Khola	5.966	31.796
7	Thado Khola	14.875	12.751

Vegetation

Sub-tropical and some temperate vegetation type are prominent around study site and catchments area. They are *Alnus nepalensis*, *Prunus cerasoides*, *Quercus glauca*, *Pinus roxburghii*, *Quercus semecarpifolia*, *Rhododendron arboreum*, *Lyonia ovalifolia*, *Myrica esculenta*, *Gaultheria fragrantissima* etc. The recorded wildlife in the study area include mammalian species such as Leopard (*Panthera pardus*), Wild boar (*Sus scrofa*), Jackal (*Canis aureus*), Rhesus monkey (*Macaca mulatta*) etc.

Fishes

The fishes found in the reservoir are silver carp (*Hypophthalmichthys molitrix*), Bighead carp (*Aristichthys nobilis*), Grass carp (*Ctenopharyngodon idella*), Common carp (*Cyprinus carpio*), Rohu (*Labeo rohita*), Naini (*Cirrhinus mrigala*), Bhakur (*Catla catla*). These fishes are farmed in the cage farm and also found in the free states in the reservoir.

Figure 11: Bighead fish

Figure 12: List of fish found in the reservoir

3.3 Field visit

The field visit was carried out on 8th Asar, 2079 and six samples were collected from the tributaries of Kulekhani reservoir (Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site) and three samples collected from different landuse (agricultural land, forest land and grassland).

3.4 Data collection

The data collected from the Indrasarobar area were carried out through primary and secondary source of data collection. The primary source of data collection included the field visit, sampling, site observation, meeting with reservoir personnel and locals, laboratory test. Similarly, the secondary source of data collection included literature review, library, newspaper, desk study, published and unpublished articles and journals, dissertation etc.

Materials required

The collection of sample from the different sites was carried out through the use of different materials. The following materials were:

- Spade or auger (screw or tube or post hole type)
- Khurpi
- Sampling bags
- Plastic tray or bucket/ Newspaper
- Plastic Bottle
- Sterile plastic bottle
- Zipper bags
- Marker
- Tags
- GPS
- Notebook/Pencil
-

(a) Soil sampling

The collection of sample from the different sites was carried out by the following procedure:

Procedure

1. The sites were divided into different homogenous units based on the visual observation and farmer's experience.
2. The surface litters were removed at the sampling spot.
3. The surface was digged into a 'V' shaped to a depth of 15 cm in the sampling spot using spade and drew the soil sample.
4. At least 5 samples were collected from each sampling unit and placed in a newspaper.
5. The samples were mixed thoroughly and removed foreign materials like roots, stones, pebbles and gravels.
6. The bulk was reduced to about half to one kilogram by quartering or compartmentalization.

7. Quartering was done by dividing the thoroughly mixed sample into four equal parts. The two opposite quarters was discarded and the remaining two quarters was remixed and the process repeated until the desired sample size was obtained.
8. The sample was collected in a zipper polythene bag.
9. The bag was labeled with information like location of the site, date of collection, name of the sampler *etc*.

(b) Water sampling

The water sample was collected from the different sites was carried out by the following procedure:

Procedure

a. A point in the stream was selected that was inputs from tributaries to allow thorough mixing.
b. The sample was collected in three bottles viz. 1 littre plastic bottle, glass stopped bottle (300 ml) and 100 ml sterile containers.
c. Sample container with the opening pointing was immersed directly down to maintain a volume of air in the container, thereby avoiding the collection of any surface films.
d. The container was filled, rinsed and empty the rinsed water or at a sufficient distance from sample site to prevent mixing of rinse water with the water to be sampled. Repeated.
e. After the collection of water sample in glass stopped bottle and then poured one ml $MnSo_4$ and one ml KI using separate pipettes in the bottle. The precipitate was appeared. The stopper was placed and the contents were shaked well and inverted the bottle. Repeated.
f. About 100ml sterile bottle was filled with sample water and labeled and put in the cold box for maintaining the temperature.
g. Completed sample labels and field data sheets.

Sampling reports should contain at least the following information:

- Location (and name) of sampling site, with coordinates and any other relevant information.
- Details of sampling point.
- Date of sampling.
- Method of sampling.
- Time of sampling.
- Name of sampler.
- General environment and climatic conditions.
- Nature of pre-treatment.
- Preservation procedure.
- Water quality parameters collected in the field.
- Any information which may affect the results of analysis.

Once collected, samples was stored, handled, and transported in such a manner as to: prevent damage to containers or labels, minimized or eliminated degradation of the sample, and prevented contamination of the sample. Upon delivery to the analytical laboratory information relating to the time between sample receipt and analysis, storage and preservation methodology employed at the laboratory, and analytical technique was documented.

3.5 Data analysis

The data analysis of the water and soil data was done using MS-excel and interpreted with National guidelines of water and soil quality of Nepal. Arc GIS (Version 10.5) software was used for study area maps, mapping of the socio-economic, biological, and physical information. The information explored in the field and secondary sources of information were triangulated from multiple sources which include consultation with experts, a local institution, and key informants.

Laboratory analysis: The collected water and soil sample was tested in laboratory (Nepal Environmental and Scientific Services Pvt.Ltd.) and interpreted with the findings.

3.6 Methods of Soil and Water analysis

Following methods were used to perform lab analysis of the sampled soil and water:

Table 3: Methods for Soil analysis

S. N.	Parameters	Test Methods
1.	pH at 23^{o}C, (1:1)	pH Meter; J.M. & Ingram, J.S.I. / USDA
2.	Electrical Conductivity, (µS/cm)	Conductivity Meter, Soil Analysis, Jackson M. L. A. L
3.	Organic Matter, (%)	Modified Walkey & Black, AndersonJ.M & Ingram, J.S. I. / USDA/ FAO Bulletin No. 19
4.	Available Nitrogen, (%)	Kjeldahl Digestion, Soil Analysis, Jackson M.L, Bremner J.M and C.S Mulvaney 1982.
5.	Available Phosphorous as PO_4-P, (µg/g)	Bary, FAO Fertilizer & Plant Nutrition Bulletin No. 19, 2008
6.	Available Potassium, (µg/g)	AAS, FAO Bulletin No. 19.

Table 4: Methods for water analysis

S. N.	Parameters	Test Methods
1.	pH at 24^{o}C	Electromeric, 4500 - H^+ B,: APHA
2.	Electrical Conductivity, (μS/cm)	Conductivity Meter, 2510 B, APHA
3.	Turbidity, (NTU)	Nephelometric, 2130 B, APHA
4.	Total Hardness as $CaCO_3$, (mg/L)	EDTA Titrimetric, 2340 C, APHA
5.	Total Alkalinity as $CaCO_3$, (mg/L)	Titrimetric, 2320 B, APHA
6.	Chloride, (mg/L)	Argentometric Titration, 4500 - Cl^- B, APHA
7.	Ammonia, (mg/L)	Direct Nesslerization, 4500 - NH_3 C APHA

8.	Nitrate, (mg/L)	UV Spectrophotometric Screening, 4500 - NO_3^- B, APHA
9.	Nitrite, (mg/L)	NEDA, Colorimetric, 4500 - NO_2^- B, APHA
10.	Biological Oxygen Demand, (mg/L)	Winkler Azide Modification (Dilution & Seeding), 5210 B, APHA, ISO 5815 – 1989
11.	Dissolved Oxygen, (mg/L)	Winkler Azide Modification, 4500 - O C, APHA
12.	Calcium, (mg/L)	EDTA Titrimetric, 3500 - Ca B & 3500 - Mg B APHA
13.	Magnesium, (mg/L)	
14.	Iron, (mg/L)	Direct Air - Acetylene AAS, 3111 B, APHA
15.	Manganese, (mg/L)	
16.	*E. coli* Count, (MPN/100mL)	Membrane Filtration, 9222 D, APHA

CHAPTER 4: RESULTS AND DISCUSSION

Five tributaries of Kulelhani reservoir were selected for this investigation. The names of the rivers are Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site. Five samples of each of the tributaries were examined. The pH, electrical conductivity, turbidity, toatal hardness as $CaCo_3$, total alkalinity, chloride, ammonia, nitrate, nitrite, biological oxygen demand, dissolved oxygen, calcium, magnesium, iron, manganese, E.coli of the rivers were evaluated. The results with discussion were reported below.

4.1 Water quality test

Electrical Conductivity (EC)

The EC measures the concentration of ions in water. The concentration of ions depends on the environment, movement and sources of water. The soluble ion in the surface water originates primarily by the dissolution of rock materials. Conductivity of an electrolyte solution is a measure of its ability to conduct electricity. Conductivity measurements play a vital role in many industrial and environmental applications. The EC measurement is a rapid, easy, and reliable way of measuring the ionic content in water. Electrolytic conductivity of water is a function of temperature. Generally, conductivity is directly linked with the total dissolved solids in water samples.

The EC values of water samples of the Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be 204, 56, 128,133, 262 and 143 µS/cm respectively. The EC values of the water of Bisenkhel river (262.0 µS/cm) was found higher than other five river water samples. The lowest EC value was reported for the Dam site water (143.0 µS/cm). The EC values of the six river waters are reported in Figure 13.

