PHYSICO-CHEMICAL WATER QUALITY PARAMETERS AND AQUATIC PLANT DIVERSITY OF DIPANG LAKE, POKHARA, NEPAL

A THESIS

SUBMITTED FOR THE

PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER'S DEGREE IN (BOTANY)

SUBMITTED BY

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KATHMANDU, NEPAL

July, 2022

DECLARATION

I, hereby declare that the dissertation work entitled **"Physico-chemical water parameters and aquatic plant diversity of Dipang Lake, Pokhara, Nepal"** is carried out by myself and has not been submitted elsewhere for any other academic degree. All the sources of information have been specifically acknowledged by reference wherever adopted from other sources.

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i

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ii

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LETTER OF APPROVAL

On the recommendation of supervisor "Prof. Dr. Kanta Paudyal", this dissertation submitted by "Mr. Arjun Thapa" entitled **"Physico-chemical water parameters and aquatic plant diversity of Dipang Lake, Pokhara, Nepal"** has been accepted for the examination and submitted to the Amrit Campus, Tribhuvan University for partial fulfillment of the requirements for Master's degree in Botany.

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iii

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CERTIFICATE OF ACCEPTANCE

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Arjun Thapa

v

ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
BOD	Biologically Oxygen Demand
COD	Chemically Oxygen Demand
DO	Dissolved Oxygen
EDTA	Ethylene Diamine Tetra Acetic Acid
ICIMOD	International Center for Integrated Mountain Department
IOE	Institute of Engineering
IUCN	International Union for conservation of Nature and Natural Resource
LCPV	Lake Cluster of Pokhara Valley
m	Meter
mm	Millimeter
nm	Nanometer
NSF	National Sanitation Foundation
NTU	Nephelometric Turbidity
ppm	Parts Per Million
SD	Standard Deviation
SDV	Secchi Dish Visibility
TDS	Total Suspended Solids
WHO	World Health Organization
WQI	Water Quality Index

Table of Contents

LIST OF TABLES

LIST OF FIGURES

List of Appendices

ABSTRACT

Dipang lake is the important but vulnerable lake of Pokhara valley due to mainly natural causes and other human activities. Understanding of different water properties is helpful in sustainable management of lake. The present investigation deals with the characterization of water quality parameters of Dipang lake situated in Pokhara- Lekhnath Metropolitan city, Kaski. The investigation was carried out on physical parameters like colour, odour, temperature and transparency while chemical parameters like pH, dissolved oxygen, free CO_2, alkalinity, total hardness, nitrate and ammonia both seasonally (rainy, winter and summer) as well as source wise (inlet, middle and outlet).

Present study highlights the natural variation of the different water quality parameters of the lake water seasonally as well as water source wise. But parameters were within the permissible limit for fishing, agricultural and domestic purposes. Statistically the recorded mean values of water parameters especially temperature i.e (27±1.76 °C in rainy to 10.95±0.55 °C in winter) and total hardness i.e (92±11.06 ppm in dry summer to 32.30 ± 6 ppm in winter) varies significantly ($p<0.05$) according to the season. Likewise, other parameters show slight fluctuations seasonally. The water parameters also affect the growth of some plant species especially *Nelumbo lutea* (Yellow lotus) which was found only towards the water inlet where the amount of ammonia is high 18±14.03 ppm.

Keywords: *Wetland, Water source, Ammonia, Importance Value Index (IVI), Yellow lotus*

CHAPTER 1: INTRODUCTION

1.1 General Background

Water is a basic and primary need of all vital processes and it is now well established that the life first arose in aquatic environment. It is one of the most important compounds that profoundly influence life. (Patil *et al.*, 2013). "Rapid industrialization and indiscriminate use of chemical fertilizers and pesticides in agriculture are causing heavy and varied pollution in aquatic environment leading to deterioration of water quality and depletion of aquatic biota." Poorly managed resources can cause water scarcity or pollution, which may lead to health, social and economic crisis. It is therefore necessary to check the water quality at regular interval of time. So the more we monitor the quality of water the better we will be able to recognize and prevent contamination problems.

Water quality includes all physical, chemical and biological factors of water that influence the beneficial use of the water (Alley, 2007). Physical parameters include colour, odour, temperature, transparency, turbidity, total solid wastes etc. Chemical characteristics involve parameters such as pH, dissolved oxygen (D.O), free CO_2, alkalinity, total hardness, presence of ammonia, phosphate, chlorine, calcium, magnesium etc. Likewise, biological indicators of water quality include fishes, macrophytes and phytoplankton. Selection of parameters for testing of water solely depends upon for what purpose we are going to use that water and what extent we need its quality and purity (Patil *et al.*, 2012).

The principle recent change in rural land use in the Pokhara valley of Nepal is that rural area are being absorbed into growing town and cities. This conversion of rural in to urban land could have several impacts on lake water quality because of development such as industrial installations and so many hotel and restaurants which are located along the bank of environmentally vulnerable lake. Dipang lake is one of the important lakes of Pokhara valley also known as "Madhumas Tal or Honeymoon lake" and is famous for picnic spot from where a good sightseeing can be done of the Himalayas and the green hills around. During spring season, wild lotuses blossom in most of these lakes and make the whole environment blissful. Due to its scenic beauties, a great number of tourists visiting Pokhara, visit here also. But at present condition the area of this lake is shrinking day by day and facing challenges due to sedimentation, eutrophication, encroachment, anthropogenic activities, chemical fertilizers and pesticides runoff from nearby agricultural fields, climatic changes, accumulation of non-degradable wastes, invasion by invasive species, etc. As these changes are very slow and takes long time, the damage is unnoticed to take measures. Hence, long historic data provides concrete evidence of change, which help us understand the cause and prevent further change (IPCC, 2014).

1.2 Water parameters and aquatic flora and fauna in wetlands.

Wetlands are essential element in biological diversity and ecosystem function. In natural condition, wetlands provide essential habitat for many wildlife such as fish species, animals, birds, amphibians and mammals, plant species (macrophytes, plankton diversity) and focal ecosystem for many other (Hernandez and Mitsch 2007; Palit and Mukherjee 2012). Aquatic plants can act as measurable indicators of the ecological conditions of surface waters. Notably, the submerged species strongly dependent on water quality have proved to be vulnerable to changes in the aquatic environment (Dawson *et al.*, 1999). Turbidity is a key water-quality characteristic because its effects on light transmission and water clarity and determine habitat characteristics, community structure, depth and vegetation diversity (Duarte *et al.*, 1986). Aquatic vegetation can also influence the abiotic conditions and influence wetland biota across multiple trophic levels (Norlin *et al.*, 2005) by providing both habitat and food. However, the aquatic macrophytes also influence the water quality changes and being used as bio-indicator of pollution (Kenney *et al.*, 2009).

Physiologically, dissolved oxygen and temperature regulate other physical and chemical properties of the water which are essential for sustaining aquatic life. Additionally, nutrient enrichment mostly with phosphorus and nitrogen stimulates unnecessary primary production, which can reduce oxygen. Furthermore, water pH regulates aquatic chemistry, which can affect water use and habitat. The health of an aquatic ecosystem is highly depended on the physico-chemical and biological characteristics of the water (Venkatesharaju *et al.*, 2010). Reduced water quality is reported to affect fish communities by impacting habitat, food availability, and dissolved oxygen levels, which in turn influence their growth potential and reproductive abilities (Reynolds 2014). Hence, changes in fish populations can be indicators of aquatic ecosystem health (Moyle 1994).

1.3 Justification of the study

The management of Dipang lakes is facing numerous challenges nowadays, some of them are natural but mostly anthropogenic activities are responsible. Climate change in particular will have serious consequences for lake environments, while man's increasing demands will require an integrated approach to lake management, considering not only the entire watershed area but also the different socio-economic and ecological aspects. Any proposed solution will require improvements in ecosystems services, and the development of lake ecosystems. Water quality monitoring can help researchers to predict and know the natural processes in the environment and determine human impacts on an ecosystem. Such knowledge can further be used in management of wetland, restoration projects and ensure environmental standards are being met.

Furthermore, more information needs to be processed and shared regarding lake and habitat restoration. Also there is not enough research work related to Dipang lake in Nepal. So to fulfill the research gap, investigation of water parameters of this lake was chosen as my research topic.

1.4 Hypothesis

- There is an effect of physico-chemical parameters on aquatic life in Dipang lake.

1.5 Objectives

The key objective of this study was to investigate the different physiochemical water parameters of Dipang lake, Pokhara and the specific objectives were:

i. To estimate the seasonal variability (rainy, winter and dry summer) in physico-chemical water parameters of the lake.
ii. To compare water parameters of different water sources (inlet, middle and outlet).
iii. To identify aquatic plants and fish species found in or around the lake.
iv. To find out how these water quality parameters effect on survival of plant.

1.6 Limitations

- Standard rules were not followed while collecting water sample from middle of the lake due to lack of sampling instruments.
- Limited secondary data and base line data of Dipang lake were only available**.**

CHAPTER 2: LITERATURE REVIEW

The term "wetland" is made up of two words-wet and land. The word wet means something moist, referring to the quality of being, or containing water or liquid. The word land means a solid or specific part of the Earth surface, not covered by water. Wetlands occur where the water table is at or near the land surface, or where the land is covered by shallow water. The Nepali term for wetland is Simsar, which means land with perennial source of water (Kafle, 2007).

Thitame and Pondhe (2009) have studied, in present investigation an attempt was made for assessment of Seasonal Variation in Physicochemical Characteristics and Quality of Pravara River Water for Irrigation during year 2008. The study reveals that most of the physicochemical parameters of river water at five selected sites show moderate variation in their concentration for all seasons.

Puri *et al*, (2011) have studied water quality index (WQI) has been calculated for different surface water resources especially lakes, in Nagpur city, Maharashtra (India), for the session January to December 2008; comprising of three seasons, summer, winter and rainy season. The calculated (WQI) for various studied lakes showed fair water quality in monsoon season which then changed to medium in winter and poor for summer season. Gorewada lake showed medium water quality rating in all season except monsoon season. Futala, Ambazari and Gandhisagar lake has also declined in aesthetic quality over past decade following invasion of aquatic weeds such as hydrilla and water primrose, so the reasons to import water quality change and measures to be taken up in terms of surface water (lakes) quality management are required.

Shah and Pant, (2012) studied the parameters such as temperature, PH, TSS, TDS, ammonia, phenol, cyanide, sulfide, oil and grease, chloride, DO, COD and BOD to assess the water quality of Sirsiya river, central southern Nepal and revealed that the physio-chemical characteristic of the river water was changing as a result of the discharge of untreated effluents from different industries. This may impact on water quality of Sirsiya River and also pose human health problems.

Breaban *et al*,. (2014*)* while working on Seasonal variation of water quality parameter in the Chirita reservoir, IASI found that "A parameters showed significant temporal differences and partial spatial variability”. The seasonal changes in water quality were influenced mostly by turbidity, organic pollution, oxide-related process, erosion as well as anthropogenic activities.

