WATER QUALITY MONITORING OF BAGMATI RIVER BASIN, KATHMANDU VALLEY

A DISSERTATION SUBMITTED TO PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER'S DEGREE IN BOTANY

Submitted to

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Amrit Campus

Institute of Science and Technology

Tribhuvan University

Kathmandu, Nepal

By

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Symbol number: 344/072

T.U. Regd no: 5-2-37-1008-2011

June 2022

DECLARATION

I, hereby declare that the dissertation work entitled "**Water Quality Monitoring of Bagmati River Basin, Kathmandu Valley**" 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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RECOMMENDATION LETTER

This is certified that the dissertation work entitled **"Water Quality Monitoring of Bagmati River Basin, Kathmandu Valley"** submitted by "**Keshab Pokhrel**" has been carried out under my supervision. To the best of my knowledge, this research has not been submitted for any other degree, anywhere else. I, therefore, recommend this dissertation work to be accepted as a partial fulfillment of Masters' degree in Botany from Amrit Campus, Tribhuvan University, Kathmandu, Nepal.

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LETTER OF APPROVAL

The dissertation work entitled **"Water Quality Monitoring of Bagmati River Basin, Kathmandu Valley"** submitted by **Keshab Pokhrel** has been accepted for the examination and submitted to the Amrit Campus, Tribhuvan University for the partial fulfillment of the requirements for Masters' degree in Botany (Ecology).

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CERTIFICATE OF ACCEPTANCE

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Keshab Pokhrel

LIST OF ABBREVIATIONS

BOD: Biological oxygen demand

CFU: Colony forming unit

COD: Chemical oxygen demand

DO: Dissolve oxygen

FC: Faceal coliform

masl: Meter above sea level

mg/L: Milligram per liter

ml: Milliliter

ºC: Celsius

p: Significance level

Std: Standard deviation

TDS: Total dissolve solids

TP: Total phosphorus

TSS: Total suspended solids

ABSTRACT

The Bagmati River in the Kathmandu Valley flows along the core urban areas. The main aim of the study was to estimate 14 parameters water pH (pH), total suspended solids (TSS), total dissolved solids (TDS), turbidity (Turb), biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), total phosphorus (TP), faceal coliform (FC), iron (Fe), manganese (Mn), copper (Cu), chromium (Cr) and cadmium (Cd) to assess the water quality of the Bagmati River. The surface water samples were collected from 11 sites in the Bagmati River during the pre-monsoon season. The highest DO record was found at headwater Sundarijal (8 mg/L) where 50% of the samples had DO less than 3 mg/L. Meanwhile, turbidity, TSS, and TDS ranged from 3 to 600 NTU, 12 to 740 mg/L and 58 to 612 mg/L respectively. All the samples were contaminated from the faceal coliforms. High BOD and COD were observed in the much-populated core urban area due to wastewater and organic load. Similarly, among 5 heavy metals tested Fe and Cu were only detected in the samples. Fe exceeds the WHO limits while Cu is within the guidelines. Only 2 clusters were obtained from cluster analysis in which C2 had a high value of all parameters except DO indicating towards polluted station i.e BA09. Meanwhile, correlation analysis between BOD and COD with TP and Cu defined wastewater and organic loads are the main sources for the high concentration of these water quality parameters.

Keywords: Water quality parameters, Bagmati River, wastewater TSS, TDS, turbidity, BOD, COD, DO

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CHAPTER 1: INTRODUCTION

1.1 Background

River ecosystem provides ecosystem services through ecological processes and ecosystem function (Shrestha *et al.*, 2019) so, it's essential to maintain the river health. The anthropogenic activities such as dumping of untreated industrial and domestic wastes, agriculture runoff, construction of roads and buildings, and deforestation alters the water chemistry and its quality (Zhang *et al.,* 1999). Similarly, the heavy metal contamination is found be increasing in the river system due to the rapid growth of urban population, industrial and agricultural production (Su *et al.,* 2013; Islam *et al.,* 2014).