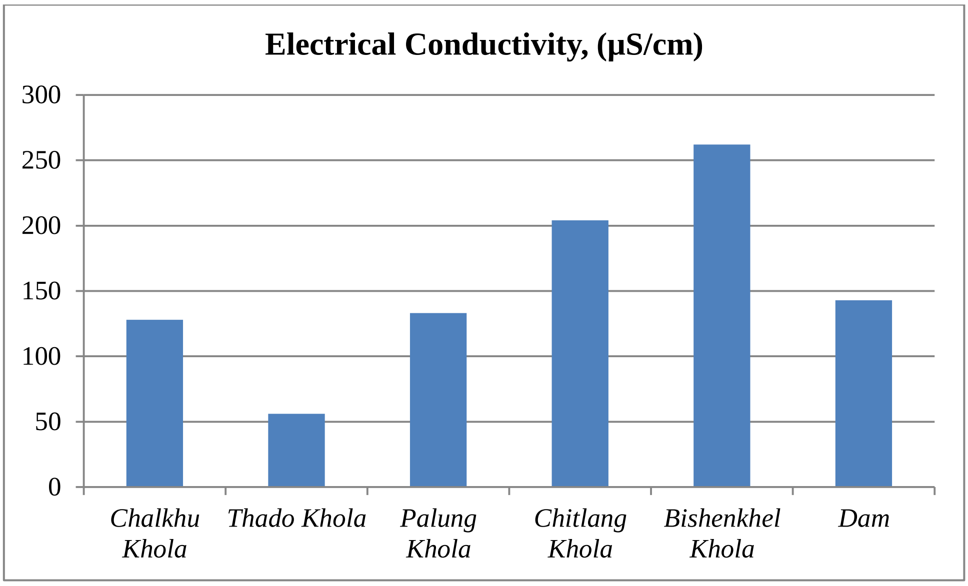


Figure 13: Electrical Conductivity

From this investigation, this is clearly indicated that the Dam site water quality is much better than that of the river Bisenkhel khola. Actually, Bisenkhel khola is flowing from the intense agricultural land, Chitlang and Bajhrabarahi Gau. A lot of agricultural and village wastes are going to the Bisenkhel khola and the khola water became polluted. The Bisenkhel khola ranks among the most polluted rivers in Indrasarobar Rural Municipality and Thaha Municipality. The distance between Dam site and Bisenkhel khola is about 3.5 kilometers. In this investigation, Bisenkhel khola and Dam site were selected. This is to be noted here that the Bisenkhel khola meets in the Kulekhani reservoir and then waters flow towards southwards for the generation of electricity.

pH

Basically the pH value is a good indicator of whether water is hard or soft. The pH of pure water is 7. In general, water with a pH lower than 7 is considered as acidic, and with a pH greater than 7 is considered as basic. The normal range for pH in surface water systems is in the range of 6.5 to 8.5. The higher values of pH represent that there is high chloride, bicarbonate, carbonate in the water samples that means the water is alkaline. The pH values of the waters of the rivers Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be 7.6, 7.9, 7.8, 7.7, 7.9 and 8 respectively. The pH range of tributaries water sample are within the range of healthy fish environment.

Figure 14 showed the pH values of six river water samples. From this investigation, it is clearly evidenced that the Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site water quality are alkaline and were within the standard value for aquaculture. It was recorded that pH level at dam site was highest and lowest in Chitlang Khola. The average value of pH 7 was also reported by (Lacoul and Freedman, 2005 and Shimkhada, 2006). However, the alkaline pH has been reported in the Gokyo lake of Sagarmatha National Park by (Gurung *et al.* 2011, Lacoul & Freedman, 2005 and Tartari *et al*. 1998b).

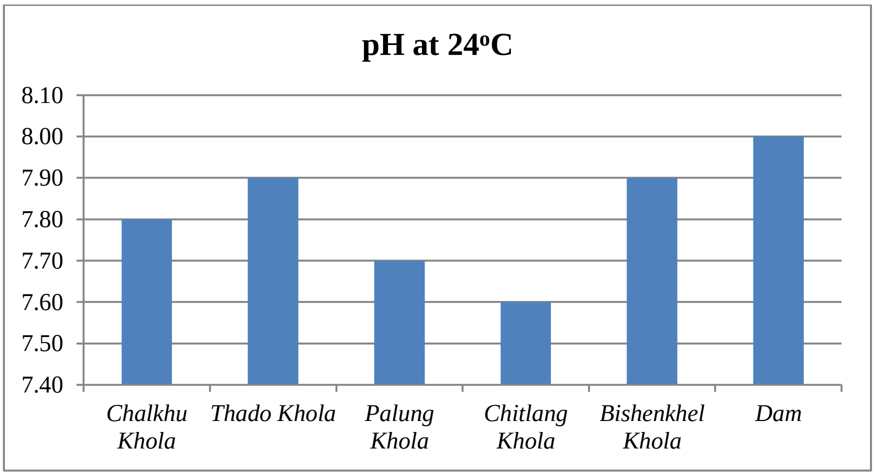


Figure 14: pH of water

Nitrate (NO^{2-} and NO^{3-})

Nitrate concentration is low in fresh domestic wastewater but in the effluent of nitrifying biological treatment plants nitrate may be found in concentrations of up to 30 mg/l. In present study, the concentration of Nitrate of the waters of the rivers Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be 8.49, 1.18, 1.11, 5.17, 7.75 and 3.84 mg/l respectively. Similarly, the concentration of Nitrite of the waters of the rivers Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be 0.03, 0.02, <0.02, 0.02, <0.02 and 0.07 mg/l respectively. According to the Nepal Water Quality Guidelines for Aquaculture, 2008 the concentration of the Nitrate and Nitrite of Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site are within the range of water quality for aquaculture i.e. suitable for cold water fish and warm water fish. The concentration of nitrogen in the tributaries of the reservoir is found to be very minimal which suggests that the contamination from fertilizers, municipal wastewaters, feedlots, septic systems in the water is very low. Similar values have been observed by Shinde et al. (2011) and Verma (2012).

Table 5: Comparison of Nitrate and Nitrite with standard value for Aquaculture

River	Nitrate, (mg/l)	Nitrite, (mg/l)	Standard value of Nitrate for Aquaculture	Standard value of Nitrite for Aquaculture
Chalkhu Khola	1.11	<0.02	<300 mg/l	0-0.05 mg/l for cold water fish 0.06-0.25 mg/l for warm fish
Thado Khola	1.18	0.02		
Palung Khola	5.17	0.03		
Chitlang Khola	8.49	0.03		
Bishenkhel Khola	7.75	<0.02		
Dam	3.84	0.07		

Chloride

Chloride is an indication of salinity in water. Surface water containing significant amount of chloride also tend to have high amount of Na ions indicating the possibility of contacts with water of marine origin. From an environmental standpoint, chloride is basically a conservative parameter and may serve as an index of pollution occurring in natural freshwater from primary sources such as industrial and municipal outlets. The chloride concentrations in the Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be 1.96, <0.5, <0.5, 1.47, 4.41 and 0.98 mg/l respectively.

The concentration of chloride is found to be high in Chitlang khola followed by Bisenkhel Khola, Palung Khola, Dam site, Thado khola and Chalkhu khola. According to the Nepal Water Quality Guidelines for Aquaculture (2008), the concentration of the chloride of Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site are within the range of water quality for aquaculture i.e. fish can survive at <600 mg/l chloride but the production is not optimum. All the tributaries of Kulekhani reservoir are within the range of chloride for the fish survival.

Table 6: Comparison of Chloride with standard value for Aquaculture

River	Chloride, (mg/L)	Standard value for Chloride for Aquaculture
Chalkhu Khola	<0.5	Fish can survive at <600 mg/l chloride but the production is not optimum
Thado Khola	<0.5	
Palung Khola	1.47	
Chitlang Khola	1.96	
Bishenkhel Khola	4.41	
Dam	0.98	

Ammonia

Ammonia is a nutrient that contains nitrogen and hydrogen. The concentration of ammonia in the Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be <0.05, <0.06, <0.05, <0.05, <0.05 and 0.11 mg/l respectively. The concentration of ammonia is found to be high in Dam site followed by (0.11 mg/l) followed by Thado khola, Bisenkhel Khola, Palung Khola and Chalkhu khola. According to the Nepal Water Quality Guidelines for Aquaculture, 2008 the concentration of the ammonia of Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site are within the range of water quality for aquaculture (Table 9). The concentration of ammonia was found lesser than acute effect level required for protection of fresh water aquatic ecosystem.

Table 7: Comparison of Ammonia with standard value for Aquaculture

River	Ammonia,(mg/L)	Standard value for Ammonia for Aquaculture	Standard value for the protection of Aquatic ecosystem
Chalkhu Khola	<0.05	For cold fish (0-25 µg/l) for warm fish (0-30 µg/l)	Target water quality range: <7 µg/l Chronic effect value: <15 µg/l Acute effect value: <100 µg/l
Thado Khola	0.06		
Palung Khola	<0.05		
Chitlang Khola	<0.05		
Bishenkhel Khola	<0.05		
Dam	0.11		

Calcium

Calcium is most abundant ion in the freshwater and is an important in shell construction, bone building and plant precipitation of lime (Jhingram, 1975). Calcium, in the form of the Ca^{2+} ion, is one of the major inorganic cations, or positive ions, in saltwater and freshwater. It can originate from the dissociation of salts, such as calcium chloride or calcium sulphate, in water. Most calcium in surface water comes from streams flowing over limestone, $CaCO_3$, gypsum, $CaSO_4.2H_2O$ and other calcium- containing rocks and minerals. Calcium carbonate is relatively insoluble in water, but dissolves more readily in water containing significant levels of dissolved carbon dioxide. The concentration of ammonia in the Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be 24.45, 4.01, 15.23, 13.63, 38.07 and 15.23 mg/l respectively. The highest concentration of calcium was found in Bisenkhel khola followed by Chitlang khola Chalkhu khola, Dam site, Palung khola and Thado khola. Calcium content in water of this reservoir is within the desirable limit.