Pandey and Devkota, (2016) studied different water parameters of Tinau River, Butwal, Nepal and reported that all the physicochemical parameters are within the standard for drinking water except turbidity and pH (Butwal station) and raw water source for potable abstraction.

Globally, the most prevalent water quality problem is eutrophication, a result of high-nutrient loads (mainly phosphorus and nitrogen), which substantially impairs beneficial uses of water (Carpenter, 1998).

According to Patil *et al*., (2013), huge pressure is being exerted on the water resources because of uncontrolled population growth and ultimately the quality as well as quantity of water has declined.

According to Acharya *et al.,* (2016), the area of Phewa lake has shrunken, whereas Rupa being increase in surface water area. Begnas had few changes. While deriving the water indices, the smaller lakes such as Gunde, Khaste, Neureni and Madi, except Dipang were not detected in the process due to smaller size of surface water than the spatial resolution of Landsat images. Hence, the change in these lakes could not calculated from mid resolution satellites. Dipang lake showed increase in surface water area after 25 years of gap (due to construction of retention walls).

Phewa Lake, which is a major tourist destination of Nepal, is at present facing high human pressure at both its urban and rural watershed areas in the absence of proper researches. Pages (IOE Graduate Conference, 2020). Similarly, Begnas and Rupa Lake situated side to each other not being an exception to the possible threats of pollution

Pant *et al.,* (2018) while studying on water quality of Begnas and Rupa lakes revealed that the water of both lakes were relatively pure with very less TDS as compared to other lakes considered for the comparison with this study. However, the concentrations of CO2 and phosphates were found to be higher than WHO guidelines for drinking water and also indicated the problem of rapid eutrophication in both of the lakes.

Marquez *et al.,* (2007) revealed that *Lotus japonicus* plants are able to use both nitrate and ammonium as inorganic nitrogen sources for ulterior assimilation, or, alternatively, they can also use atmospheric nitrogen through *Mesorhizobium loti* symbiosis. Primary nitrate assimilation takes place predominantly in the roots of the plant, being strongly dependent on the age and limitation of space for root growth.

Haryuni *et al.,* (2014) have studied that water quality parameters regulates the growth of vegetation, (IVI) of Mangroove plant in the coastal area of Seruyan Regency, Indonesia.

According to Verma and Khan (2015), water quality generally means the component of water which must be present for optimum growth of aquatic organisms

Wang *et al.*, (2019), on studying a redundancy analysis between the submerged plants and environmental factors found that the water transparency, turbidity, and water depth were the key environmental factors affecting the plants. These results suggest that the long-lasting severe flooding of Liangzi Lake in 2010 led to the degradation of both the submerged plant community and water quality.

Lake monitoring and tested water quality parameters

Temperature: Temperature is an important parameter in characterization of natural water bodies. It affects the water chemistry such as saturation and concentration of dissolved gases, especially oxygen (Vincent and Vallarino, 1969). The rate of chemical reactions generally increases as temperature increases. Temperature also affects biological activity and regulates the kinds of organisms that can live in the lake. The temperature of the surface water will change according to the sun intensity, while the bottom of the lake remains constantly cold (Jorgensen, 1980).

Turbidity: Turbidity indicates the amount of suspended solids in the water, either mineral (such as soil particles) or organic (like algae). The turbidity analysis is a measure of the amount of light scattered in water and more suspended particles cause greater scattering and thus high turbidity value. Various suspended components of water turbidity can affect the productivity of submerged macrophytes (Korschgen, 1997).

pH: The pH of a solution is a measure of the concentration of hydrogen ions (H^+) and it represents the negative logarithm of hydrogen ions concentration. It expresses the intensity of the acid or the alkaline condition of a solution (Sawyer & McCarty, 1978). The pH of water determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals (Rao, 1989). One of the reasons of pH change in water is the photosynthesis. This process absorbs carbon dioxide from the water and uses the sun's energy to convert it to simple organic carbon compounds and to produce oxygen (Equation 1.1). Carbon dioxide in solution has acidizing effect as it reacts with water and forms carbonic acid ($H_2CO_{3)}$. As long as plants and algae remove it, the water becomes more alkaline and the pH increases (Equation 1.1).

Equation 1.1 – Growth of algae by photosynthesis:

$106\ CO_2 + 16\ NH_4^+ + HPO_4^{2-} + 65\ H_2O$ --------- $C_{106}H_{181}\ O_{45}\ N_{16}P + 118\ O_2 + 14H+$

Unlike the photosynthesis process, respiration has an acidizing effect as it consumes the dissolved oxygen in water and releases carbon dioxide.

With photosynthesis being dominant during the day, the plants have a net alkalizing affect during daylight hours. However, during the night, plants stop photosynthesis but normal respiration continues, so there is only oxygen removal from water and carbon dioxide release with a net pH decrease.

Other processes affecting the water pH is the bacterial degradation of organic (Equation 1.2) and conversion of inorganic matter (equation 1.3) as they utilize oxygen.

Equation 1.2 – aerobic degradation of organic matter:

COHN + O_2 + nutrients --------- CO2 + $NH4^+$ + $C_5O_7H_2N$ + other end- products

(Organic matter) (New cell)

Equation 1.3 - Nitrification:

$NH4^+ + 1.86\ O_2 + 1.98\ HCO_3^-$------ $0.02\ C_5H_7\ O_2\ N + 0.98NO_3^- + 1.88\ H_2\ CO_3 + 1.04\ H_2O$

Dissolved oxygen: Dissolved oxygen is an important parameter in aquatic environments. It governs the majority of biological processes in aquatic ecosystems. Its concentration is the result of physical, chemical and biological processes that whether produce or consume oxygen.

Oxygen is added into water bodies by air-water exchange, diffusion and mixing in the water and by photosynthesis. It is consumed by the phenomena of photo-oxidation, chemical oxidation reactions and by aquatic organisms for respiration and bacterial degradation (Equations 1.2 and 1.3).

The biological processes have dominant influence on the concentrations of oxygen. Thus, in areas where organic matter accumulates and become degraded, those areas may become anoxic or totally anaerobic and death of aquatic life will occur. In addition, if nitrogen load is high, oxygen consumption by nitrification will also be significant (Equation 1.3). However, in eutrophic areas, major developments of phytoplankton can cause super saturation.

The presence of dissolved oxygen is of fundamental importance in maintaining aquatic life and the aesthetic quality of water (Tchobanoglous and Schroeder, 1987).

Ammonia: Ammonium nitrogen is used to measure the strength of pond water in natural bodies such as rivers or lakes, or in artificial water reservoirs. Nitrogen is present in the atmosphere on various chemical form including organic nitrogen, ammonium, nitrite and nitrates. Nitrogen is a constituent of proteins present in the biological compounds like plants and animals; initially the complex organic matter is decomposed by the bacterial and converted ammonia acids into ammonia. If oxygen is present, then ammonia is oxidized to nitrite (NO_2) and then to nitrate (NO_3).

Nitrate results from the bacterial degradation of organic matter where nitrogen is released and converted to ammonia. The ammonia undergoes bacterial conversion, known as nitrification in aerobic conditions, producing nitrite and finally nitrate. This condition makes up a major percentage of nitrogen supply in the pond water.

Phosphate: Phosphorus in surface water is mostly from runoff of soil particles. It also enters waterways through fertilizer runoff, sewage discharges, natural mineral deposits, and wastes from other industrial processes. Dissolved phosphate is used by algae while particulate phosphorus will settle on lake bottom. As sediments are stirred up, phosphates may reenter the phosphorus cycle in the way that they are taken up by aquatic plants and then travel up through successive stages of the aquatic food chain. Generally, the concentration of phosphorus in many natural water is low and usually limits the algal growth (Tchobanoglous & Schroeder, 1987).

CHAPTER 3: MATERIALS AND METHODS

3.1. Study Area

3.1.1. Location and geo-morphology

Pokhara owes much its popularity to the enchanting fresh-water clusters of nine diverse lakes of different sizes which include the popular Phewa, Begnas, Rupa, Dipang, Khaste, Maidi, Gunde, Neureni, Kamalpokhari and Pokhara Seti catchment, lakes. These lakes cover an area of 262 km^2 with the water bodies covering an area of 9 km^2. The lakes give Pokhara its name and also play vital role in sustaining the biodiversity, ecosystem and locally livelihood. The Lake Cluster of Pokhara Valley (LCPV) is located in Kaski district of Gandaki province of Nepal. It is included as 10^{th} Ramsar site of Nepal in Feb. 2, 2016. (Integrated Lake Basin Management Plan of Lake Cluster of Pokhara Valley, Nepal, 2018). The proposed study area, Dipang lake is the fourth largest lake of LCPV situated between green hills fed by Ashrene Khola, Khatre Khola and Kusunde Khola. It serves as fishing for inhabitants, recreational purposes for visitors and also irrigation of the downstream irrigation field (located downstream the South outlet).

Location	Pokhara-Lekhnath Metropolitan city, Kaski, Gandaki Province, Central Nepal
Coordinate	**Longitude:** 84°03’44.8”- 84°04’48.0” East **Latitude:** 28°10’42.0” - 28°12’9.1” North
Altitude	690 masl
Total Catchment Area	2.39 sq. km
Water Body	0.14 sq. km
Depth	3-5 meter
% water body	6.2
Wetland Type	Freshwater Lake

Table 1. Detail about Study Area (Dipang Lake)