The Bagmati River is one of the most important rivers of Nepal and is considered as the source of Nepalese civilization and urbanization. It originates from the southern slope of Shivapuri Nagarjun National Park at an altitude of 2650 m, Northeast to Kathmandu at Baghdwar Falls, where three headwater streams converge, and water flows out through a gargoyle shaped like a tiger's mouth. The river flows southwest about 10 km through the Kathmandu Valley reaching Pashupatinath Temple. (https://en.wikipedia.org/wiki/Bagmati_River - cite_note-Davis-227-5) Beyond the temple, the river flows south and is joined by the larger west-flowing Monahara River, then turns west itself and reaches highly urbanized Kathmandu city where more tributaries enter such as Dhobi Khola and sewage-laden Tukucha Khola (Davis, 1977). Then the river bends south and the Bishnumati enters it at Teku Dovan. As it passes the centre of Kathmandu, this tributary becomes heavily polluted and choked with trash. Finally, the Bagmati reaches the edge of the Kathmandu valley and enters Chobhar gorge at Chobhar. The Chobhar gorge cuts through the Mahabharat range, The Bagmati flows southwest also crossing the lower Sivalik Hills before reaching the Terai, then crosses into India. and merges into the Ganges in India (Sharma, 1977). Its total length is about 196 km in Nepal and the catchments area of the river is 3610 sq. km which is 2.25% of total area of Nepal (Shanker and Kiran cited by Dahal et al. 2011).

The Bagmati River System is important from the point view of cultural and economic value. It is also used for the small-scale hydroelectricity, irrigation, and drinking water source (Baniya *et al.,* 2019; Raut *et al.,* 2018). The upper stream of the Bagamati River is healthy however the core urban region in downstream is highly polluted. This river is being used as dumping sites for solid wastes, outlets for domestic sewerage, industrial and agricultural effluents, and the riverbanks are being encroached upon by slum dwellers (Paudyal *et al.,* 2016).

The contaminated river water is a threat for the human health and other aquatic organisms. The quantity and quality of river water are at extremely concerning levels, especially during the dry season in the majority of the river's path through the valley. Low dissolved oxygen levels, bacterial pollution, and metal toxicity are some of the issues with the Bagmati River's water quality (Mishra *et al.,* 2017). The main causes of pollution in the Bagmati River are thought to be the lack of regulations, inadequate adherence to laws governing municipal and industrial wastewater generation, uncoordinated rapid urban expansion, inadequate wastewater treatment facilities, and low levels of awareness (Mishra *et al.,* 2017). So, maintaining the good quality of water is essential for vital functioning of the ecosystem. Water quality of river can be monitored by examining its various physico-chemical and microbial parameters (Shrestha and Basnet, 2018).

The main pollution parameters that must be considered for surface water quality management include water temperature, pH, dissolved oxygen, dissolved and suspended solids, compounds of phosphorus and nitrogen, biochemical oxygen demand and chemical oxygen demand (Baniya *et al.,* 2019). Any alteration beyond the permissible range in these parameters makes the water polluted (Anake *et al.,* 2013) and unfit for any purposes. So, regular monitoring and analyzing of the river water is essential to track the changes in the water quality due to anthropogenic activities.

1.2 Justification of study

The previous study in the Bagmati River System has showed that water quality has deteriorated mainly in the urbanized areas (Kannel *et al.,* 2007; Mishra *et al.,* 2017; Paudyal *et al.,* 2016). The concentration of the trace and heavy metals are reported in the urbanized section of the Bagmati River (Bhatt *et al.,* 2014; Paudyal *et al.,* 2016).

For the cleanliness, the campaign called “Bagmati Sarsafai Abhaiyan” was launched on May 19, 2013 A.D with the initiatives of few organizations including Advertising Association of Nepal (AAN), Film Artist Association of Nepal (FAAN), Gayatri Pariwar, and Jeevan Vigyan, Kathmandu. With the movement gaining public support and popularity, several social, spiritual, academic, governmental, non-governmental institutions have joined the effort. Since the campaign is still ongoing and the rivers are more dynamic there might be change in the water quality. This study has been carried out to find if there is any change to the water quality parameters due to this campaign "Bagmati Sarsafai Abhaiyan 2074"

1.3 Research questions

This study was designed to obtain general understanding of the following research questions:

- What is the status of water quality parameters in the Bagmati River within Kathmandu valley?
- Has the endeavor made by government and NGOs have brought significant change in the water quality of the river?

1.4 Hypothesis

The proposed study is driven by following hypotheses:

- There is a significant change in water quality parameters in the Bagmati River due to "Bagmati Sarsafai Abhiyan 2074"

1.5 Objectives of study

The objective of the research is water quality monitoring of Bagmati River Basin, Kathmandu Valley.

The specific objectives are as follows:

- To measure current status of water quality parameters in the Bagmati River.
- To compare water quality parameters in the Bagmati River before and after "Bagmati Sarsafai Abhiyan, 2074".

1.6 Limitation of the study

The limitations of the present study are as follows:

- This study was carried out within Kathmandu Valley.
- The study only covers single season as the water quality differs with seasons.