The concentration of calcium ions (Ca^{2+}) in freshwater is found in a range of 0 to 100 mg/L and usually has the highest concentration of any freshwater cation (Abboud, 2014). A level of 50 mg/L is recommended as the upper limit for drinking water. High levels are not considered a health concern; however, levels above 50 mg/L can be problematic due to formation of excess calcium carbonate deposits in plumbing or in decreased cleansing action of soaps. If the calcium ion concentration in freshwater drops below 5 mg/L, it can support only sparse plant and animal life, a condition known as oligotrophic.

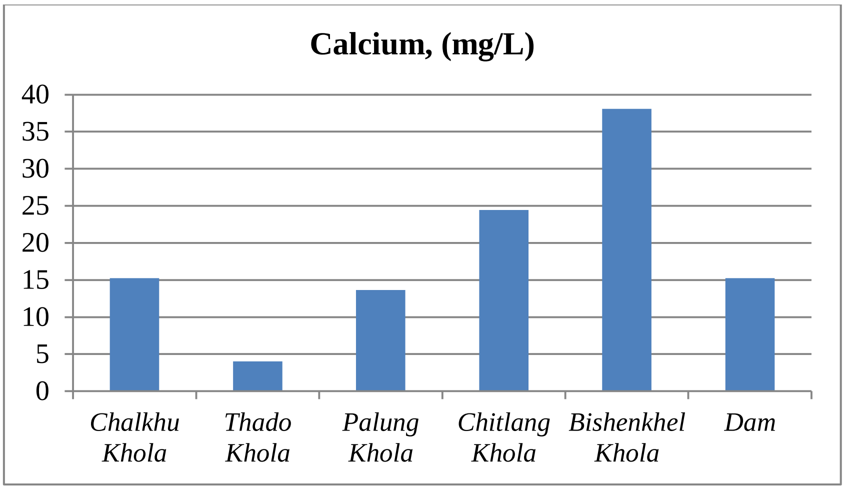


Figure 15: Calcium level of water

BOD

BOD is a measure of the dissolved oxygen consumed by microorganisms during the oxidation of reduced substances in waters and wastes. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen aquatic organisms which become stressed, suffocate and die. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, eedlots and food-processing plants; failing septic systems; and urban storm water runoff. The discharge of wastes with high levels of BOD can cause water quality problems such as severe dissolved oxygen depletion and fish kills in the receiving water bodies (Penn *et al.* 2003). Chlorine can also affect BOD measurement by inhibiting or killing the microorganisms that decompose the organic and inorganic matter in a sample. In chlorinated waters, such as those below the effluent from a sewage treatment plant, it is necessary to neutralize the chlorine with sodium thiosulphate (APHA, 2005).

In present study BOD values varied between 2 to <1 mg/l (Table 01**)**. The BOD level of Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be <1, <1, <1, <1, 1 and 2 mg/l respectively. The present study concluded that the rate of pollution in the tributaries of Kulekhani reservoir is low and thus quality of water for fish and other aquatic life is fair.

Table 8: Comparison of Ammonia with standard value for Aquaculture

River	Biological Oxygen Demand, (mg/L)	Standard value for BOD for Aquaculture
Chalkhu Khola	<1	< 15 mg/l
Thado Khola	<1	
Palung Khola	<1	
Chitlang Khola	<1	
Bishenkhel Khola	1	
Dam	2	

DO

Oxygen is the single most important gas for most aquatic organisms; free oxygen or DO is needed for respiration. The DO levels below 1 ppm will not support fish; levels of 5 to 6 ppm are usually required for most of the fish population. The average value of DO levels (6.5mg/l) indicates the average quality of river water (APHA, 2005). The range of DO levels for cold water species, intermediate water species and warm water species are 6-9, 5-8 and 5-8 mg/l respectively (GoN, 2008). DO values in our study varied between 6.1 to 9.9 mg/l. The levels of DO of Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site were found to be 7.0, 7.1, 8.1, 7.5, 6.1 and 9.9 mg/l respectively. The highest level of DO was found in Dam site and lowest in Bisenkhel khola. The DO levels of all the samples were within the range of standard value of aquaculture. But the DO level at Dam site is quite high than standard value which signifies the water pollution. The difference in the concentration of DO in water sample of a particular area might be explained by a combined effect of temperature, Photosynthesis, respiration, organic waste, aeration and sedimentation concentration (Badge *et al.*, 1985) The maximum solubility of oxygen in water at standard pressure (1 atm) ranges from about 15 mgL^{-1} at 0ºC to 8 mgL^{-1} at 30ºC i.e. ice-cold water can hold twice as much dissolved oxygen as warm water (Wetzel, 2001).

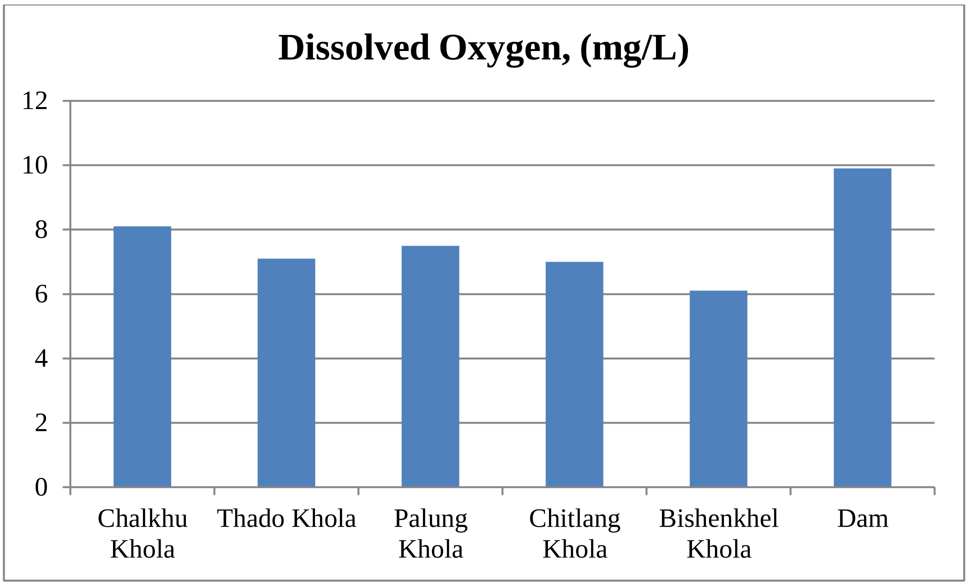


Figure 16: DO level of water

Magnesium

The present study showed that the magnesium level in the Chitlang khola (8.75 mg/l) was the highest followed by Bisenkhel khola (8.51 mg/l) and lowest in Thado Khola (2.19 mg/l). The magnesium level in all the samples meets the standard value of aquaculture (<15 mg/l). Important contributors to the hardness of a water, magnesium salts break down when heated, forming scale in boilers. Chemical softening, reverse osmosis, or ion exchange reduces magnesium and associated hardness to acceptable levels. Magnesium is an essential element in chlorophyll and in red blood cells. Some salts of magnesium are toxic by ingestion or inhalation. Concentrations greater than 125 mg/L also can have a cathartic and diuretic effect (APHA, 2005).

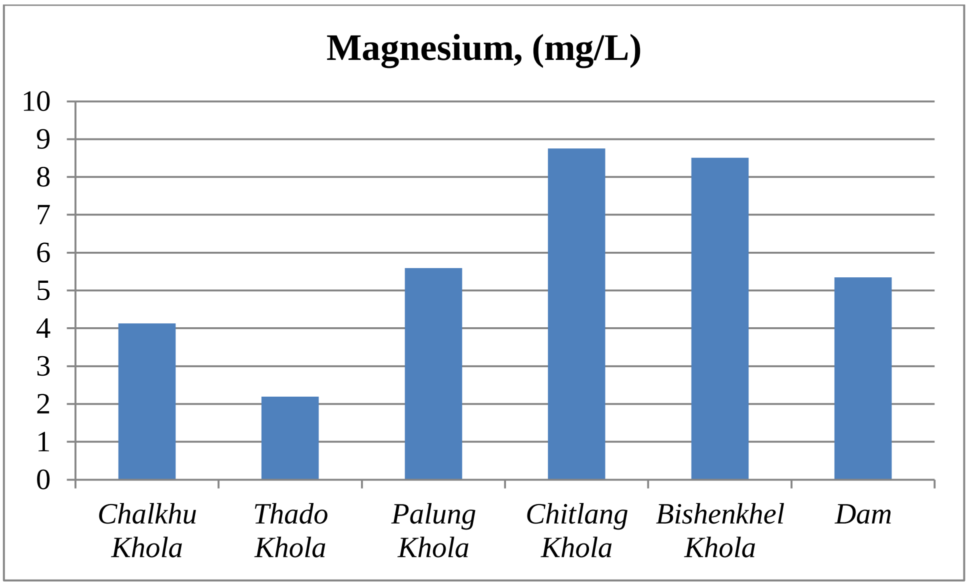


Figure 17: Magnesium concentration in water sample

Manganese

The samples were collected from the Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site. The samples were examined in the laboratory. The highest level of manganese was found in Bisenkhel khola and lowest in Chalkhu khola and Dam site. It refers that the concentration of manganese in all the samples are below the standard range of aquaculture.