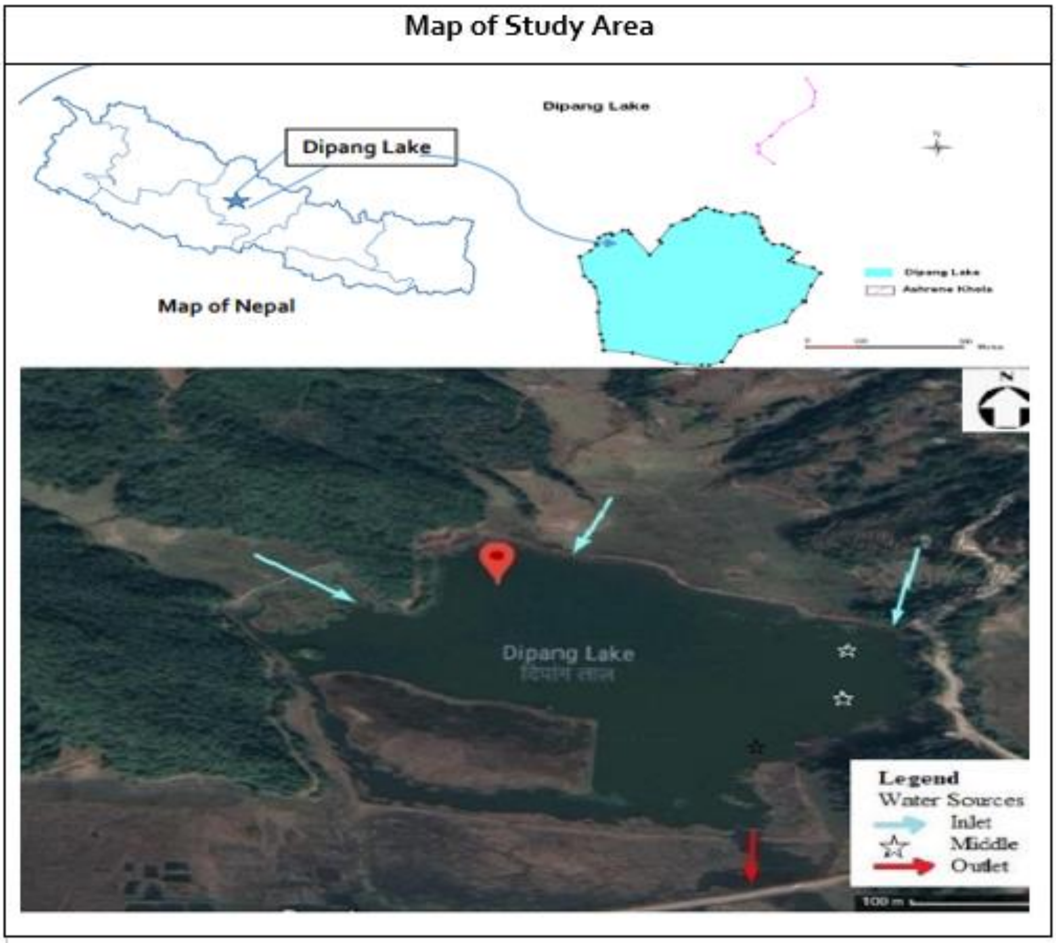

Figure 1: GIS map and Satellite imagery of Dipang lake

3.1.2 Climate

The climate of the Lekhnath area where Dipang lake lies is humid and sub-tropical with monsoon rainfall pattern. It is characterized by the moderate humid, heavy monsoon rainfall and distinct seasonal variations (Oli, 1996). The annual mean temperature is 21.6 ^{0}C with a minimum of 13 ^{0}C in January and a maximum of 25.5 ^{0}C in July (Narayani Basin Office, 2007-2008).

The annual rainfall averages 3,353 mm (June 2007- May 2008) with seventy-seven percent of precipitation occurring during the summer months from June to September Local convection hailstorms in autumn and strong winds during the dry spring are the occasional local climatic phenomena. Occasionally, ground fog appears on winter mornings. The seasonal cycle is cool-warm-hot-warm.

3.1.3 Vegetation

The sub-tropical temperature and heavy monsoon rainfall allow vigorous growth of numerous plants, with a rich variety of both evergreen and deciduous plants. *Shorea robusta* and *Schima wallichi – Castonopsis indica* are the predominant trees around the Dipang hills (Oli, 1999).

A study in Dipang lake explored a total 254 species of plant that comprised of 57 species of trees (22.45%), 25 shrubs (9.8%), 62 species of herbs and grasses (24.4%), 17 species of climbers (6.69%), 32 spp cultivated (12.6%), 34 spp aquatic plants (13.39%) and 18 spp invasive plants (7.09%) including 9 spp invasive aquatic plant. Of this, 211 species were terrestrial and 53 species were aquatic plants. (Tiwari, 2021).

3.2 Methods

The whole experimental procedure was carried out in two parts:

The field works which included the infield measurement of some parameters such as temperature, pH, conductivity, salinity, dissolved oxygen and Secchi disk depth. It also included sampling and preservation of water for laboratory testing purposes.

Analysis of DO, CO_2, total hardness, alkalinity, nitrogen, phosphorus, ammonia, chlorine etc in the samples was done in lab. Since, the experimental site is far from the Amrit campus lab and the chances of contamination might be high during transportation, hence experiments were done in Fisheries Research Lab, Begnas- Pokhara.

3.2.1 Field Sampling

As the objective was to characterize the entire lake which covers an area of 0.14 sq. km. Three inlet sources stations in the lake (i.e inlet 1, inlet 2 and inlet 3), one middle and one station in the outlet stream were selected to provide an adequate characterization of the lake as shown in (Figure 2).

Regarding the sampling, samples were taken near the surface (about 1-meter depth) as the lake is relative shallow (1m – 5m) and no significant variation in water quality can be expected from surface to bottom apart from oxygen and pH.

Study area was divided into three sites (water inlet, middle part of lake and water outet) according to water sources. Water sample was collected from one-meter depth in a cleaned rinsed BOD bottles and Plastic bottles separately from each site during three seasons i.e (Rainy, Winter and dry summer) i.e Totals of 15 BOD bottles and 9 plastic bottles in each season.

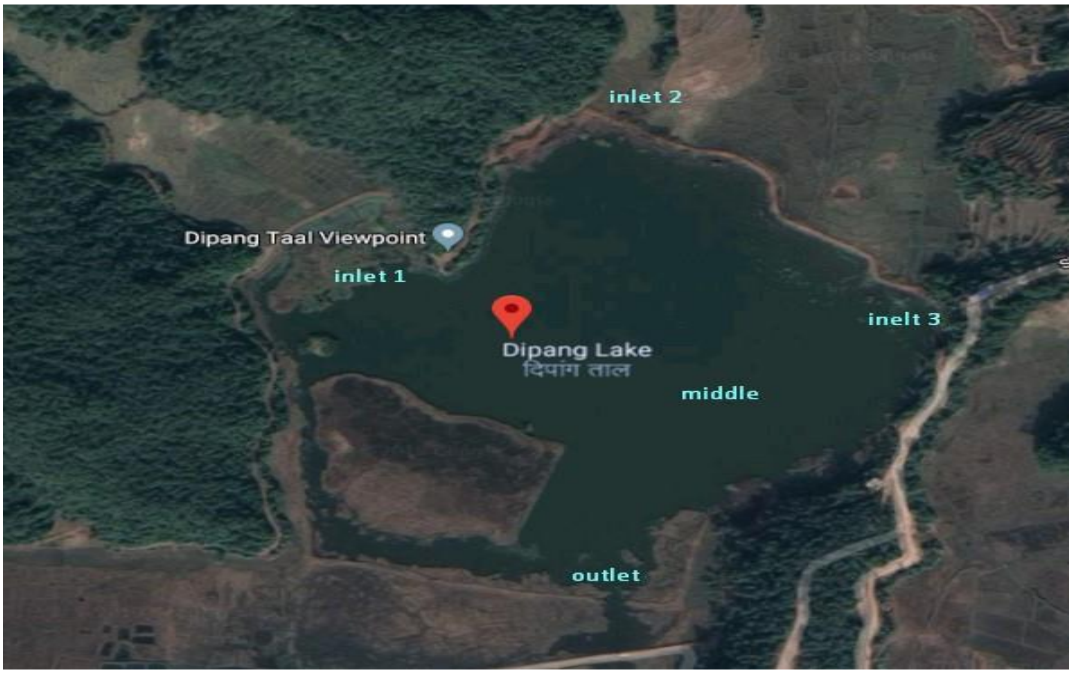

Figure 2. Source wise sampling sites

3.2.2 Water quality Test

- Physical parameters of water like colour, odour was measured by direct observation while water temperature, pH measured in the spot using thermometer and pH meter respectively.
- Chemical parameters of water i.e Dissolved Oxygen (D.O), free carbon dioxide was measured in Fisheries research lab, Begnas lake following Zobel *et al.* (1987).
- Total Hardness, Alkalinity, Nitrate (NO_3-), Phosphate (PO_4), Chlorine, Ammonia (NH3) of water was also measured in Fisheries research lab, Begnas using Digital water testing instruments (exact ECO-CHECK).

3.2.3 Field measurements

a. Temperature: Both digital and lab thermometer were used to measure the temperature of water. The thermometer was dipped into the water for 5 minutes and reading was taken.
b. pH: The pH of the water was measured with digital pH meter. pH meter was dipped into the water and correct reading was taken from all the sources of water (inlet, middle and outlet) in three different seasons.

c. Turbidity: Turbidity was measured with the help of the Secchi Disc following Zobel *et al,* (1987). It is a metallic disc of 20 cm diameter with four quadrants on upper surface painted black and white alternately. The disk is attached to a rope and lowered into the water and depth (cm) at which it disappears and reappears was noted.

It was calculated by:

SDT (cm)= $\frac{A+B}{2}$

Where, A= depth at which disc disappears

B= depth at which disc reappears

SDT= Secchi disc transparency (cm)

(Note: Transparency is indirectly proportional to the turbidity

The relation between NTU and suspended solids is as follows:

1 mg/l (ppm) is equivalent to 3 NTU

3.2.4 The laboratory analyses

a. Dissolved Oxygen: Dissolved oxygen of water was determined by the Winkler's Method following Zobel *et al.*, (1987). In this method, BOD bottle of capacity 200 ml was filled with sample water avoiding any kind of bubbling after placing the cap. 2 ml of $MnS0_4$ and 2 ml of KI solution were added to it which gave precipitate. The stopper was placed and the solution was shaken repeatedly and kept for a while to settle the precipitate. Whole solution was taken in a conical flask and 8 drops of starch was added to it as an indicator to give blue colour. It was then titrated with the standard sodium thiosulphate $Na_2S_20_3$ (0.025 N) solution and the end point was noted when the colour changed from blue to colourless. This titration was repeated until we get concurrent reading.

It was calculated by:

Dissolved Oxygen (mg/l)= $\frac{\text{V1N x 8 x 1000}}{V2-V3}$

Where,

$V_{1=}$ Volume of the titrant i.e $Na_2S_20_3$ consumed in the titration

N = Normality of titrant i.e $Na_2S_20_3$ (0.025)

V_2= Volume of the sample taken for the test

V_3= Volume of $MnS0_4$ and KI added.

(Note: The equivalent weight of the oxygen = 8)

b. Free Carbon dioxide: Carbon dioxide of water was determined by theTitrimetric method following Zobel *et al*,. (1987). In this Method 100 ml of sample was taken in a conical flask and 4 drops of phenolphthalein was added to it as an indicator. When there was no change in colour (if the solution turns pink by the addition of indicator CO_2 is absent) it was then titrated with standard NaOH (0.05 N) and the end point was noted when the colour changed from colourless to pink. This process was repeated until we get concurrent reading.

$$\text{Carbondioxide (mg/l)} = \frac{\text{Volume of the titrant (ml) x 1000 x 44x 0.05}}{Volume\ of\ sample\ taken\ (ml)}$$

Where, 0.05 is the normality of NaOH solution.

3.2.5 Aquatic Flora and Fauna

Floating sampling quadrate of (1m x 1m) was made and thrown randomly in different sites. Macrophytes were directly observed, counted and noted to calculate the relative density, relative frequency and relative coverage and Important Value Index (IVI).

Importance Value Index (IVI)

Importance value index deals that which plant species is more important and dominant (i.e. in terms of relative density, relative frequency and relative density) in the study area and calculated by using formula given by Zobel *et al.* (1987).

Importance Value Index (IVI) = Relative Frequency (RF) + Relative Density (RD) + Relative Coverage (RC)

Phytoplankton were collected with the help of plankton net of mesh size of 600 μ. Different algal bloom were also collected. These samples were preserved in 5% formalin and brought to the laboratory for identification. Identification of these planktons was done after Encarta (2006).