CHAPTER 2: LITERATURE REVIEW

2.1 Pollutants and effluents which cause water pollution and effects

Many water resources are available in earth like a River, Ponds, Ocean, and Groundwater. But only 1/4% water is suitable for drinking. The ocean water is very large area coverage of Earth (Kudesia 1990). In the process, this invaluable resource was reduced to a convenient means of waste disposal.

Dwivedi, (2017) reviewed that more than 70% of the fresh water in liquid form of India is converted into being unfit for consumption due to various sources of pollution such as sewage discharge, industrial effluents, and agricultural runoff. Similarly, Chakraborty *et al.,* (2013) reported some natural causes of pollution in river which are mixture of biodegraded portion of animal and plants to pure water, siltation by erosion of riverbanks.

In Nepal, few studies have been conducted by several scholars about industrial effluent. Sah *et al.,* (2000) studied effect on soil properties by effluents and reported adverse effects on plant growth and development. Similarly, the effect of heavy metals on germination and growth of crop plants of brassicaceae have been studied by Pokhrel, (2000) and concluded that Pb imposed significantly affected. Also, the crops were found to accumulate this metal ion in considerable amount.

Wastewater such as municipal sewage is a major culprit followed by industrial effluents and agricultural run-off (Matta, 2014). Neupane, (2003) studied effect of industrial effluents on agricultural crops and soil; found that most of the soil parameters were relatively higher in irrigated land with effluent contaminated water than that of irrigated land with uncontaminated water.

2.2 Status of water quality of river in Nepal

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 physic-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.

Regmi and Mishra, (2016) reported that the condition of the rivers in the Kathmandu Valley has been rapidly degrading. The river basin currently faces a number of serious environmental and ecological challenges. Urbanization and industrialization of the basin headwaters in Kathmandu contribute to deterioration in water quality, with regional consequences for the aquatic ecosystem and the health of organisms.

Basnet, (2013) reported that the biotic indices (BMWP, ASPT, FBI, CLI, and EPT) revealed that the ecological condition of the river was good at the upstream sites and very poor in the downstream direction. The relationship between biotic indices and dominant taxa of the sampling stations of the Bagmati River with the physico-chemical parameters was highly significant.

In recent years, the volume of wastewater produced in urban areas has increased substantially because of rapid growth in the human population, industrial production, and commercial activities, as well as changes in water consumption behavior. In most urban areas in developing nations, excess wastewater is disposed of directly, or without effective treatment, into surface water bodies, resulting in their severe degradation; despite the adoption of countermeasures (Ismail and Abed, 2013; Purandara *et al.*, 2012). Water pollution threatens the sustainability of urban systems. Pollution in the Bagmati River is a serious concern for the sustainable development of the Kathmandu Valley (Shrestha *et al.,* 2015; Regmi *et al.,* 2014; ICIMOD, 2007)

Shrestha and Tamrakar, (2010) reported that comparison of morphological parameters of river of two different period 1992 and 2009 (17 years) shows that the river morphology is changing abnormally. The sinuosity of river has increased in all order segments but meander stream length, belt width, meander wavelength and radius of curvature has lower values. Total channel length is increased by 10 Km indicating the river is undergone through system wide instability and affecting river system of the Kathmandu valley.

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.

2.3 Water quality monitoring

Kannel *et al.,* (2006) reported that the influences of various water quality management strategies have on DO concentrations were examined considering: (i) pollution loads modification; (ii) flow augmentation; (iii) local oxygenation. The study showed the local oxygenation is effective in raising DO levels.

Bhattarai *et al.,* (2008) reported studied water quality of Sundarijal area and reported that although public awareness and proper management of watershed and reservoir premises were lacking, yet the physico-chemical characters were within the standard of World Health Organization (WHO) and European Commission (EC) for drinking water. However, the coliform bacteria were high, and water was not safe to consume without intense treatments with disinfectants.

Karamouz *et al.,* (2009) performed an entropy-based approach for design of an on-line water quality monitoring network for the Karoon River, which is the largest and the most important river in Iran. In the proposed algorithm of design, the number and location of sampling sites and sampling frequencies were determined by minimizing the redundant information, which is quantified using the entropy theory.

Bohora, (2016) prepared water Quality Index (WQI) map of southern part of Kathmandu valley and showed that the upstream river areas contain good water quality than the downstream areas. The areas like Kalanki and Satdobato have poor water quality according to the guidelines of Nepal Drinking Water Quality Standard. Similarly, Sharma *et al.,* (2016) reported that the multi-metric approach is suitable for application in the monitoring and assessment of rivers and this study was done in Adhikhola River, Nepal.

Shah *et al.,* (2020) performed Redundancy analysis (RDA) in 38 stretches of Karnali River and indicated that water quality parameters temperature and pH as major environmental predictors for benthic macro invertebrate variability between river types. Therefore, river type-based conservation efforts that account for upstream–downstream linkages of aquatic biota and resources in freshwater ecosystems can ensure the ecological integrity of the whole river basin.