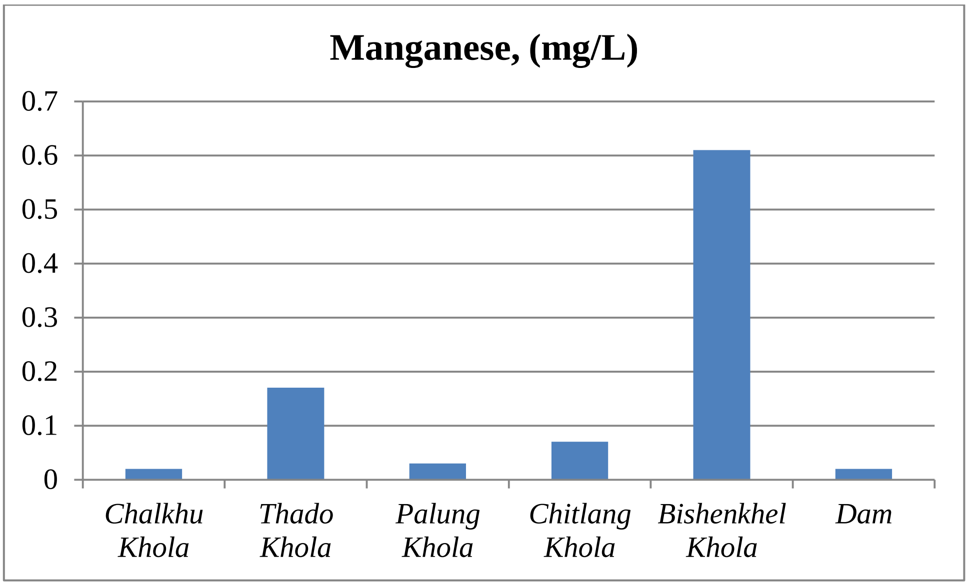


Figure 18: Manganese concentration in water sample

Iron

From the figure, it is illustrated that iron content is highest in Bisenkhel khola and lowest in Chalkhu khola. The content of iron in Chtilang khola, Thado Khola, Chalkhu khola, Palung khola, Bisenkhel khola and Dam site was found to be 1.32, 0.85, 0.13, 0.55, 6.06 and 0.34 mg/l respectively. It refers that the concentration of iron in all the samples are below the standard range of aquaculture and protection of fresh water aquatic ecosystem.

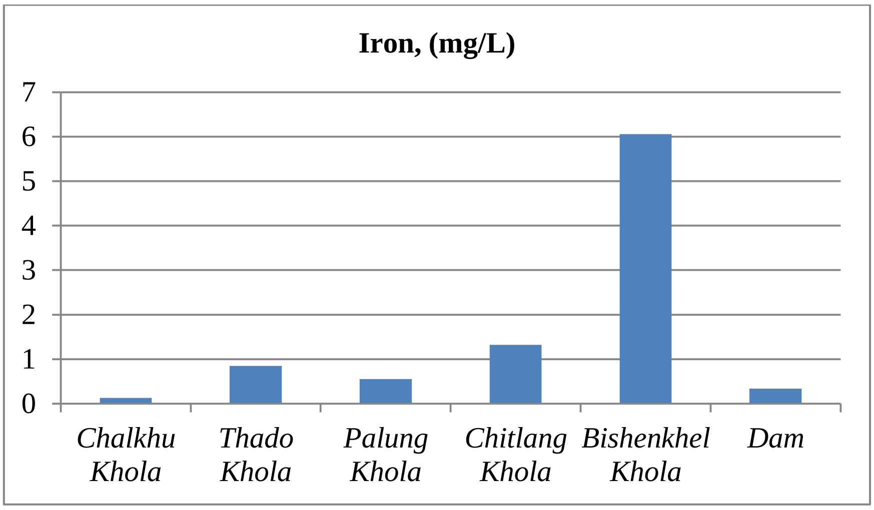


Figure 19: Iron level of water

Alkalinity

Total alkalinity is the measure of the capacity of water to neutralize of strong acid. The alkalinity in water is generally imparted by the salts of carbonates, bicarbonates, phosphates, nitrate, borates, and silicates etc. together with the hydroxyl ions in Free State. The alkalinity was mainly due to water soluble bicarbonates salts whereas the carbonates salts were not in predictable amount because there would be practically no carbonates in water with pH from 4.5 to 8.3 (Jhingran, 1975). The highest alkalinity concentration was in the Bisenkhel Khola at 28% $CaCo_3$ followed by Chitlang Khola (22% $CaCo_3$), Dam site (16% $CaCo_3$), Chalkhu khola (14% $CaCo_3$), Palung khola (13% $CaCo_3$), and Thado Khola (7% $CaCo_3$). It recommends that the concentrations of iron in all the samples are below the standard range of aquaculture. The lower alkalinity indicates that the contamination of HCO_3^- and OH^- ions from minerals and rocks has decreased over the time. Similar results were obtained by Chinnaiah *et al*. (2011).

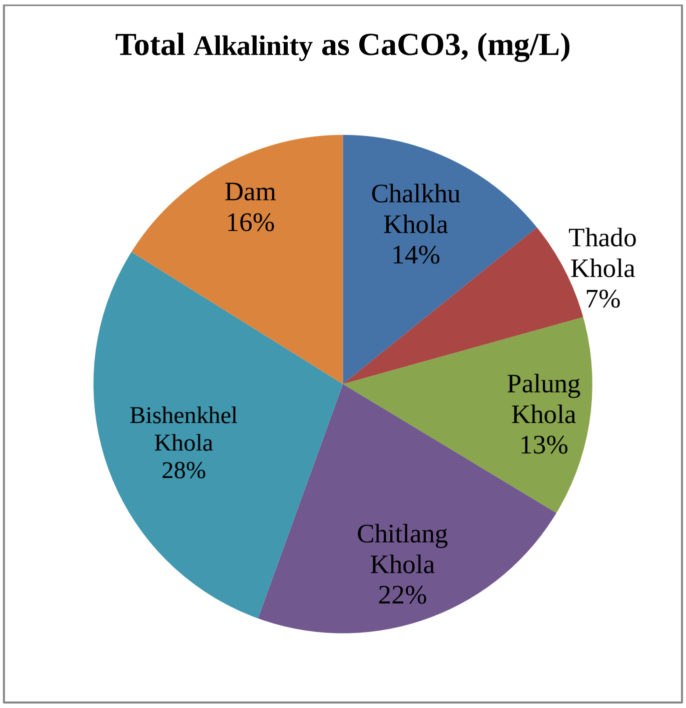


Figure 20: Alkalinity Percentage of water sample

Hardness

Hardness is governed by the concentration of calcium and magnesium salts largely combined with bicarbonates and carbonates giving temporary hardness while sulfate, chloride and other anions of mineral acids causing permanent hardness. The greatest hardness concentration is from the Bisenkhel Khola at 31% $CaCo_3$ followed by Chitlang Khola (23% $CaCo_3$), Palung khola (14% $CaCo_3$), Dam site (14% $CaCo_3$), Chalkhu khola (13% $CaCo_3$) and Thado Khola (5% $CaCo_3$). The hardness level in all the samples meets the standard value of aquaculture (20-100 mg/l). The higher value of hardness was during summer may be due to decrease in water level and evaporation of water. Similar trend was reported by Sangpal *et al.* (2011).

WHO (1991) has classified water on the basis of hardness values as 00 mg/l to 60 mg/l is soft, 61 mg/l to 120 mg/l is moderately hard, 121 mg/l to 180 mg/ l is hard and greater than 180 mg/l is very hard. According to this classification water of the tributaries of this reservoir falls in the category of soft hard. However, hardness of tributaries of this reservoir was within the permissible limit (Department of irrigation, 2008). According to Nepal Water quality guidelines for aquaculture 2008, the target water quality for total hardness as $CaCO_3$ ranges from 20 -100 mg/l.

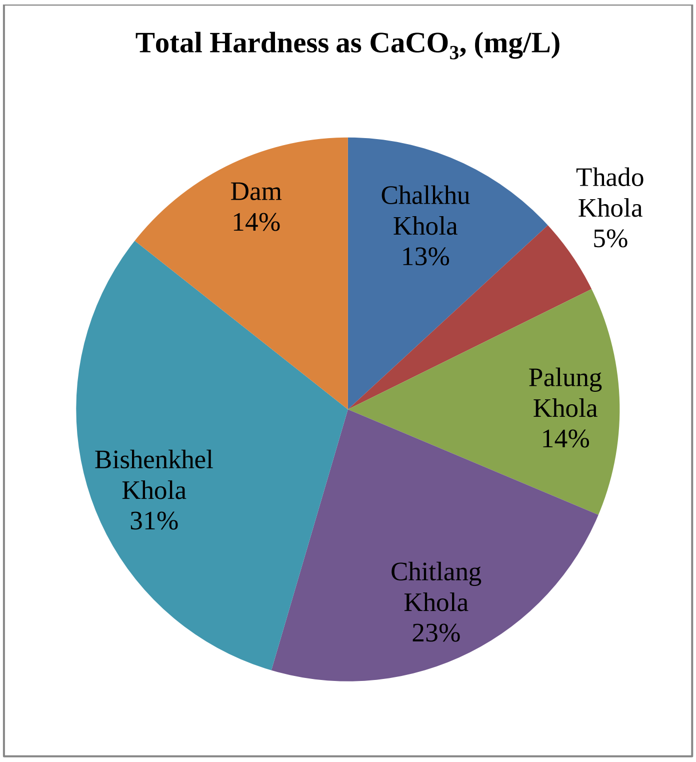


Figure 21: Hardness of water sample

Turbidity

The greatest turbidity concentration is from the Bisenkhel Khola at 79% followed by Chitlang Khola (11%), Thado Khola (4%), Dam site (2%), Palung khola (2%), and Chalkhu khola (1%). The turbidity of water increases with the increase in sedimentation, dissolved solids. High turbidity can be caused by silt, mud, algae, plant pieces, melting glaciers, sawdust, wood ashes or chemicals in the water.