The fish specimens caught by the local fishermen were collected and interviewed by using questionnaire method (Appendix I.b) to document the native and exotic fish species available in the lake.

3.2.6 Statistical Analysis

Computer software M.S-Excel was used for record, compiling, organizing and analysis of numerical and statistical data, for different calculation like average, mean, standard deviation etc and graphical representation. One-way ANOVA followed by Tukey's HSD was conducted to find out the significance between different water parameters both seasonally and source wise using R version 3.5.1. Then data and graphical representation were presented using MS-Word.

CHAPTER 4: RESULTS

4.1 Water Quality Analysis

4.1.1 Seasonal variability in physico-chemical parameters of water

The water is slightly muddy colour in all the season without any odour. Turbidity was little bit high in rainy season i.e 7.1 NTU than in rainy and winter season. Similarly, average temperature was high in Rainy i.e 27.13 °C, followed by summer i.e 22.14 °C and least in winter i.e 0.95°C. pH of water was statistically insignificantly in all season and was slightly acidic. D.O was high in winter but free CO_2 was found to be significantly high in rainy i.e 12.18 mg/l than in winter i.e 4.43 mg/l and summer i.e 5.2 mg/l. Total hardness in summer was found significantly ($p < 0.05$) higher than other seasons. Alkalinity and Nitrate were significantly different in rainy than that of summer and winter respectively. There is no statistically difference in value of phosphate and chlorine seasonally (Table 2).

Table 2. Mean ± SD values of water seasonally during rainy, winter and summer season. Different letters in subscript (small alphabets) implies significant difference in physio-chemical water parameters among various season.

	S.N	Properties	Rainy	Winter	Dry Summer
Physical Parameters	**1.**	Colour	Muddy colour	Clear	Muddy colour
	2.	Odour	No	No	No
	3.	Turbidity (NTU)	7.1	4.8	6.3
	4.	Temperature (°C)	27.13 ± 1.76^{a}	10.95 ± 0.55^{b}	22.14 ± 2.07^{c}
Chemical Parameters	**5.**	pH	6.65 ± 0.24^{ab}	6.76 ± 0.21^{a}	6.51 ± 0.06^{b}
	6.	D.O (mg/l)	5.14 ± 1.73^{a}	7.76 ± 1.2^{b}	6.28 ± 0.65^{a}
	7.	Free CO_2 (mg/l)	12.18 ± 2.64^{a}	4.43 ± 0.6^{b}	5.2 ± 0.78^{b}
	8.	Total Hardness (ppm)	65.31 ± 3.64^{a}	32.30 ± 6.0^{b}	92 ± 11.06^{c}
	9.	Alkalinity (ppm)	29.61 ± 2.63^{a}	22.38 ± 2.9^{b}	14.14 ± 4.41^{b}
	10.	Nitrate (NO_3-) (ppm)	1.01 ± 0.33^{a}	7.51 ± 0.44^{b}	4.17 ± 3.54^{b}
	11.	Phosphate(PO_4) (ppm)	1.18 ± 0.58^{a}	0.39 ± 0.04^{a}	0.78 ± 0.12^{a}
	12.	Chlorine (ppm)	0.11^{a}	0.15^{b}	0.11^{a}
	13.	Ammonia(NH_3) (ppm)	0.26^{a}	6.02^{b}	0.09^{a}

4.1.2 Source wise variability in physico-chemical parameters of water

Statistically, there is no significantly differences between different physical water parameters like colour, odour and temperature source wise. Chemical parameters pH, D.O, free CO_2, Alkalinity, total hardness, nitrate are also similar. But the mean value of ammonia in inlet i.e 18 mg/l is significantly ($p < 0.05$) higher than middle i.e 0.207 mg/l) and outlet i.e 0.17 mg/l respectively (Table 3).

Table 3. Mean ± SD values of water based on water sources inlet, middle and outlet of the lake. Different letters in subscript (small alphabets) implies significant difference in physio-chemical water parameters according to source of water taken.

			Water sources		
	S.N	**Properties**	**Inlet**	**Middle**	**Outlet**
Physical Parameters	**1.**	Colour	Clear	Slightly muddy	Slightly muddy
	2.	Odour	No	No	No
	3.	Temperature (°C)	18.76 ± 5.94^{a}	21.38 ± 7.05^{a}	21 ± 7.86^{a}
Chemical Parameters	**4.**	pH	6.62 ± 0.25^{a}	6.63 ± 0.26^{a}	6.56 ± 0.09^{a}
	5.	D.O (mg/l)	6.48 ± 1.7^{a}	6.3 ± 2.07^{a}	5.105 ± 2.05^{a}
	6.	Free CO_2 (mg/l)	7.89 ± 4.41^{a}	6.68 ± 3.04^{a}	6.23 ± 3.5^{a}
	7.	Total Hardness (ppm)	71 ± 7.6^{a}	64.57 ± 43.19^{a}	47.37 ± 37.98^{a}
	8.	Alkalinity (ppm)	9 ± 2.93^{a}	7.71 ± 2.19^{a}	29.25 ± 7.66^{a}
	9.	Nitrate (NO_3^-) (ppm)	3 ± 3.63^{a}	3.01 ± 3.23^{a}	3.2 ± 3.36^{a}
	10.	Phosphate (PO_4)(ppm)	0.6 ± 0.62^{a}	0.105 ± 0.07^{a}	1.63 ± 0.19^{b}
	11.	Chlorine (ppm)	0.09 ± 0.08^{a}	0.06 ± 0.07^{a}	0.28 ± 0.05^{a}
	12.	Ammonia (NH_3) (ppm)	18 ± 14.03^{a}	0.207 ± 0.135^{b}	0.17 ± 0.06^{b}

Temperature

The change in season would adversely effects on the water temperature as shown in (Figure. 3a.). The mean temperature of lake water is found to be high in rainy season i.e 27 ±13 °C and low i.e 10 ± 95 °C in winter. Water source wise, the temperature of inlet was slightly cooler in the inlet at mean temperature i.e 18° ± 76 °C as compared to outlet i.e 21 °C (Figure 3b).

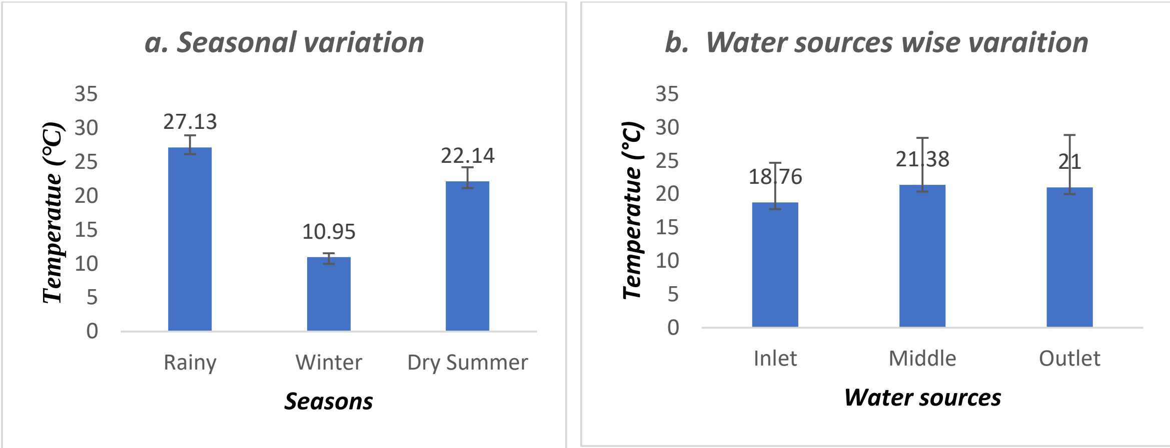

Figure 3. Variation in surface water temperature (a) seasonally and (b) source wise.

Turbidity

The high turbidity is condition resulted from the suspended solids in water including slits, clays that are washed into the river coming from nearby agricultural fields during rain. The highest and lowest range of turbidity has been observed in the rainy season i.e 7.1 NTU and winter season i.e 4.8 NTU respectively as shown in (Figure 4).

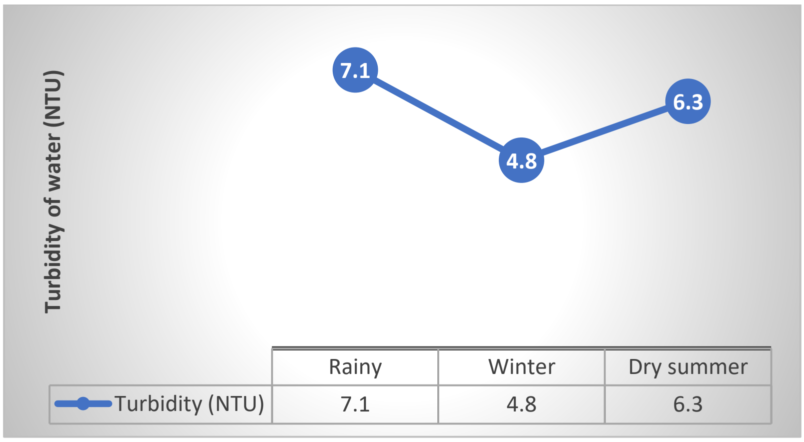

Figure 4. Line chart showing turbidity of water in different seasons.

pH

During the sampling periods, the mean values of pH were found to be in range from 6.51 to 6.76. There was a small variation during the different season as well as different sources of water as (Figure 5).

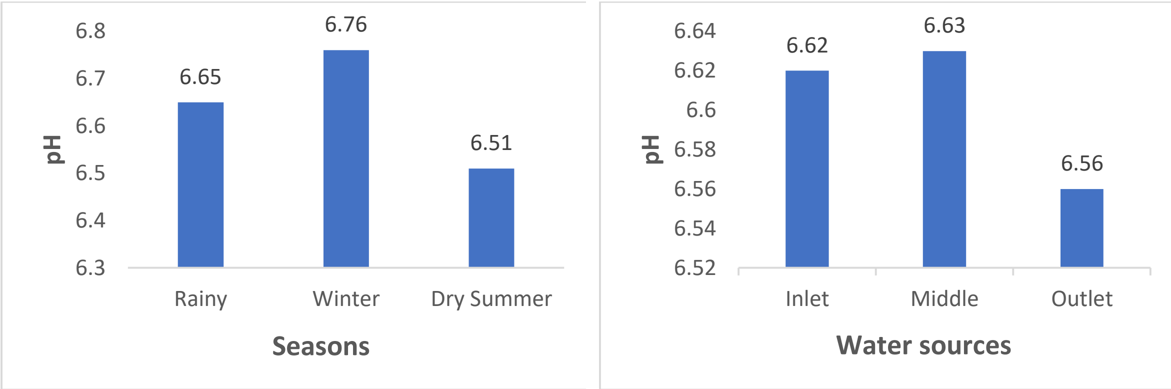

Figure 5. Variation in pH of water in Dipang lake; seasonally (left) and source wise (right).