Nicholson *et al., (*2018) performed assessment for the drinking water within Sagarmatha national park and reported that samples from the more populated, lower elevation (< 3500 m) areas had higher levels of Escherichia coli and of coliform bacteria in general.

Since the Bagmati River is very polluted river which runs in the core urban area. The dynamics of river changes so the monitoring of Bagmati River is required time and again. For the cleanliness of Bagmati River a campaign titled “Bagmati Sarsafai Aviyan” was launched. The effectiveness of Bagmati Sarsafai Aviyan is urged to be studied for effective restoration plan of the Bagmati River.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

3.1.1 General description

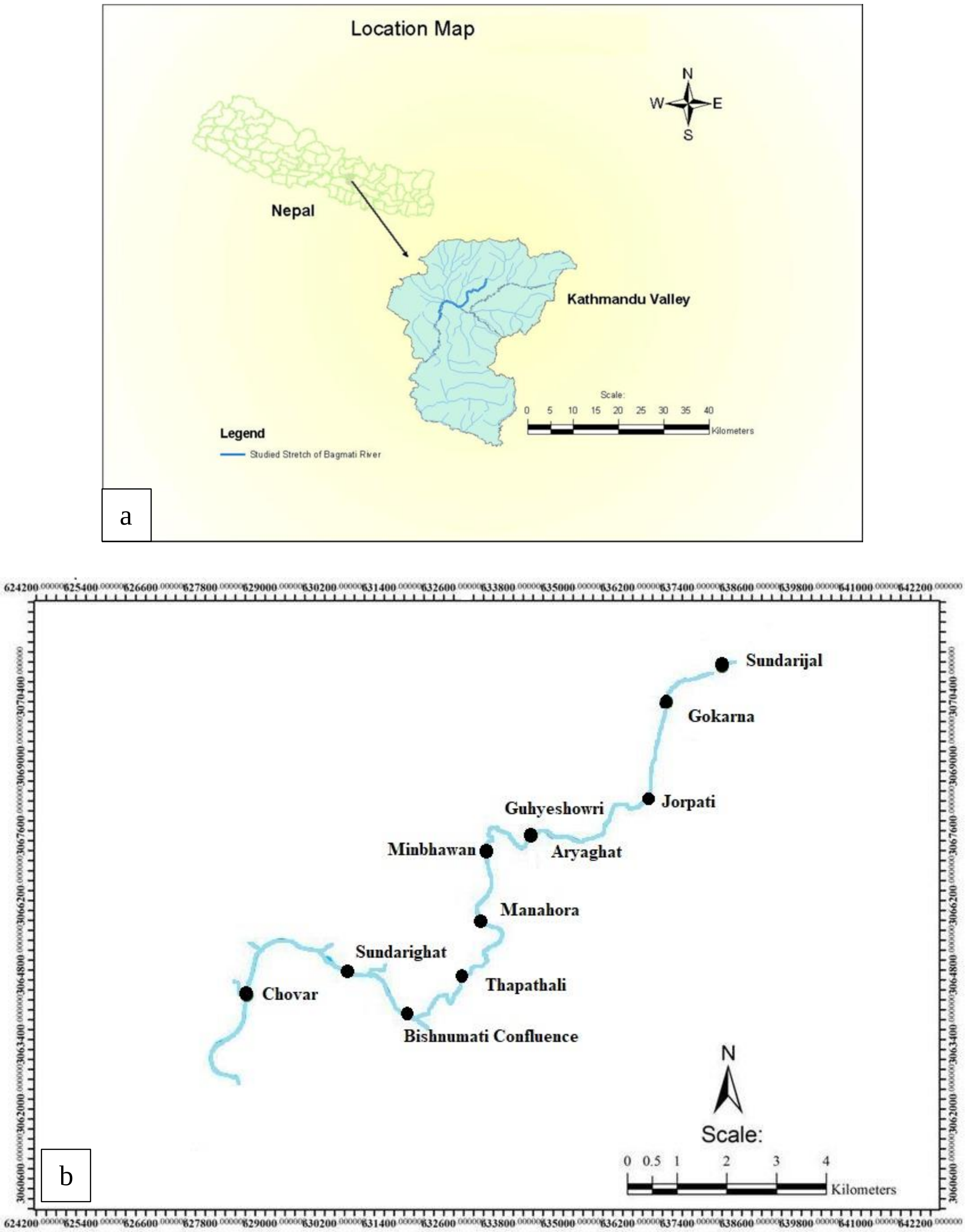

Figure 1:a. Map showing the location of studied stretch of Bagmati River and b. Sampling stations in Bagmati River in Kathmandu Valley.