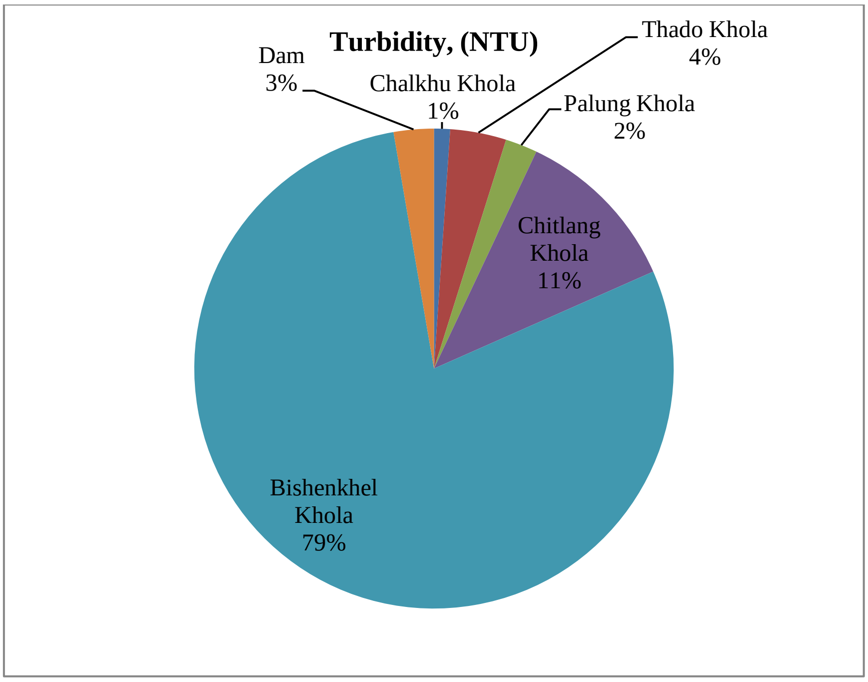


Figure 22: Turbidity of water

E.coli

The most probable number of *E.coli* per 100 ml is found highest in the Palung khola followed by Bisenkhel khola (460), Chitlang khola (460), Chalkhu khola (240), Thado Khola (150) and Dam site (9). Pradhan (2001) also found the contamination of *E.coli* in Bagmati river. Das and Jha (2002) analyzed MPN of coliform in drinking water samples of handpumps, taps and ponds at Janakpur. Shrestha *et al.* (1991) reported FC in Madrikhola, Bhotekhola and Amalabisauni reservoir of Pokhara. The number of coliform refers that it is not recommended for drinking purpose.

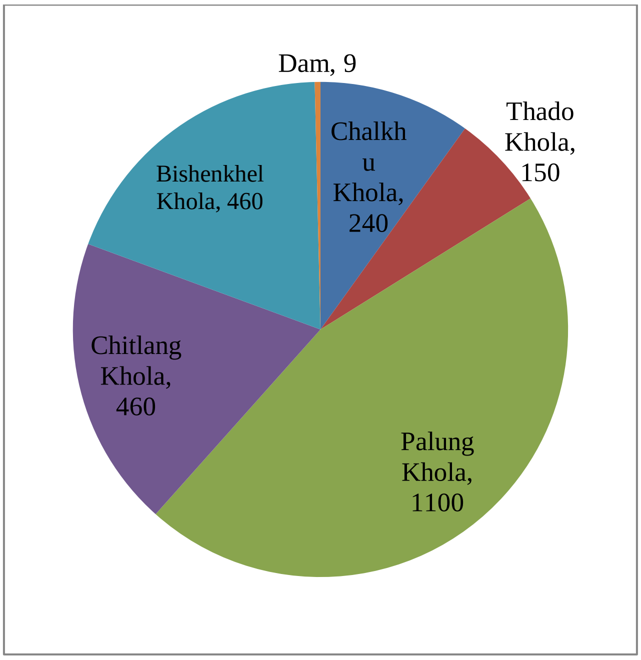


Figure 23: *E.coli* count in water sample

4.2 Soil quality test

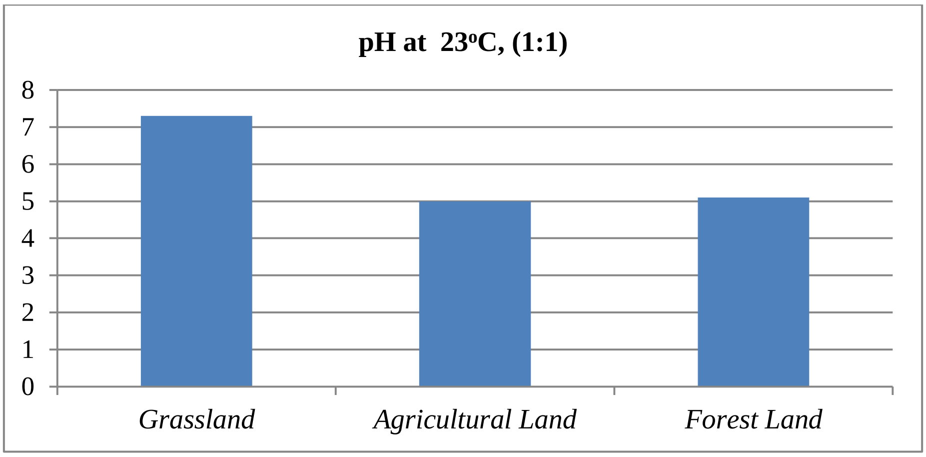


Figure 24: Graph showing pH values of Soil

The pH values ranges from 5.1 to 7.3, the highest pH is recorded in grassland and lowest in forest land and agricultural land. The pH value of grassland is neutral in range (i.e. 7.3) which is suitable for cultivation and healthy growth of grass and availability of nutrients in the soil. But, the pH values of agricultural (pH 5) land and forest land (pH 5.1) fall in acidic range (NARC, 2013). Thus, the reasons for the lower pH levels in agricultural land are most likely to be the input of chemical fertilizer and the effect of leaching induced by the irrigation of agricultural land, contributing to the more acid conditions. Higher rate of application of chemical fertilizer in khet is one of the reasons for acidic pH in the agricultural land as it is reported that farmers used higher dose of chemical fertilizer in agricultural land to meet the demand of crops. Regmi *et al.* (2004) also reported that lowest pH was recorded in agricultural land. Kalu *et al.* (2015) who reported that higher level of pH was observed in pasture than in the forest in Panchase area of western Nepal. This may be due to the forest was dominated by *Pinus roxburghii* forest which characterized the presence of acidic nature (Amatya *et al.*, 2016). Budhathoki (2012) also reported that the pH value of agricultural land showed slightly acidic nature.

Organic matter

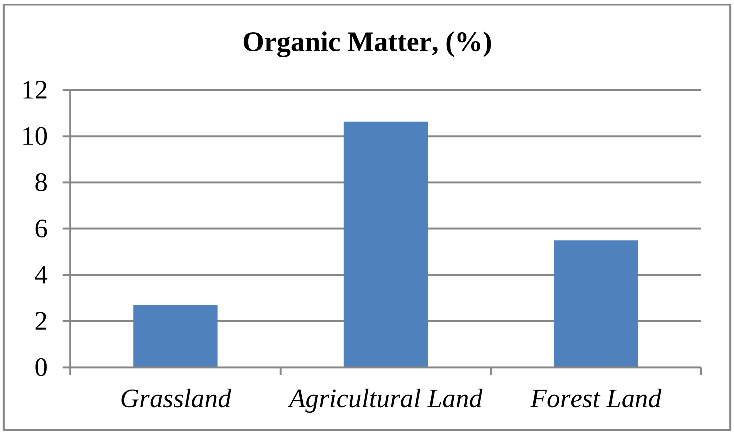


Figure 25: Graph showing organic matter content

From the analysis, it was found that the highest organic matter content was found in agricultural land (10.63%). The organic matter content of forestland was high but in grassland was medium (NARC, 2013). Organic matter content was found to be very high in agricultural land due to the regular input of fertilizer and compost manure while the matter content of forestland was comparatively high due to the litter residues accumulated on the forest floor. According to the NARC, 2004, the observed value for the organic matter content in the grassland was at medium rating level (2.5-5%) while for agricultural land and forestland was at high rating level (>5%). Regmi *et al.* (2004) also reported that organic matter content is higher in bari land and also concluded that use of farmyard manure, compost and fertilizer increases the organic content in soil. Ghimire *et al.* (2018) unsupported the present findings and concluded that organic matter content is higher in forest land than agricultural land. Fu *et al.* (2004) reported that organic matter in the cultivated soils is less than in uncultivated soils because of the removal of large quantities of the biomass during land preparation, clearing, a reduction in the quantity and quality of organic inputs to the soil and increasing soil organic matter decompositions rates due to enhanced biological activity caused by soil mixing from tillage and higher temperatures form increased soil exposure. Budhathoki (2012) also unsupported the current findings and reported that organic matter content is higher in forest land than bari land.