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Dissolved oxygen

The mean value of dissolved oxygen concentration in lake water slightly increases from the winter i.e 7.76 mg/l to the summer seasons i.e 6.51 mg/l and decline in the rainy seasons i.e 5.14 mg/l. Source wise, mean value of D.O is found to be higher towards inlet i.e 6.48 mg/l than outlet i.e 5.105 mg/l as shown in (Figure 6).

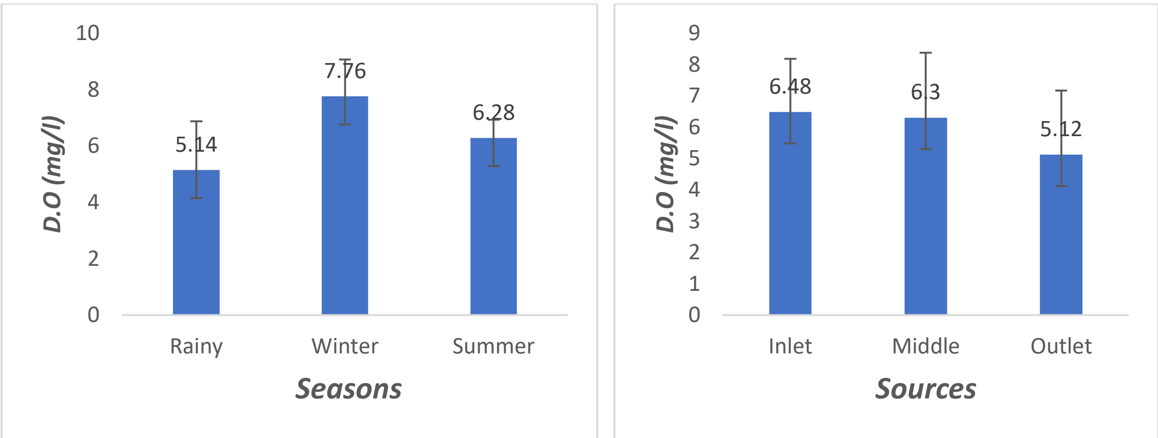
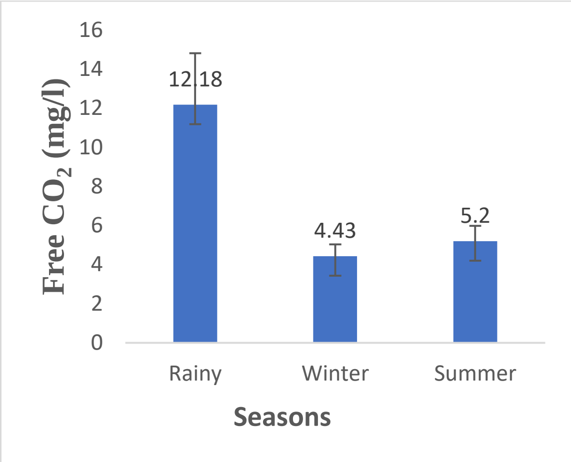


Figure 6. Variation in Dissolved Oxygen (D.O) in Dipang lake; seasonally (left) and source wise (right).

Free carbon dioxide

The seasonal mean value of free carbon dioxide varies from 12.18± 2.64 mg/l in rainy season to 4.43± 0.6 in winter season. Similarly, there is no vast difference in the mean value of free carbon dioxide in water (Figure 7).



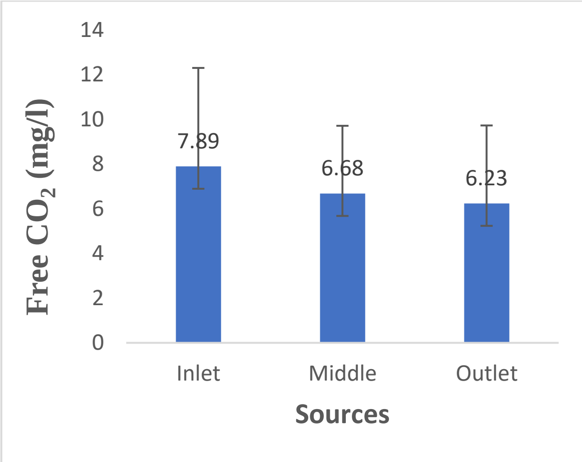
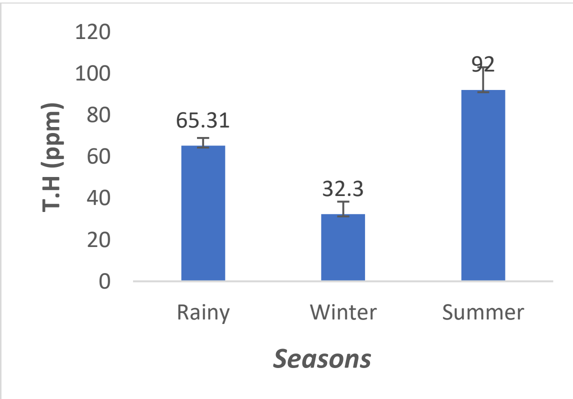


Figure 7. Variation in Free CO_2 in Dipang lake; seasonally (left) and source wise (right).

Total hardness

Seasonally, the variation in mean value of water hardness ranged from 65.31± 3.64 ppm in rainy season to 92± 11.06 ppm in dry summer. Likewise, the minimum value was recorded towards outlet during winter i.e 47.37± 37.98 ppm while maximum during dry summer at Inlet i.e 71± 7.6 ppm source wise (Figure 8).



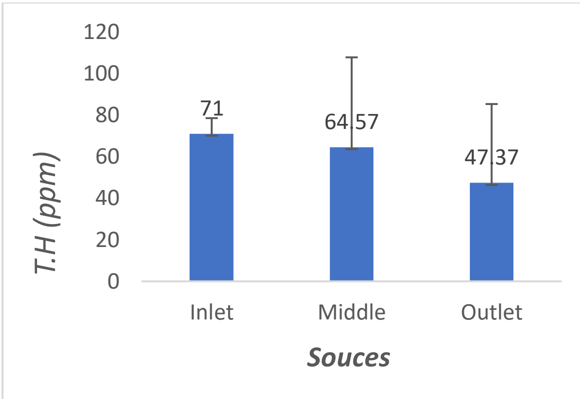


Figure 8. Variation in Total hardness in Dipang lake; seasonally (left) and source wise (right).

Alkalinity

The mean values of total alkalinity range from 29.61±2.63 ppm (in monsoon) to 14.14± 4.41 ppm (in summer) seasonally. Similarly, the lower mean value of alkalinity was observed in the middle part of the lake i.e 7.71± 2.19 ppm and higher mean value towards outlet 29.25±.7.66 ppm (Figure 9).

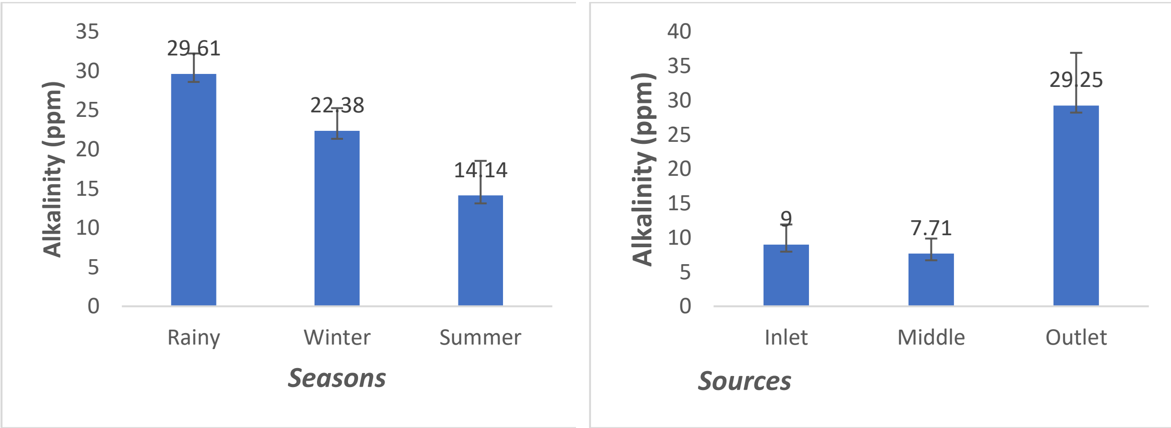


Figure 9. Variation in Alkalinity in Dipang lake; seasonally (left) and source wise (right).

Nitrogen content [Nitrate (NO_3^-) and Ammonia]

The seasonal and source wise variation of nitrates in the lake water is shown in (Figure. 10). The highest mean concentration of nitrate was found in the month of winter i.e 7.51 ± 0.44 and lower concentration was found in rainy season i.e 1.01±0.33 ppm. Sector wise, the mean value of nitrate (NO_3) is almost similar in all the sources with an average value of 3.01.

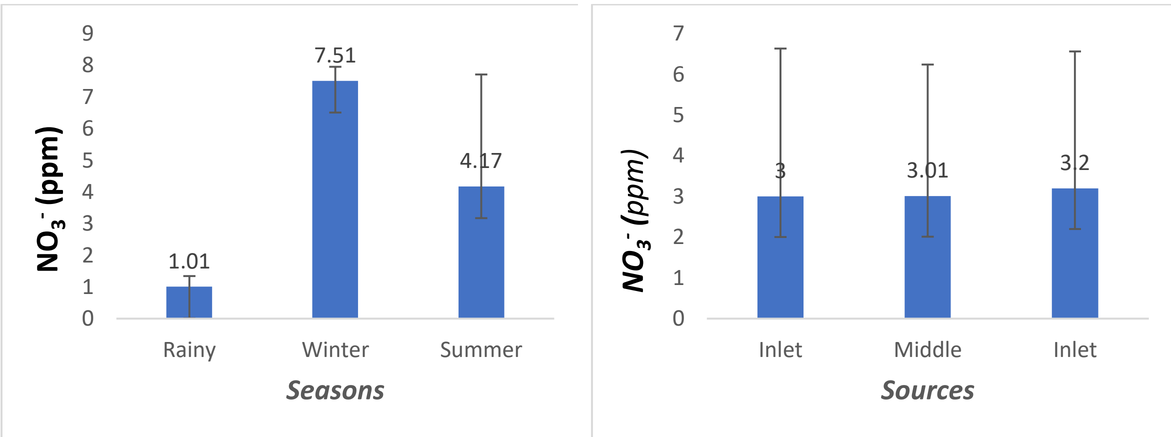


Figure 10. Variation in Nitrate (NO_3^-) in Dipang lake; seasonally (left) and source wise (right).

Seasonally the highest mean value of ammonia i.e 6.02 ppm was found in winter season and low in summer season i.e 0.09 ppm. One of the interesting find out of this research is that highly fluctuation of ammonia according to water source wise. The value is in peak towards inlet i.e 18 ± 14.03 ppm and low in middle and outlet i.e 0.21±13 and 0.17±0.06 ppm respectively (Figure 10).