Kathmandu lies in between coordinates 27^0 42' 14''N and 85^0 18' 31''E. The Bagmati watershed is in the central mountain region of Nepal which encompasses nearly 3719 km^2 within Nepal and joins the Ganges River in India (Sharma and Shakya, 2006). The Bagmati River in the Kathmandu Valley stretches for 51 km with a catchment area of 678 km^2 (Shrestha and Tamrakar, 2012). Water sample was taken from 11 different locations of the river is shown in Figure 1b. The detail information about sampling stations is shown in Table 1.

Table 1: Sampling station with site descriptions

Sample ID	Sampling Stations	Site descriptions
BA01	Sundarijal	Just before Sundarijal Town
BA02	Gokarna	Near Gokarna Village
BA03	Jorpati	Just downstream of Jorpati overpass bridge
BA04	Guheshowri	Just downstream of Guheshowri
BA05	Aryaghat	Just downstream of Pashupati Temple
BA06	Minbhawan	South of Bagmati bridge at Minbhawan
BA07	Manahora – Bagmati Confluence	Manahora – Bagmati Confluence
BA08	Thapathali	Bagmati - Tukucha confluence
BA09	Bagmati - Bishnumati Confluence	Bagmati - Bishnumati Confluence
BA10	Sundarighat	Sundarighat
BA11	Chovar	Just end of the Chover

3.1.2 Climate

Meteorological data were taken from Department of Hydrology and Meteorology, Kathmandu 2020 A.D. Mean maximum temperature ranged from 16.21°C to 26.79°C. Mean minimum and maximum temperature recorded of the coldest month (January) and warmest month (June) is 2.8°C and 26.79°C. The annual rainfall is 1676.49 mm on average with about more than 80% of this occurring between June to September. Relative humidity (RH) was recorded higher in the months of July to August and low in March and April. The monthly rainfall and temperature are illustrated in the Figure 2.

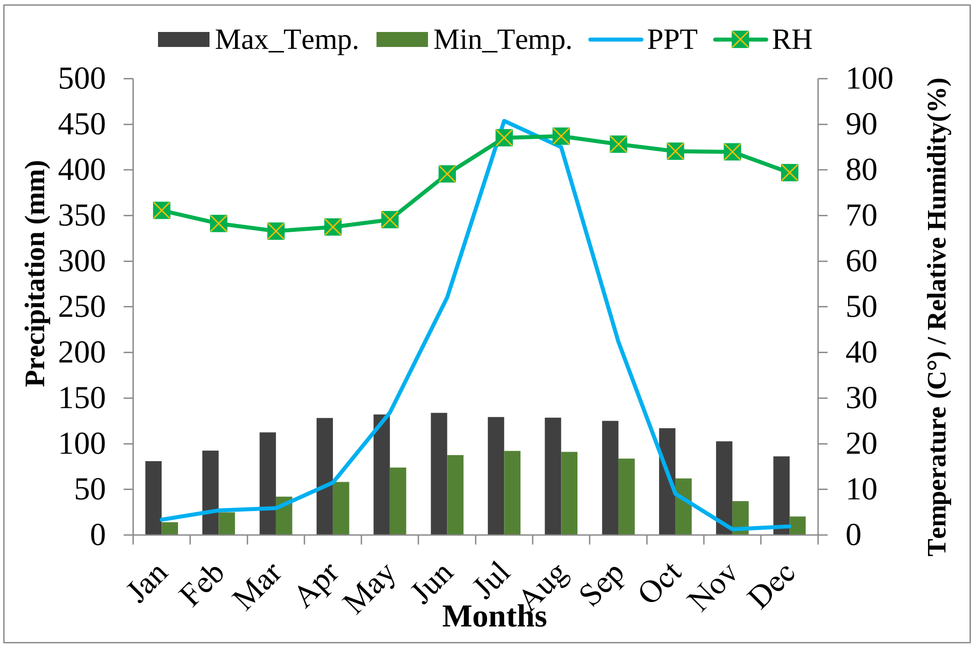

Figure 2: Temperature, precipitation, and humidity records of Sunadrijal station in Kathmandu District for thirty years (1990-2019).

(Source: Department of Hydrology and Meteorology / Government of Nepal, Kathmandu, 2020).