Available Potassium

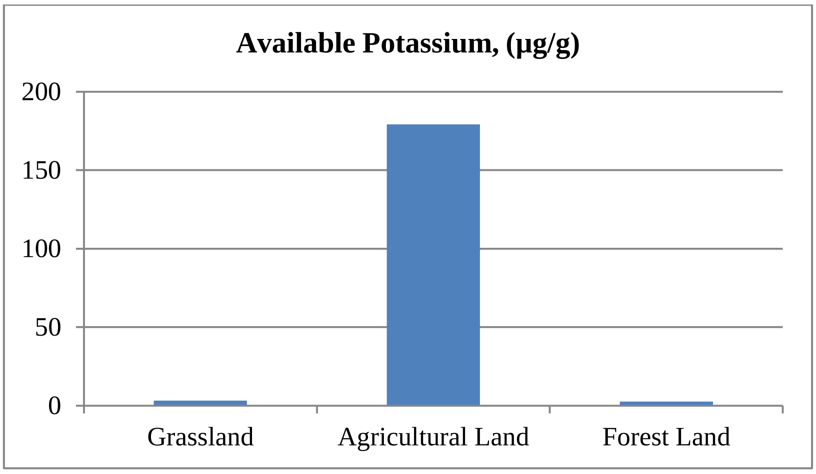


Figure 26: Graph showing available potassium

Available potassium content was found to be medium in agricultural land (179.21 µg/g) whereas it was found to be very low in grassland (3.2 µg/g) and forestland (2.51 µg/g). According to the NARC, 2004, the observed value for the available potassium content in the agricultural land was at medium range and values for grassland and forestland was at very low range (NARC, 2013). The use of Urea fertilizer and organic manure is the main reason for higher phosphorous and potassium content in the agricultural land. Tiwari *et al*. (2006) also reported that higher available phosphorous and available potassium in cultivated land than in forest land. Similalry, Kalu *et al.* (2015) also reported that both available phosphorous and available potassium contents were higher in bari and khet land than in forest and pasture land in Panchase area of western Nepal. Vaidhya *et al.* (1995) concluded that cultivated soil have higher level of available of phosphorous and available of potassium.

Available phosphorous

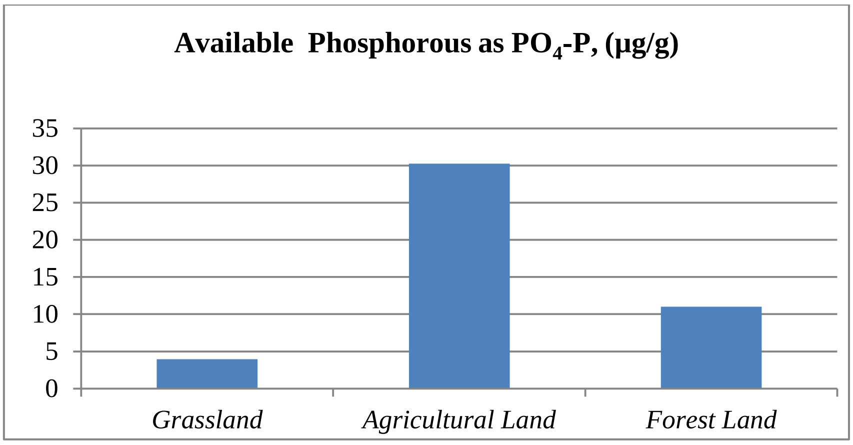


Figure 27: Graph showing available phosphorous content

The observed value of phosphorous content in different landuse viz. grassland, agricultural land and forest land were 3.94 µg/g, 30.24 µg/g and 11 µg/g respectively. The phosphorous content was found medium in agricultural land, low in forest land and very low in grassland (NARC, 2013). The use of Urea fertilizer and organic manure is the main reason for higher phosphorous and potassium content in the agricultural land. Tiwari *et al*. (2006) also reported that higher available phosphorous and available potassium in cultivated land than in forest land. Similalry, Kalu *et al.* (2015) also reported that both available phosphorous and available potassium contents were higher in bari and khet land than in forest and pasture land in Panchase area of western Nepal. Vaidhya *et al.* (1995) concluded that cultivated soil have higher level of available of phosphorous and available of potassium.

Available Nitrogen

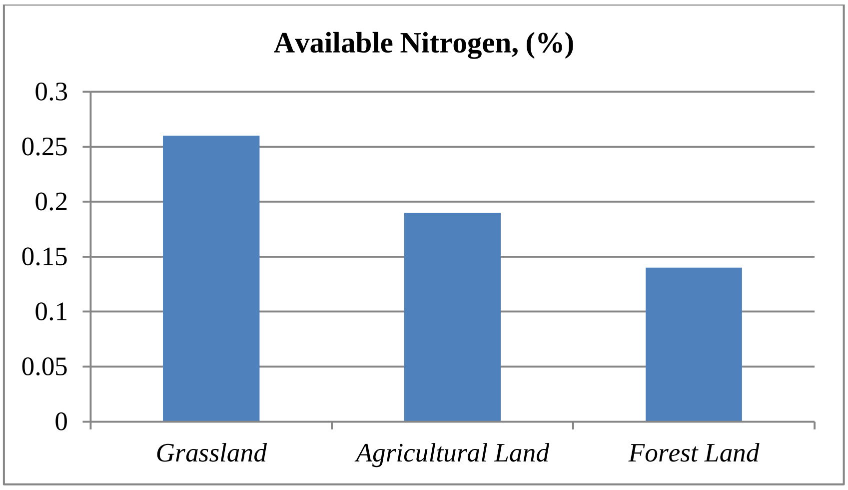


Figure 28: Graph showing the available nitrogen content

From the analysis, it was found that the available nitrogen content is high in grassland (0.26%) followed by agricultural land (0.19%) and forest land (0.14%). The available nitrogen content is high in grassland is due to the available of leguminous vegetation (clover, alfalfa etc.) (NARC, 2013). This leguminous vegetation nitrifies the atmospheric nitrogen to available nitrogen and accumulated in the soil. However, nitrifying vegetation is unavailable in agricultural land and forest land. The present findings is unsupported by Kalu *et al.* (2015) who reported that total nitrogen levels were higher in forest and bari land than in khet and pasture land in Panchase area of western Nepal. Fu *et al.* (2004) also reported that soil nutrient in the cultivated soils is less than in the uncultivated soils because of the removal of large quantities of the biomass during land clearing, ploughing, a reduction in the quantity and quality of organic inputs to the soil and increasing soil organic matter decompositions rates.

Electrical Conductivity

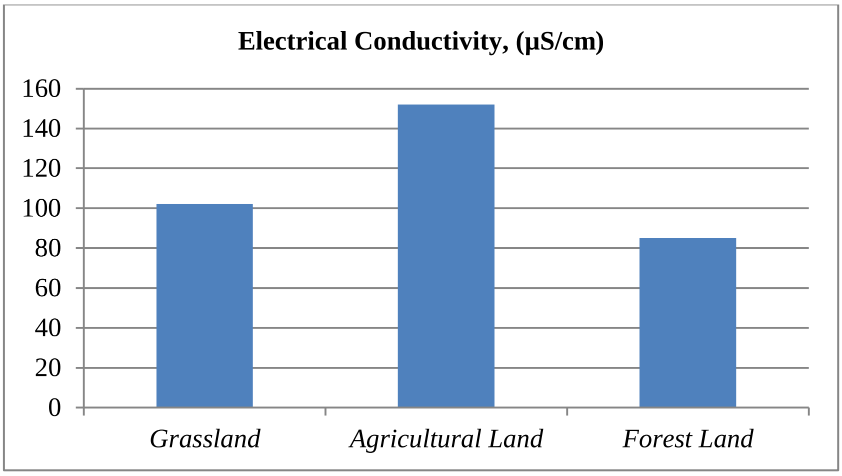


Figure 29: Graph showing the available nitrogen content

Soil electrical conductivity (EC) is a measure of the amount of salts in soil (salinity of soil). It is an excellent indicator of nutrient availability and loss, soil texture, and available water capacity. It affects crop yields, the suitability of the soil for certain crops, the amount of water and nutrients available for plant use, and the activity of soil micro-organisms, which influences key soil processes such as the emission of greenhouse gases, including nitrogen oxides, methane, and carbon dioxide As shown in figure 29, the soil electrical conductivity is higher in agricultural land (152 µs/cm) followed by grassland (102 µs/cm) and forest land (85 µs/cm). Salt levels can increase as a result of cropping, irrigation, and land management. Although EC does not provide a direct measurement of specific ions or salt compounds, it has been correlated to concentrations of nitrates, potassium, sodium, chloride, sulfate, and ammonia. Soil EC can also be an effective way to determine the texture of the surface layer because smaller clay particles conduct more electrical current than larger silt and sand particles. Similar findings also justified by Adingo (2021) which showed that soil electrical conductivity of farmland was significantly higher than that of abandoned farmland, natural grassland, artificial lemon woodland, and poplar woodland.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This investigation showed that the water quality of Kulekhani reservoir and its feeding streams is good for aquaculture and aquatic ecosystems. The present study also states that overall water quality within the reservoir area and its tributaries is natural. Most of the values obtained during the study period were within the Nepal water quality guidelines for aquaculture and water quality guidelines for protection of aquatic ecosystems values. The temporal variations of parameters have been significantly low in the study sites. The dense vegetation cover in the Markhu, Bisenkhel and Thado sub-watershed ensures a steady flow of water from the area. All the physico-chemical parameters are within the standard for aquaculture and fresh water aquatic ecosystem. Microbiologically, the water of the study sites contains high number of total coliforms. The water is not recommended for the drinking water.