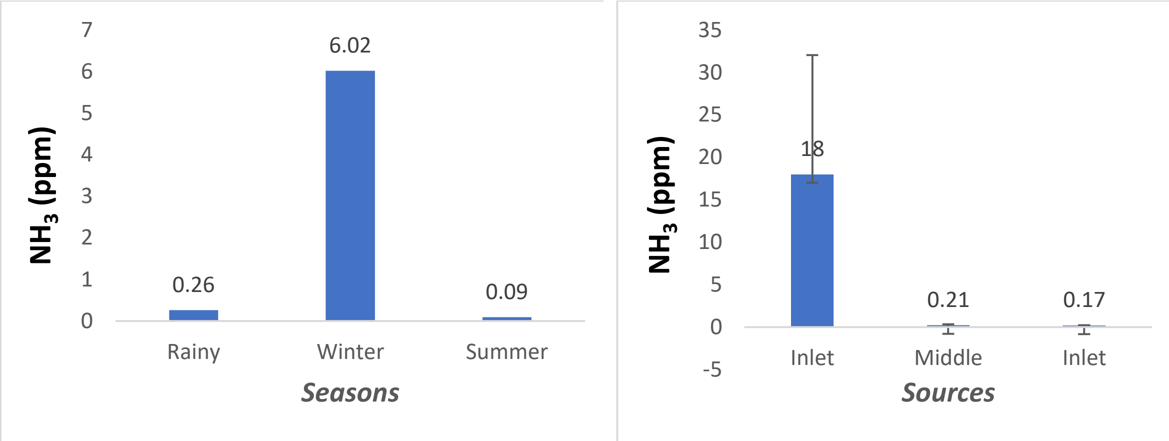


Figure 11. Variation in Ammonia in Dipang lake; seasonally (left) and source wise (right)

4.2 Aquatic Flora and Fauna

On random sampling in different water sources using floating quadrate of (1x1) m^2, eight aquatic and amphibian plants were found in or around the lake. Based on their relative density, relative frequency and relative coverage, their source wise Important Value Index (IVI) was calculated and presented in (Table 4).

Table 4. Important Value Index (IVI) of some aquatic plants of the Dipang lake source wise. The values of IVI of *Nelumbo lutea* (Yellow lotus) i.e 82 followed by *Sagittaria sagittifolia* (Arrowhead) i.e 34 was found to be higher than that of other plants species but only in water inlet. However, *Schoenoplectus mucronata* (Bog bulrush), *Persicaria hydropiper* (Marshpepper knotweed), *Cyperus esculentus* (Yellow nutsedge) can be found in all part of the lake (Table 4).

S.N	Name of species	IVI		
		Inlet	Middle	Outlet
1	*Nelumbo lutea*	82	61	10
2	*Sagittaria sagittifolia*	34	6	0
3	*Schoenoplectus mucronata*	21	22	15
4	*Azolla imbricata*	48	47	26
5	*Hydrilla verticillata*	20	37	20
6	*Lemma minor*	55	59	26
7	*Persicaria hydropiper*	20	23	5
8	*Cyperus esculentus*	19	23	0

Lab analysis of phytoplankton sampled shows some common species of algae like *Spirogyra* sp, *Vaucheria* sp, *Nostoc* sp, *Chara* sp, *Gloeotrichia* sp, *Lyngbya* sp, *Oscillatoria* sp etc.

Most common fish species found in the lake were *Labeo rohita* (Rohu) *Cyprinus carpio* (Common carp), *Ctenopharyngodon idella* (Grass Carp), *Aristichthys nobilis* (Bighead Carp). *Oreochromis niloticus* (Nile Tilapia). Other fish species like *Catla catla* (Bhakur), *Tor putitora* (Sahar) and *Clarias batrachus* (Asain Magur) were also recoreded. Among them, Nile Tilapia, Common Carp and Bighead Carp are invasive fish species.

CHAPTER 5: DISCUSSION

5.1. Physico-chemical properties of water

Water quality testing is an important part of environmental monitoring since it plays significant role for survival of aquatic organisms and other ecosystem process. When water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well. These sections detail all of the parameters that affect the quality of water in the environment.

Temperature is one of the very important parameters in of an aquatic environment. It also participates in a major role in the physio-chemical and metabolic position of aquatic ecosystem. The lower temperature during winter season is due to atmospheric temperature and duration of sunlight (Kundangar *et al*., 1996). Water source wise, the mean temperature of inlet was slightly cooler in the inlet than outlet due to presence of more vegetation like *Nelumbo nucifera, Sagittaria sagittifolia etc* towards inlet which decrease the water temperature. Similar result was found by Dale and Gillespie (2011).

The highest turbidity in the rainy season is due to heavy rain that brings the silt and soil particles from the surrounding area. These particles absorb light and increase temperature in the water surface which causes low dissolved oxygen level found in the pond water. The higher transparency during winter season may be due to clear atmosphere, better light intensity and settlement of silt and suspended particle. The findings of Pandey and Pandey (1983) and Manjare *et al,*. (2010) coincide with the present investigation.

The Dipang lake water is slightly acidic. During the sampling periods, the pH values ranges from 6.51 to 6.76. There was a small variation during the different season as well as different sources of water. Water with pH ranging from 6 to 9 is usually suitable for growth of organism (Shrestha, 2006) and results represents that the pH values are within the acceptable limit.

The dissolved oxygen was an important factor which represents the water quality and organic pollution in water bodies. Dissolved oxygen is one of the most important physical, chemical and biological characteristics of water. D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. D.O. enters water by diffusion from the atmosphere and as a by- product of photosynthesis by aquatic plants. The dissolved oxygen concentration in Dipang lake water slightly increases from the winter (7.76 mg/l) to the summer seasons (6.51 mg/l)) and decline in the rainy seasons (5.14 mg/l) (fig 4.a). This is because of high temperature and turbidity due to surface runoff during rainy season. The slits, clays particles absorb light and increase temperature in the water surface which causes low dissolved oxygen level found in the pond water (Kataria *et al*. 2006)

Source wise, D.O is found to be higher towards inlet (6.48 mg/l) than outlet (5.105 mg/l). The reason is presence of large amount of aquatic plants towards inlet which promotes oxygen level during photosynthesis. D.O value 5-7 mg/l is good for fish development (Sharma & Grover, 1982). When the dissolved oxygen drops below 4 mg/l, fishes die and badly affect the reproduction and spawning (Shrestha, 1997).

Free CO_2 is the raw material without which autotrophs cannot prepare their own food. On the other hand, through the phenomenon of photosynthesis, these autotrophs liberate O_2 that ultimately supports other forms of life in all sorts of ecosystem. Temperature, depth, rates of respiration and decomposition of organic matter influences the concentration of free carbon dioxide in freshwater. Concentration of free CO_2 sometimes depends upon alkalinity and hardness of the water body. Present investigation revealed that the lower values of free CO_2 was recorded in the months of winter. The lower value of free CO_2 during winter season might be due to increased transparency which ultimately enhances the rate of photosynthesis. Hence, the free carbon dioxide is utilized by autotrophs. Similar trend of lower values during summer season was given by Phukon and Biswas (2011) and Patralekh *et al.,* (2012). On the contrary, higher values of free CO_2 were noted in the months of rainy. It might be due to cloudy environment and lower level of transparency which ultimately diminish the rate of photosynthesis. Hence level of free carbon dioxide is increased. Higher value of free CO_2 during monsoon season was also observed by Sayeshwara *et al.,* (2010) and Ghosh and Nath (2012).

Total hardness is mainly classified as temporary hardness and permanent hardness. Temporary hardness is due to carbonates and bicarbonates of calcium and magnesium while permanent hardness is the effect of chlorides and sulphates. Total hardness is a key indicator for the suitability such as drinking, cooking, washing etc. The present investigation revealed that the level of total hardness was decreased during the months of monsoon and winter season due to dilution of water by rain. Increase in total hardness during the months of dry summer season may be due to evaporation rate and decreased water level. Leaching of calcium and magnesium from catchment area may also cause increased level of hardness. The total hardness ranges are similar to above findings that were emphasized by Sarma and Dutta (2012) for two riverine wetlands from Assam. Sawyer (1960) classified water into categories on the basis of hardness as soft (00 mg/l to 75 mg/l), moderately hard (76 mg/l to 150 mg/l) and hard (151 mg/l) and above. From the above findings, Dipang freshwater body falls under the moderate category. Since this water body is very untouched by human activities.

Total alkalinity is an important parameter that indicates the buffering capacity of water. Total alkalinity is attributed to bicarbonates, carbonates, OH ions, borates, silicates and phosphates (Kataria *et al*., 1995). The present study exhibited the definite pattern of total alkalinity seasonally. The total alkalinity was declined in the months of summer season while it was observed inclined in the months of rainy and winter season. Decrease in total alkalinity during summer months may be due to fluctuations in the bicarbonates while higher values of alkalinity during rainy season may be due to nutrients run off from catchment area i.e agricultural field. The later statement is in agreement with (Sharma and Dutta, 2012). Very few workers have noted the alkalinity values lower during summer season such as Ohal and Kamle (2011) and (Verma *et al*., 2011). However, total alkalinity values higher during winter season were noticed by many authors like Angadi *et al.,* (2005) and Hujare (2005).

Phosphorus has been considered as the main nutrients for the productivity of aquatic ecosystem. It occurs in both organic and inorganic form. It is the important nutrient essential to all biotic community present in an aquatic ecosystem (Lind, 1974). During the present study higher PO_4 value during rainy season might be due to surface run off from adjacent agricultural land fertilized with phosphate as indicated by Heron (1961). The lower value during winter might be due to rapid biological uptake and the formation of water insoluble calcium carbonate (Zutshi and Khan 1977). The lake can be categorized as eutrophic based on PO_4 as suggested by Forsberg and Ryding (1980)

Nitrogen occurs in the aquatic system both as a result of decomposition of organic matter in the lake and bacterial fixation of atmospheric nitrogen (Lind 1974). The higher value of nitrate and ammonia during winter season might be due to high microbial activity which causes decomposition of aquatic plant i.e lotus and excretory products of aquatic animal. Similarly, low value during rainy season might be due to inactiveness of microbes when decomposition rate becomes low. Similar views were expressed by Kafle (2000) in Rupa Lake, and Simkhanda (2003) in Gaindahawa lake.

High IVI of lotus was found towards the inlet where concentration of ammonia is rich. This is due to the ability of the plant to absorb ammonia (NH_3) by the lotus plant. Lotus plants are able to use both nitrate and ammonium as inorganic nitrogen sources for ulterior assimilation (Orea *et al.*, 2001; Pajuelo *et al*., 2002).