3.1.3 Vegetation

Among aquatic plants alga such as *Chara* sp., *Najas* sp., *Potamogeton* sp., *Vallisneria* sp., and *Hydrilla* sp. were the most common, some of the diatoms were *Diatom* sp., *Cyclotella* sp., *Melosiragranulate* sp., *Fragillaria* sp., *Navicula* sp., *Nitzschiapalea* sp., *Amphora* sp., *Cymbellatumida* sp., *Cymbellaaspara* sp., *Cymbellahelvestica* sp., *Cymbellaventricosa* sp., *Cyclotella* sp. In some places, *Ranunculusaquatilis*, *Marshiliam* sp., *Ceratophyllum* sp., and *Cyperus* sp., were mostly observed (Kushwaha, 2016). Mosses like *Polytrichum* sp., and other bryophytes like *Riccia*, *Marchantia* were also seen in dried condition. Ferns like *Adiantum* sp., *Pteris* sp. were also common. Some of the invasive species like *Alternanthera* sp., *Ageretina adenophora*, *Ageretina haustonianum, Lantana camera* were frequently observed on the edges of river. Many species of angiosperm via *Cynodon* sp., and *Artemisia* sp., were also seen.

3.2 Research design

In order to address the aforementioned research questions and objectives, both field investigations and the laboratory analysis along with the various analytical procedures were conducted. Water samples were collected from different sites of Bagmati River and analyzed whereas secondary data from earlier published research articles in journals, dissertation and other research works were used for comparison. The research design for this study is shown in Figure 3.