However, the agricultural run-off and anthropogenic wastes from unhygienic settlements of Markhu, Bisenkhel, Palung and Chitlang are the obvious reasons for increasing pressure on the water quality as well as for negative consequences for watersheds and catchments area. Moreover, Kulekhani reservoir site is also used by visitors for boating, fishing, recreation purposes. The reservoir premises are also used for cattle grazing, farming by local people so that these activities help to deteriorate water quality of the reservoir. When compared to all the study sites, the pollution problem is higher in Bisenkhel and Palung Khola than other study sites. It shows high values of physico-chemical and bacterial parameters. Among the study sites Thado khola is in best condition.

In the context of soil quality, the pH, NPK level of agricultural land was found to be acidic and medium state respectively. But the pH, NPK level of grassland land was found to be neutral and very low rate respectively. While, the pH, NPK level of forest land was found to be acidic, medium, low and very low respectively. The organic matter content was very high in the agricultural land due to the high input of fertilizers and organic manure and pesticides but OM in grassland and forestland was medium and high respectively.

Recommendations

Though water quality of the reservoir is in natural condition however, several causative factors have been identified that harbor pollution causing effect on the water of the streams feeding the reservoir. The following recommendations can be followed to safeguard the reliable aquaculture and fresh water aquatic ecosystem from the Kulekhani reservoir:

- Improvement in the existing agricultural practices should be encouraged inside the watershed and upstream of the intake sites that will help to reduce siltation in the reservoir and reduce total suspended solids in the water.
- Excessive use of fertilizers and pesticides should be discouraged.
- Mixing of sewage and waste substances in the reservoir should be controlled.

- Excessive use of pesticides and chemical fertilizers should be discouraged because agricultural run-off increases the heavy metal parameters as well as Nitrogen, Phosphorus etc. so that water quality become deteriorates.
- The water of feeding tributaries of Kulkhani reservoir is not recommended for drinking purposes because it is contaminated with *E.coli* bacteria.
- Stall-feeding practice should be encouraged instead of open grazing of cattle that will significantly reduce the potential problem of water borne Faecal contamination.
- Local people should be motivated to use latrines for defecation.
- Cattle grazing as well as other anthropogenic activities that deteriorate water quality inside the reservoir premises should be strictly prohibited.
- People's participation in conservation program and community awareness is very important aspect for conservation. Program for community awareness such an orientation, training, participation, postering etc. should be organized timely.
- The water quality parameters should be regularly monitored downstream of the settlements. In case of an alarming increase in the trend of certain polluting parameters, the settlements should be given notice of corrective action.
- Activities such as grass plantation, fodder-tree plantation etc. should be necessarily conducted in the settlements of watershed area.

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Appendix 1: Physio-chemical and Microbiological Parameters of Water quality test

River	pH at 24ºC	Electrical Conductivity, (µS/cm)	Turbidity, (NTU)	Total Hardness as $CaCO_3$, (mg/L)	Total Alkalinity as $CaCO_3$, (mg/L)	Chloride, (mg/L)	Ammonia, (mg/L)	Nitrate, (mg/L)	Nitrite, (mg/L)	Biological Oxygen Demand, (mg/L)	Dissolved Oxygen, (mg/L)	Calcium, (mg/L)	Magnesium, (mg/L)	Iron, (mg/L)	Manganese, (mg/L)	*E. coli* Count, (MPN/100mL)
Chalkhu Khola	7.8	128	2	55	59	<0.5	<0.05	1.11	<0.02	<1	8.1	15.23	4.13	0.13	0.02	240
Thado Khola	7.9	56	7	19	27	<0.5	0.06	1.18	0.02	<1	7.1	4.01	2.19	0.85	0.17	150
Palung Khola	7.7	133	4	57	54	1.47	<0.05	5.17	0.03	<1	7.5	13.63	5.59	0.55	0.03	1100
Chitlang Khola	7.6	204	21	97	91	1.96	<0.05	8.49	0.03	<1	7	24.45	8.75	1.32	0.07	460
Bishenkhel Khola	7.9	262	146	130	118	4.41	<0.05	7.75	<0.02	1	6.1	38.07	8.51	6.06	0.61	460
Dam	8	143	5	60	67	0.98	0.11	3.84	0.07	2	9.9	15.23	5.35	0.34	0.02	9

Appendix 2: Physio-chemical Parameters of Soil quality test

Soil	pH at 23ºC, (1:1)		Electrical Conductivity, (µS/cm)	Organic Matter, (%)		Available Nitrogen, (%)		Available Phosphorous as PO4-P, (µg/g)		Available Potassium, (µg/g)
Grassland	7.3	Nearly Neutral	102	2.69	Medium	0.26	High	3.94	Very Low	3.2
Agricultural Land	5	Moderately acidic	152	10.63	High	0.19	Medium	30.24	Medium	179.21
Forest Land	5.1	Moderately acidic	85	5.49	High	0.14	Medium	11	Very Low	2.51

Appendix 3: Water quality guidelines for Aquaculture

S.N.	Constituents	Target Water Quality Range	Remarks
1	Alkalinity	20-100 mg/l as $CaCO_3$	High alkalinity reduces natural food production in ponds below optimal production.
2	Ammonia(for cold water fish)	0-25 *µg/l*	
3	Ammonia(for warm water fish)	0-30 *µg/l*	
4	Arsenic	0-0.05 *µg/l*	
5	Bacteria(E.coli)	<10 counts of E.coli/g of fish flesh	
6	Chloride	Value not recommended (fish can survive at <600 mg/l Chloride but the production is not optimum0	
7	Dissolved oxygen	6-9 mg/l for cold water species 5-8 for intermediate water species 5-8 for warm water species.	
8	Iron	<10 *µg/l*	0.2-1.75 general lethal threshold for fish.
9	Magnesium	<15 mg/l	
10	Manganese	<100 *µg/l*	Above 500 *µg/l increasing risk of lethal effect.*
11	Nitrate-N	<300 mg/l	1000 mg/l is below the 96-hour LC_{50} for many fish species.
12	Nitrite-N	0-0.05 mg/l for cold water fish 0.06-.25 mg/l for warm water fish	>7 mg/l is LC_{50} for many fish species.
13	pH	6.5-9.0	Outside this ranges the health of fish is adversely affected.
14	Total hardness as $CaCO_3$	20-100 mg/l,	In > 175 mg/l osmoregulation of fish is affected.

Appendix 4: Water Quality Guidelines for Protection of Aquatic Ecosystem

S.N.	Parameters	Target Water Quality Range	Chronic Effect Value	Acute Effect Value
1	Ammonia, (*µg/l*)	<7	<15	<100
2	Residual Chloride, (*µg/l*)	<0.2	0.35	5
3	Dissolved Oxygen, (Percent Saturation)	80~120	60	>40
4	Iron	The iron concentration should not be allowed to vary by more than 10% of the background dissolve iron concentration for a particular site or case, at specific time		
5	Manganese,(*µg/l*)	<180	370	1300
6	pH, all aquatic ecosystem	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, or by >5%, and should be assessed by whichever estimate is the more conservative.		

Appendix 5: Photo plate

Figure 1: Collecting water sample for DO test

Figure 2: Palung Khola

Figure 3: Removing the foreign particles from the soil sample

Figure 4: Kulekhani Reservoir

Figure 5: Thado Khola

Figure 6: Dam site

Figure 7: Field Visit

Figure 8: Chitlang Khola

Figure 9: Agricultural land

Figure 10: Recording the coordinate of sample site by GPS

Figure 11: Field visit with Federal Watershed Resource Management Centre personnels

Figure 12: Settlements along the bank of Kulekhani reservoir

Appendix 6: Monthly Precipitation (mm) from 1981-2021 around Kulekhani catchment area