5.2 Aquatic Flora and Fauna

Wetlands support exceptionally high biodiversity and provide valuable ecosystem services. But the richness of plant species in aquatic and wetland habitats is relatively low compared with most terrestrial communities (Richardson and Vymazal, 2001). Present investigation counts total of eight macrophytes and seven microphytes within or around the Dipang lake. Lake Cluster of Pokhara Valley (LCPV) comprises of 230 plant species belonging to 70 families and 177 genera. Asteraceae (25 species), Poaceae (22 species), Fabaceae (18 species), Cyperaceae (16 species), and Lamiaceae (11 species) were species-rich families. Among 230 species, 183 species were native and 47 species naturalized; among the naturalized species, 21 species were invasive (Pathak *et al.*, 2019). Nepal is rich in fish diversity with total of 230 native fish species belonging to 104 genera and 34 families (Rajbanshi 2012). Among them, five native fish species and three invasive fish species were recorded from Dipang in my study. Likewise, 17 species of fishes (11 indigenous and six exotic) fish species belonging to five orders, seven families and 17 genera were recorded from Begnas lake which lies very near to Dipang lake (Pokharel and Chand, 2019).

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CHAPTER 6: CONCLUSION AND RECOMMEDATIONS

6.1 Conclusion

The tested phyisco-chemical water parameters showed variation within sampling stations both seasonally and source wise. Peak values of temperature, turbidity, free CO_2, Total hardness, Alkalinity, Phosphate were recorded in rainy season seasonally. Source wise the maximum values of D.O, fee CO_2, Total hardness and Ammonia were recorded towards water inlet located to the North.

The important finding of this research is that water parameters also affect the growth of some plant species especially yellow lotus (*Nelumbo lutea*) which can grow in that place i.e towards inlet where peak value of ammonia is high i.e 18±14.03 ppm. The high concentration of ammonia is due to runoff of fertilizers and chemicals from agricultural fields that lies above the inlet of the lake.

For long term use, Lake can be used for aquaculture (fish farming) as the water quality parameters like pH, temperature and D.O are quite suitable for survival of fishes.

Three main inlets carry wastewater from agricultural fields into the Lake. The outlet flow is very low even insignificant. Rehabilitation of vulnerable lakes should be done on time with appropriate measures suitable for the area. Bioengineering measures, vegetative and concrete masonry etc. are applied for the rehabilitation of these degraded sites. Gabion walls, loose stone check dam, single check dam, grass and tree plantation, etc. can be applied for watershed managements and are cost effective also.

6.2 Recommendation

i. Further research on the higher availability of the lotus in ammonia rich water should be carried out to study the absorbent quality of plant so that the plant could be used for phytoremediation property if it has any.
ii. The remediation methods for Dipang Lake should focus on the reduction of the nutrient level in the lake water. It can be achieved by reducing the nutrient loads and by increasing their uptake from the lake water.
iii. Increasing the gazing capacity of the fish population in the lake is also another option. It might include introduction of new plankton phage fish species which live on algae.
iv. Retention walls should be constructed to increase water body area of the lake.

REFERENCES

Acharya, T.D., Yang, I.T., Subedi, A. and Lee, D.H. 2016. Change Detection of lakes in Pokhara, Nepal using Landsat Data. *Proceedings* 2017. 1, 17.

Alley, E.R. 2007. Water quality control handbook. Vol. 2. New York: *McGraw-Hill*.

Angadi, S. B., Shiddamalliayya, N. and Patil, P. C. 2005. Limnological studies of Papnash pond, Bidar (Karnataka). J*ournal of Environmental Biology*. 26, 213-216.

Breaban, I.G., Oiste, A.M., Stoican, A.E., and Tibuleac, C. 2013. Seasonal variation of water quality parameters in the Chirita reservoir, IASI. *The anthropogenic impact upon Black Sea region biodiversity*, 82.

Carpenter, S.R. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen, *Ecological Applications*. 8, 559-568.

Dawson, F.H., Newman, J.R., Gravelle, M.J., Rouen, K.J and Henville, P. 1999 Assessment of the tropic status of rivers using macrophytes. *Evolution of the Mean Tropic Rank. Research and development. Technical report E39, Environment Agency,* Bristol.

Duarte, C.M., Kalff, J. and Peters, H. 1986. Patterns in biomass and cover of aquatic macrophytes in lakes. *Can J Fish Aquatic Science* 43, 1900–1908.

Forsberg, C. and Ryding, S.O., 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste receiving lakes Arch. *Hydrobiological*. 89, 189−207.

Ghosh, R and Nath, S. 2012. Physico-chemical and biological parameters of water of semiurban ponds of Konnagar, West Bengal. *Journal Ecobiology*. 31**(1-4),** pp 149-160.

Ghimire, M. D., (Dhakal) K. Sharma, Saud, D.S. 2020. A Checklist of Wetland Flora Reported from Nepal. Department of Plant Resources (DPR), Thapathali, Kathmandu, Nepal

Haryuni, Marsoedi, Harahab and N., Setyohadi, D. 2014. Mangrove Vegetation and Water Quality Conditions in the Coastal Area of Seruyan Regency, Central Kalimantan, *International Journal of Ecosystem*, Vol 2**, (4)**, 89-94.

Hernandez, M.E. and Mitsch, W.J. 2007. De-nitrification in created riverine wetlands: influence of hydrology and season. *Eco Engineering*. 30, 78–88

Heron, J. 1961. Phosphorus adsorption by lake sediments. *limnology and Oceanography*, 6, 338.

Hujare, M.S. 2005. Hydrological studies of perennial tanks from Kolhapur district. Ph.D. Thesis submitted to Shivaji University, Kolhapur.

Intergovernmental Panel on Climate Change (IPCC). 2014. Summary for policymakers in climate change 2014. *Cambridge University Press*, 1-32.

Jain, Y. and Dhamja, S. K. 2000. Studies on polluted lentic water body of Jabalpur with special reference to its physico-chemical and biological parameters. *Journal of Environment Poll.* 7 **(2),** 83-87.

Jorgensen, S.E. 1980. Lake management. water development, supply and management, *University of Copenhagen, Denmark.* 14,146.

Kafle, R.R., 2000. Growth and clump maintenance of *Trapa quadrispinosa* Roxb. in response to physico-chemical parameters of Phewa and Rupa lakes, Pokhara, Kaski, Nepal. M.Sc. Dissertation Submitted to Central Department of Botany, Kirtipur, Kathmandu, Nepal.

Kataria, H. C., Singh, A. and Pandey, S. C. 2006. Studies on water quality of Dahod Dam, India. *Pollution Research.* 25, 553- 556.

Kenny, M.A., Sutton-Grier, A.E., Smith, R.F. and Gresens, S.E. 2009. Benthic macro invertebrates as indicators of water quality: The intersection of Science and policy. *Terrestrial Arthropod Reviews*.2, 99-128.

Korschgen, C.E., Green,W.L., and Kenow, K.P. 1997. Effects of irradiance on the growth and winter bud production by *Vallisneria americana* and consequences to its abundance and distribution. *Aquatic Botany*, 58, 1-9.

Kundangar, M.R.D., Sarwar, S.G. and Hussain, J. 1996. Zooplankton Population and Nutrient Dynamic of Wetlands of Wular Lake Kashmir, India. *In*: Jha, P.K., Ghimire, G.P.S., Karmacharya, S.B., Baral, S.R. and Lacoul, P. (eds.), Environment and Biodiversity: In context of South Asia, *Ecological Society (ECOS)*, Kathmandu, Nepal, 128-134.

Kunwar, D. and Devkota, A. 2012. Seasonal Variation on Physiological parameters and macrophytes production of Rupa lake, Kaski, Nepal. *J. Nat. Hist. Mus*. Vol. 26, 80-87.

Lind, O.T.,1974. *Handbook of common methods in limnology.* C.V. Mosby Co. Saint Louis, USA, pp:199.

McCartney, M.P. and Houghton-Carr, H.A. 2009. Working wetland potential: an index to guide the sustainable development of African wetlands. *Natural Resource Forum* 33 **(2).** 99–110.

Manjare, S. A., Vhanalkar, S. A. and Muley, D. V. 2010. Water quality assessment of Vadgaon tank of Kolhapur (Maharashtra) with special reference to zooplankton. *Inter. J. Adv. Biotech and Res*. 1 **(2),** 91-95.

Moyle, P.B. 1994. Biodiversity, biomonitoring and the structure of stream fish communities. *Publishing*, Inc.; 171–186.

NBO, 2007-2008; Office Data, Narayani Basin Office, Government of Nepal, Ministry of Science and Technology, Department of Hydrology and Meteorology P. O. Box 406, Pokhara.

Norlin, J.I., Bayley, S.E. and Ross, L.C.M. 2005 Submerged macrophytes, zooplankton and the predominance of low-over high-chlorophyll states in western boreal, shallow-water wetlands. *Freshwater Biology*. 50, 868–881.

Orea A., Pajuelo P., Pajuelo E., Marquez A.J. and Romero J.M. 2001. Characterisation and expression studies of a root cDNA encoding for ferredoxin-nitrite reductase from *Lotus* japonicus. *Physiologial Plantarum,* 113, 193-202.

Oli, KP., 1996. An environmental study of Nepal's Begnas and Rupa Lakes. NPC/IUCN, National conservation strategy implication project.

Oli, Krishna P. (edited by). 1999. Conservation and Development of Lekhnath Municipality. Kathmandu: IUCN Nepal. Xii +121 pp.

Pajuelo P., Pajuelo E., Orea A., Romero J.M. and Marquez A.J. 2002. Influence of plant age and growth conditions on nitrate assimilation in roots of *Lotus japonicus* plant. *Functional Plant Biology*, 29, 485-494.

Palit, D. and Mukherjee, A. 2012. Studies on the water quality and macrophytes composition in wetlands of Bankura district, West Bengal India. *Indian Journal in Plant Science.* 1, 221–228

Pandey, U.C. and Pandey, D.C. 1983. Periodicity, Density and Productivity of Phytoplankton of Mepherson lake, *Allahabad. Sci. Cult.* 49:178-180.

Pathak, H.N., Shrestha, B.B., Bhuju, D. R., and Bhandari, P. 2019 Floristic Diversity in the lake cluster of Pokhara Valley, Central Nepal. Journal of Natural Histrory Museum Vol 31.

Patil, P.N., Sawant, D., and Desh, R.N., 2012. Physico-chemical parametres for testing of water- a review. *International Journal of Environmental Science.* 3, 1194-120

Patil, S. R., Sawant, R. S., Patil, S. S., Sathe T. V. and. Patil, R. S. (2013). Avian fauna and physico-chemical parameters of Gajargaon Pond of Ajara Tahsil, Kolhapur (M. S.). *Rasayan Journal of Chemistry*, 6 **(1):** 76-79.

Patralekh, M., Sinha, S. K., Kumar, A. and Patralekh, L. N. 2012. Analysis of some physico-chemical parameters of Shivganga pond of B. Deoghar, Jharkhand, India. *Environment and Ecology.* 28 **(2A):** 1022-1025.

Phukon, H., and Biswas, S. P. 2011. Study of habitat ecology and fish diversity of a wetland in Upper Assam. *Geobios.* 38 **(1):** 45-48.