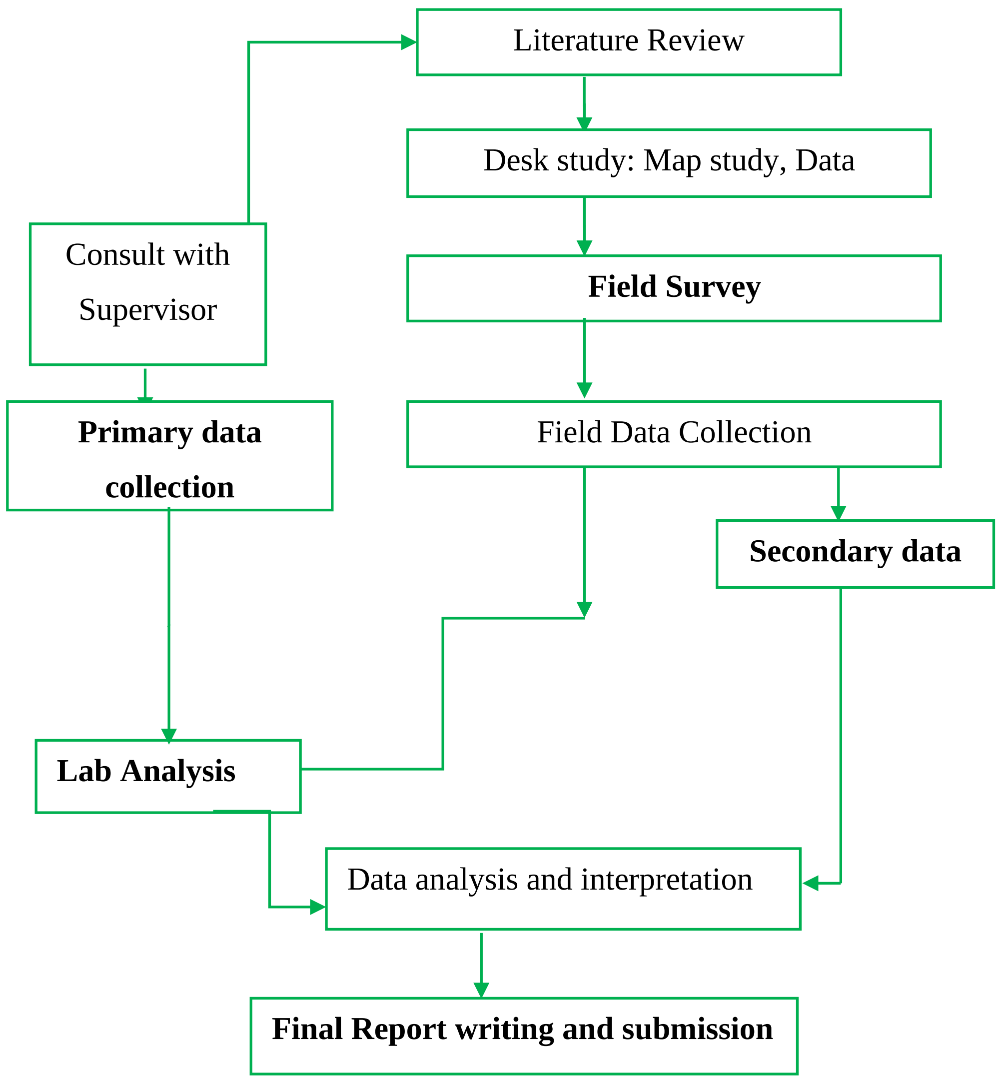

Figure 3: Research design of the study

3.3 Methods of data collection

3.3.1 Sample collection and analysis

Water samples were collected from 11 different locations of Bagmati River in the months of April/May 2019 representing pre monsoon season. Composite sample number of samples three were collected from each location in safe rubber bottles. The samples were in the taken to lab of Department of Botany, Amrit Campus for the testing of water quality parameters following APHA(1988) except heavy metals. The laboratory analysis for heavy metal was performed by Central office of Bagmati Sarsafai Abhiyan, Guheshwori Kathmandu. Water quality parameters like presence of heavy metals, chemical oxygen demand (COD), biological oxygen demand (BOD), water pH, dissolve oxygen (DO), total suspended solid (TSS), total dissolved solid (TDS), turbidity, total coliform and total phosphate were analyzed in this study to determine water quality of Bagmati River in Kathmandu Valley.

3.3.2 Laboratory analysis

a. pH

The pH of the water sample was measured by using pH meter by using HANNA multiprobe meter. At first, pH meter was stabilized before measuring pH at least 10 minutes. pH meter was calibrated with standard buffer solutions. Hanna pH buffers are made of Potassium Di-Hydrogen Phosphate and Di-Sodium Hydrogen Phosphate. pH buffer solutions are usually mixtures of weak acids and the salt of these acids combined with a strong base, or mixtures of weak bases and the salt of these bases combined with a strong acid. Buffer solutions are significant by the fact that they resist change to their pH value regardless of additions of small quantities of acids or bases. The electrode of pH meter was washed with distilled water each time before immersing into beaker containing sample water. The pH value was read by pH meter.

b. Turbidity

Turbidity was measured by nephelometric method where suspension of hydrazine sulphate was used. At first, distilled water was filled into the turbidity tube of nephelometer. Then, it was standardized using standard of 40 NTU and 20 NTU stock turbidity solution. Then, sample was introduced into tube and unit of turbidity was noted.

c. Total Suspended Solids (TSS)

The total suspended solids in water were determined by galvanometric method. An aliquot sample was filtered through membrane filter paper (1 mm) using vacuum filter. The filter paper was dried with residue at 103^0C-105^0 C and the final weight was noted. Total solid matter was obtained following Zobel *et al.,* (1987) and calculated by following equation:

$$\text{Total solids (ml/L)} = \frac{\text{wt. of resudue (g)}}{\text{Volume of sample taken (ml)}} \times 1000000$$

d. Dissolve oxygen (DO) and Biological Oxygen Demand (BOD)

Dissolve oxygen and BOD are the amount of the oxygen and is the amount of biodegradable matter present in the water respectively. At first the sample was saturated with oxygen by shaking vigorously. Then, the sample water was transferred in two BOD bottles of known capacity. Among two bottles, one was used to measure initial DO level whereas another BOD bottle was incubated in incubator at 20 ^{0} C for 5 days. For the determination of initial DO, 1 ml of manganous sulfate was immediately added followed by 1 ml of alkali azide reagent. Then, the stopper was carefully placed excluding air bubbles. The bottle was shaken in 8 shapes and for several times and allowed to stand. When the precipitate was settled down approximately half of the bottle then 1 ml of concentrated sulfuric acid was added. After this, the whole volume of sample solution was transferred into 500 ml Erlenmeyer flask and titrated against the 0.025N standard sodium thiosulfate solution until it becomes pale straw color. Then approximately 1 ml of starch indicator was added and again titrated until blue color disappears. The volume of sodium thiosulfate consumed was noted and dissolved oxygen level was calculated. After 5 days, the DO of the incubated water sample was also measured using same procedure for initial DO.

It was calculated by the following formula as given by Trivedy and Goel, (1986):

$$\text{DO (mg/L)} = \frac{(\text{ml} \times \text{N}) \text{ of titrant} \times 8 \times 1000}{\text{V}_2 \left(\frac{\text{V}_1 - \text{V}}{\text{V}_1}\right)}$$

Where,

V = Volume of MnSO4 and KI solution (ml)

V_1 = Volume of sampling bottle after placing the stopper (ml)

V_2 = Volume of fraction of the contents used for titration (ml)

Again,

$$BOD\ (mg/l) = (D0–D5) \times dilution\ factor$$

Where,

DO= Initial DO in the sample

DO5 = DO after 5 days

e. Chemical Oxygen Demand (COD)