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1981	26.37	0	26.37	58.01	142.38	147.66	421.88	247.85	110.74	0	26.37	0	1207.62
1982	73.83	5.27	21.09	21.09	36.91	68.55	247.85	200.39	131.84	0	10.55	5.27	822.66
1983	0	0	10.55	0	42.19	116.02	163.48	68.55	47.46	63.28	0	10.55	522.07
1984	5.27	10.55	5.27	5.27	36.91	168.75	232.03	232.03	200.39	15.82	0	0	912.3
1985	15.82	0	0	0	26.37	36.91	369.14	210.94	200.39	79.1	0	0	938.67
1986	0	15.82	0	5.27	36.91	174.02	247.85	116.02	21.09	31.64	0	31.64	680.27
1987	5.27	0	0	5.27	21.09	31.64	274.22	232.03	195.12	89.65	0	0	854.3
1988	0	0	36.91	26.37	73.83	105.47	337.5	258.4	68.55	10.55	0	26.37	943.95
1989	26.37	5.27	5.27	0	58.01	58.01	237.3	105.47	58.01	10.55	0	0	564.26
1990	0	26.37	5.27	0	10.55	100.2	464.06	147.66	110.74	10.55	0	0	875.39
1991	0	0	5.27	0	26.37	42.19	163.48	110.74	94.92	0	0	21.09	464.06
1992	0	0	0	0	15.82	68.55	142.38	121.29	84.38	47.46	5.27	0	485.16
1993	5.27	0	31.64	10.55	47.46	105.47	184.57	79.1	100.2	0	0	0	564.26
1994	15.82	0	0	0	15.82	100.2	126.56	73.83	126.56	0	0	0	458.79
1995	5.27	5.27	0	0	10.55	126.56	210.94	205.66	58.01	10.55	26.37	10.55	669.73
1996	31.64	21.09	0	31.64	10.55	116.02	147.66	226.76	63.28	31.64	0	0	680.27
1997	5.27	0	0	31.64	21.09	84.38	200.39	137.11	26.37	5.27	0	21.09	532.62
1998	0	5.27	5.27	0	36.91	58.01	189.84	216.21	105.47	36.91	0	0	653.91
1999	5.27	0	0	5.27	26.37	94.92	84.38	131.84	58.01	58.01	0	0	464.06
2000	0	0	0	0	58.01	179.3	158.2	200.39	137.11	0	0	0	733.01
2001	0	0	5.27	10.55	52.73	68.55	174.02	168.75	142.38	31.64	0	0	653.91
2002	5.27	5.27	21.09	5.27	73.83	84.38	131.84	68.55	52.73	21.09	0	10.55	479.88
2003	5.27	42.19	0	5.27	0	105.47	174.02	79.1	36.91	26.37	0	10.55	485.16
2004	26.37	0	15.82	142.38	116.02	189.84	400.78	189.84	158.2	58.01	21.09	0	1318.36
2005	47.46	10.55	15.82	15.82	21.09	163.48	337.5	295.31	79.1	163.48	0	0	1149.61
2006	0	0	26.37	15.82	137.11	247.85	348.05	184.57	205.66	31.64	0	21.09	1218.16
2007	0	84.38	26.37	47.46	63.28	232.03	363.87	290.04	210.94	21.09	0	0	1339.45
2008	15.82	0	10.55	21.09	105.47	369.14	395.51	337.5	226.76	26.37	0	0	1508.2
2009	0	0	5.27	0	121.29	121.29	247.85	358.59	52.73	58.01	0	5.27	970.31
2010	0	10.55	0	0	63.28	116.02	247.85	358.59	247.85	42.19	0	5.27	1091.6
2011	0	10.55	5.27	15.82	147.66	221.48	305.86	300.59	184.57	5.27	0	0	1197.07
2012	15.82	5.27	10.55	10.55	10.55	68.55	369.14	237.3	332.23	21.09	5.27	0	1086.33
2013	10.55	31.64	5.27	26.37	121.29	337.5	242.58	379.69	195.12	163.48	0	0	1513.48
2014	10.55	15.82	15.82	5.27	137.11	242.58	316.41	348.05	237.3	79.1	0	21.09	1429.1
2015	10.55	10.55	79.1	63.28	58.01	205.66	332.23	458.79	142.38	52.73	0	0	1413.28
2016	0	5.27	21.09	0	121.29	290.04	390.23	94.92	268.95	73.83	0	0	1265.62
2017	10.55	0	52.73	58.01	116.02	147.66	274.22	406.05	158.2	36.91	0	0	1260.35
2018	0	0	5.27	84.38	131.84	195.12	284.77	268.95	84.38	5.27	0	0	1059.96
2019	5.27	68.55	26.37	79.1	68.55	163.48	511.52	221.48	247.85	10.55	31.64	26.37	1460.74

2020	31.64	26.37	47.46	89.65	131.84	348.05	569.53	142.38	258.4	10.55	0	5.27	1661.13
2021	0	0	10.55	39.2	281.64	344.39	478.15	509.56	214.98	146.75	0.68	34	2059.9

Appendix 7: Relative Humidity at 2 meters (%) from 1981-2021 around Kulekhani catchment area

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1981	53	39.06	37.12	35.25	47.88	55.19	86.88	87.94	85.25	65.19	54.12	43.75	57.69
1982	42.81	46.62	43	32.06	31.44	51.75	67.88	82.56	80.19	57.06	50.25	39.62	52.12
1983	34.5	24.38	21.5	27.56	34.44	39.88	69.25	75.38	74.44	60.5	41.44	36.31	45.12
1984	31.94	29.12	19.25	19.56	34.69	67.31	81.88	81.44	84.19	62.12	40.94	36.69	49.12
1985	41.19	22.81	16.06	20.62	28.81	42.25	77.69	83.81	87	81.81	66	57.5	52.38
1986	42.81	40.81	27.69	23.19	31.44	47.56	83.75	80.25	74.94	53.38	35.12	39.38	48.44
1987	35.31	28.62	27.31	20.69	27	37.19	76.19	85.56	85.06	77.62	51.06	43.88	49.81
1988	38.25	30.38	32.19	24.31	38.75	55.31	82.94	85.94	84.44	61.5	40.81	39.69	51.31
1989	39.06	32.25	24.75	13.5	33.44	54.94	73.44	81.38	76.19	50.81	32.94	30.88	45.44
1990	25.62	40.56	28.88	19.19	34.06	52.25	80.25	86.19	85.5	65.19	41.69	37.75	49.81
1991	36.44	25	22.62	15.94	24.19	53.25	69.75	76.88	79.12	50.06	32.69	37.31	43.75
1992	36.5	29.56	19.19	16	28.75	44.69	63.38	75	72.19	54.94	44.06	36.94	43.5
1993	37.81	25.12	27.56	28.25	34	50.62	69.19	74.81	78	47.5	38.44	24.31	44.75
1994	34.94	32.38	17.88	18.62	29.5	50.75	68.88	72.88	73.31	47.94	36.31	27.38	42.62
1995	31.5	29.44	21.69	15.25	25.12	56.44	78.38	84.31	80.19	54.12	39.75	38.88	46.38
1996	39.25	36.88	28.81	21.81	22.81	55.75	73.19	83.12	80.62	64.56	36	28.81	47.69
1997	30.81	23.06	19.81	32.88	23.38	42.75	78.62	81	74.31	49.38	39.56	46.44	45.31
1998	33.94	31.38	30.88	24.56	37.38	46.94	77.56	84.81	82.12	68.19	47.62	32.62	50
1999	33.06	24.56	12.56	11.31	39	52.38	72.38	76.44	77	61.12	36.38	34.25	44.38
2000	26.12	27.25	16.75	18	45.06	68.06	79.75	81.88	81.94	58.81	45.94	34.88	48.75
2001	30.62	21.31	17	21.19	44.38	62.44	71.81	77.06	82.19	68	46.81	39.44	48.69
2002	41.56	32.44	27.44	27.12	47.31	55.75	64.12	73.31	67.88	54.06	40.56	36.5	47.44
2003	35.81	43.19	33.12	22	27.62	52.25	76	77.06	75.06	53	44.12	44.19	48.69
2004	45.06	35.62	26.25	37	46.62	70	85.81	85.75	84.75	70.12	56.81	53.94	58.25
2005	51.44	45.56	39.19	26.06	34.06	48.5	83.5	86.88	84.12	74.19	59.94	44.62	56.62
2006	38.81	38.06	32.31	30.5	52.75	70.62	84.94	84.06	86.06	74	58	51.12	58.56
2007	38.5	54.94	43.94	37.94	46.06	66.19	83.31	86.44	86.06	81.88	64.5	50.12	61.69
2008	46.06	39.31	32.25	30.31	44	77.44	87.88	88.69	85.94	80.94	70.88	64.62	62.44
2009	47.69	34.94	26.25	21.88	48.56	51.5	75.62	86.56	84.56	64.75	52	47.69	53.69
2010	41.25	34.19	24	19.94	42.69	53	78.81	85.81	87.12	78.69	72.19	50.31	55.81
2011	49.44	40.56	32	33.38	50.75	63.19	87.5	87.62	86.62	75.88	70.06	51.38	60.81
2012	51.56	39.44	28.31	30.31	25.38	44.19	81	84.88	86.5	79.25	62.38	54	55.69
2013	48.62	50	39.06	36.81	37.44	72.31	83.56	85	85.62	83.69	70.69	64.69	63.19
2014	58.38	51.69	40.25	26.94	41.19	56.31	84.88	86.38	85.81	79.44	61.5	55.12	60.75
2015	54.88	45.31	48.81	47.25	37.5	56.5	81.88	87.69	83.44	68.88	58.69	49	60.12
2016	41.31	33.06	31	21.12	45.62	68.31	88	84.94	87.62	75	61.56	53.5	57.69

2017	44.56	35.62	37.38	37.25	48.12	58.88	84.25	89.38	88.94	75.94	62.19	46.81	59.25
2018	41.5	35.12	28.81	44.12	54.38	68.62	82.06	86.75	86.75	62.88	52.12	46.06	57.56
2019	45.19	48.62	40.06	41.94	37.75	57.69	85.19	87.31	88.12	86	74.44	64.19	63.12
2020	68.69	56.5	54.31	48.56	56.5	79.38	90.75	87.94	88	71.88	58.69	54.31	68
2021	44.25	38.38	27.94	23.88	56.44	83.19	89.56	90.81	89	89.25	84	75.62	66.19