Pokharel, K.K. and Chand, S. 2019. Diversity, Distribution and Occurrence of Fishes in Begnas Lake, Pokhara, Nepal. *Zoo-Journal*. 5, 16-22

Proceedings of 8th IOE Graduate Conference in sewage system in Pokhara city. 2020. Vol; 8.

Puri, P.J., Yenki, M.K.N., Sangal, S.P., and Gandare, N.V., 2011. Surface water (lakes) quality assessment in Nagpur city based on water quality index (WQI), *Rasayan Journal of Chemistry* 4 **(1),** pp: 43-48.

Rajbanshi, K.G. 2012. Biodiversity and distribution of freshwater fishes of Central/Nepal Himalayan region. *NEFIS*, pp 65

Rao, S. S. (1989). Acid stress and aquatic microbial interactions. Ed. *CRC Press.* Pp:176.

Reynolds, J. 2014. Effects of water quality on fish species in Cutler Reservoir. Available: https://digitalcommons.usu.edu/student_showcase/107. (Accessed: 22/07/2021).

Richardson, C.J., and J. Vymazal. (2001). Sampling macrophytes in wetlands. Pp. 297-338 (Chapter 14) in Rader, R., D.P. Butzer, and Scott A. Wissinger (eds.). *Bio-assessment and Management of North American Freshwater Wetlands.* New York: John Wiley & Sons. 469.

Sarma, D. and Dutta, A. 2012. Ecological studies of two riverine wetlands of Goalpara District of Assam, India. *Nat. Envi. and Poll. Tech*. 11 **(2):** 297-302.

Sawyer, C. N. 1960. Chemistry for sanitary engineering. *Mc Graw Hill Publication*. New York, USA.

Sawyer, C.N. and McCarty, P.L. (1978). Chemistry for Environmental Engineering (3rd ed.) *New York: McGraw-Hill Book Co.*

Sayeshwara, H. A., Mahesh, A.G. and Ravikumar, M. (2010). Limnological studies of Santhekadur pond, Bhadravathi, Karnataka, India. *Geobios,* 36 **(4):** 293-296.

Shah, B., and Pant, B.R. 2012. Water Quality Assessment of Sirsiya River. *Nepal Journal of Science and Technology.* Vol. 13 **(2),** 141-146.

Shrestha, T.K. 1997. The Mahseer: In the rivers of Nepal disrupted by dams and ranching strategies. Published by Mrs, Bimala Shrestha, Kathmandu.

Simkhada, D., 2003. Ecology and management issues of Gaindahawa lake, Rupandeni, Nepal. M.Sc. Dissertation Submitted to Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Tchobanoglous, G., & Schroeder, E.D. 1987. Water quality: characterization, modeling, modification. *University of California*. pp: 706

Tiwari, A., Gurung, J. and Pokharel, S. 2021. Biodiversity of Dipang Basin on Lake Cluster of Pokhara Valley, Kaski.

Venkatesharaju, K., Ravikumar, P., Somashekar, R.K and Prakash, K.L. 2010. Physico-chemical and bacteriological investigation on the river Cauvery of Kollegal stretch in Karnataka. *Journal of Science Engineering Technology.* 6**(1):**50– 59

Verma, P. U., Chandawat D. K., and Solanki, H. A. 2011. Seasonal variation in physico-chemical and phytoplankton analysis of Kankaria Lake. *Life sciences leaflets*, 19: 842- 854. pp 49-63.

Verma, S. and Khan, J.B. 2015. Analysis of water quality by physico-Chemical Parameters in Fateh Sagar Talab in Bagar, Dist. Of Jhunjhunu, India. *IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS)* 10, 41-45

Vincent, J., and Vallarino, L. M. (1969). Chemistry. Ed. Prentice-Hall, *University of California.* pp: 844.

Wang, L., Han, Y., Yu, H., Fan, S., and Liu, C., Nov 2019. Submerged Vegetation and Water Quality Degeneration from Serious Flooding in Liangzi Lake, China. *Front Plant Sci.*

Zobel D.B., Jha, P.K., Behan, M.J. and Yadav. U.K.R, 1987. *A practical manual for ecology*. Ratna Book distributors, Kathmandu, Nepal.

Zutshi, D.P. and Khan, M.A. 1977. Limnological investigations of two subtropical lakes, *Geobios*.(4). pp: 45−58.

APPENDICES

Appendix I; a Data Sheet for **water quality parameter** in the Dipang Lake.

Date: ______________

Time: _______________

Season: ______________

A. **Field measurement**

Properties	Inlet	Middle	Outlet
Colour			
Odour			
Temperature			
Turbidity			
pH			

B. **Lab measurement**

For Titration	Sources	Initial reading (I)	Final Reading (F)	Difference (F-I)
D.O	Inlet Middle Outlet	i. ii. iii. . . .		
Free CO2	Inlet Middle Outlet	. ii. iii. . . .		

Properties	Source			
	Inlet	Middle	Outlet	Mean
Total Hardness	i. ii. iii.			
Alkalinity				
Nitrate				
Phosphate				
Chlorine				
Ammonia				

C. **IVI (Important Value Index)**

Source: __________________ **Date: ___________**

S.N	Name of species	Qudarants					Total	Freq	R.F	Density	R.D	Coverage	R.C	IVI
		Q_1	Q_2	Q_3	Q_4	Q_5								
1.														
2.														
3.														
4.														
5.														
6.														
7.														
8.														
9.														

Appendix I: b Questionnaire used for **Fish Study** in the Dipang Lake

Date:

Name of Interviewer: ____________________________

Age: ________________________ Education: _________

Occupation: ___________________________

Residence: _____________________________

1. How long you have been fishing in Dipang Lake? ___________
2. In which category of Fisherman do you lie?
   a. Full time ( ) b. Part time ( ) c. Occasional ( )
3. What techniques do you use to catch fish?
   ____
4. At which section of the lake do you get more fish? ________________
5. What are the different species of fish that you have catch in this river? Any invasive fish?

Name of the fish			

Tick for invasive

Appendix II: List of Aquatic plant species found in or around Dipang Lake

S.N	Scientific Name	Common Name	Family
1	*Nelumbo lutea* Willd.	Yellow Lotus	Nelumbonaceae
2	*Sagittaria sagittifolia* L.	Arrowhead	Alismataceae
3	*Schoenoplectus mucronata* (L.) J Jung & H.K Choi	Bog bulrush	Cyperaceae
4	*Cyperus esculentus* L.	Yellow nutsedge	Cyperaceae
5	*Hydrilla verticillata* (L.f) Royle	Waterthyme	Hydrocharitaceae
6	*Lemma minor* L.	Common Duckweed	Araceae
7	*Persicaria hydropiper* (L.) Delabre	Marshpepper knotweed	Polygonaceae
8	*Azolla imbricata* (Roxb. Ex Griff.)	Mosquito Fern	Salviniaceae

Appendix III: Density (D), Relative Density (R.D), Frequency (F%), Relative frequency (RF), Coverage (C), Relative Coverage (RC) and Important Value Index (IVI) of plants species source wise i.e Inlet, Middle and Outlet).

Source: Water Inlet							
Name of the species	**Density (D)**	**(R.D)**	**Freq (F)**	**R.F**	**Coverage (C)**	**R.C**	**IVI**
Nelumbo lutea	7.0	14.6	100.0	15.2	60.0	52.2	82.0
Sagittaria sagittifolia	2.2	4.6	80.0	12.1	20.0	17.4	34.1
Schoenoplectus mucronata	2.4	5.0	80.0	12.1	5.0	4.3	21.5
Azolla imbricata	14.4	30.1	100.0	15.2	3.0	2.6	47.9
Hydrilla verticillata	1.6	3.3	80.0	12.1	5.0	4.3	19.8
Lemma minor	18.4	38.5	100.0	15.2	2.0	1.7	55.4
Persicaria hydropiper	1.0	2.1	60.0	9.1	10.0	8.7	19.9
Cyperus esculentus	0.8	1.7	60.0	9.1	10.0	8.7	19.5
Total	**47.8**		**660.0**		**115.0**	**100.0**	

Source: Water middle							
Name of the species	**Density (D)**	**(R.D)**	**Freq (F)**	**R.F**	**Coverage (C)**	**R.C**	**IVI**
Nelumbo lutea	4.0	7.9	100.0	16.1	25.0	36.8	60.8
Sagittaria sagittifolia	0.2	0.4	20.0	3.2	2.0	2.7	6.3
Schoenoplectus mucronata	1.4	2.8	80.0	12.9	5.0	6.7	22.3
Azolla imbricata	12.2	24.1	100.0	16.1	5.0	6.7	46.9
Hydrilla verticillata	7.2	14.2	100.0	16.1	5.0	6.7	37.0
Lemma minor	18.8	37.2	100.0	16.1	4.0	5.3	58.6
Persicaria hydropiper	1.6	3.2	80.0	12.9	5.0	6.7	22.7
Cyperus esculentus	1.6	3.2	80.0	12.9	5.0	6.7	22.7
Total	**47.0**		**660.0**		**56.0**		

Source: Water Outlet							
Name of the species	**Density (D)**	**(R.D)**	**Freq (F)**	**R.F**	**Coverage (C)**	**R.C**	**IVI**
Nelumbo lutea	0.6	0.0	40.0	10.0	2.0	0.1	10.1
Sagittaria sagittifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Schoenoplectus mucronata	3.0	0.1	60.0	15.0	5.0	0.3	15.4
Azolla imbricate	6.8	0.3	100.0	25.0	4.0	0.2	25.5
Hydrilla verticillata	1.6	0.1	80.0	20.0	3.0	0.2	20.2
Lemma minor	9.4	0.4	100.0	25.0	5.0	0.3	25.7
Persicaria hydropiper	0.2	0.0	20.0	5.0	1.0	0.1	5.1
Cyperus esculentus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**21.6**		**400.0**		**20.0**		

APPENDIX IV: PHOTOPLATES

PLATE - I

A. Dipang Lake

D. Fisheries Lab, Pokhara

B. Field work

E. Lab experiment

D. Water samples

F. Digital Water Testing Instrument (ECO-CHECK)

PLATE – II

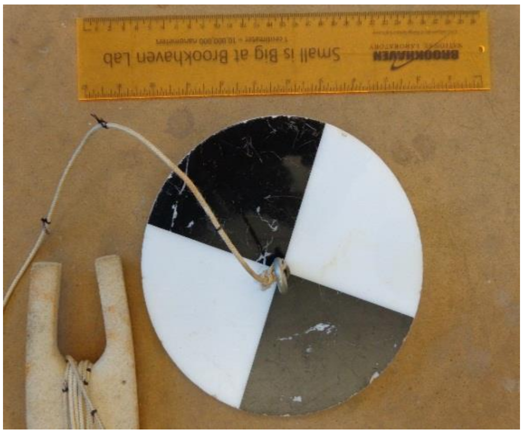
A. Titration

D. Yellow lotus Flower *(Nelumbo lutea)*

B. Stripe for water quality test

E. Tilipia *(Oreochromis niloticus)*

C. Water quality test via ECO-CHECK



F. Secchi Disc