Chemical oxygen demand is the measure of oxygen consumed during the oxidation of the oxidizable organic matter by a strong oxidizing agent. Potassium dichromate in the presence of sulphuric acid was used as an oxidizing agent and COD was determined as described in Trivedy and Goel, (1986). For the measurement, 20 mL thoroughly mixed sample was poured on reflux flask and pinch of mercuric sulphate and silver sulphate dust. Then, 10 ml of 0.25N potassium dichromate solution was added to remove chloride concentration. Then, 30 ml of conc.H_2SO_4 was added and left for 15-20 minute. Then, whole content was reflux for 2 hours at 150^{o}C. The flask was removed and cooled. This reflux solution transferred to measuring cylinder and was made 140 mL adding distilled water. Then 2-3 drops of ferroin indicator were added and titrated with 0.1 N ferrous ammonium sulphate solutions till color change to reddish brown to blue green.

$$\mathrm{COD(\ mg/L)} = \frac{(\mathrm{b} - \mathrm{a}) \times \text{Normality of ferrous ammonium} \times 44}{\text{Volume of sample in mL}}$$

Where,

a = ml of titrant with sample

b = ml of titrant with blank

f. Total Phosphorus (TP)

Total Phosphorus was measured as described in Trivedy and Goel, (1986). Available phosphorus was determined by Olsen's sodium bicarbonate (pH 8.5) solution extraction method. The blue color of phosphorus ammonium molybdate complex in an acidic medium containing Stannous chloride was determined by spectrophotometer at the wavelength of 660 nm by following Muhr *et al.*,(1965).

For the measurement, 25ml of sample was pipetted in a beaker. Then, 5ml of conc. nitric acid was added followed by 1 ml of conc. Sulphuric acid. The mixture was digested over hot plate up to white fumes commences. Then it was cooled and wash for the interior of the beaker with small volume of distilled water. Then, the solution was neutralized to phenolphthalein indicator and pink colour with 5N sulphuric solution. Then it was cooled and diluted with distil water and made upto 100 ml volumetric flask and it was let to stand for the settling of formed precipitate. The blank was prepared using distilled water as sample proceeded as sample treatment. Again, 50 ml of blank was pipetted, and sample was allowed to settle in 100 ml Erlenmeyer flask separately. 8 ml of combined reagent was added into each content. Then, it was let to stand for 10 -15 min for complete color development and absorbance was read in 880 nm. The concentration of the phosphate was calculated from the graph.

g. Faceal Coliform Count (FC)

Faceal coliform count was determined by multiple tube fermentation method. For the measurement,

At first, 10 ml of each Mac Conkey Broth Solution single strength and double strength media was pipetted in the culture tubes and introduced into drums tube avoiding the air. Then, it was sterilized into an autoclave at 15 1b pressure for 30 minutes. The prepared media was cooled. Three culture tubes were taken containing double strength culture media and 10 ml of well shaken sample was introduced in each tube by sterilized pipette. Again, six culture tubes were taken containing single strength culture media and 1 ml sample was introduced in three tubes whereas introduced 0.1 ml sample in remaining three tubes. The culture tubes were shaken well and kept inside the incubator at temperature 37 ^{0}C. Number of positive tubes was noted after 48 hours and calculated the MPN number the standard MPN table.

h. Heavy metal test

Heavy metals Iron, Cadmium, Copper, Manganease, Chromium was done by the laboratory of Bagmati Sarsafai Abhiyan, Guhyeshwori. The heavy metal was tested in atomic absorption spectrometry device at different wavelength as per the heavy metal.

3.4 Data analysis

The descriptive statistical analysis such as average and standard deviation (Std) was performed using MS-Excel. Multivariate analysis such as correlation analysis and cluster analysis were performed using IBM SPSS version 20. MS-Excel and SPSS were used to analyze data in graphical forms.

a. Cluster Analysis (CA)

CA forms the group of cases into clusters based on similarities within a class and dissimilarities between different classes. Hierarchical agglomerative clustering is the most common approach, which provides intuitive similarity relationships between any one sample and the entire data set and is typically illustrated by a dendrogram (tree diagram). The dendrogram provides the summary of the clustering process reducing the dimensionality of original data (McKenna, 2003). In this study, the parameters having similar relationship between one sample and the entire dataset (McKenna, 2003) along with the water quality (Zhang *et al.,* 2009) are clustered together.

b. Correlation Analysis

The correlation analysis is statistical tools for describing the degree of relation between two parameters. It can be obtained from the correlation analysis of different chemical variables of water between different physiochemical parameters. Spearman's rho correlation matrix was applied in the present study since data is non-normalized.

CHAPTER 4: RESULTS

4.1 Water Quality Parameters

Altogether 14 water quality parameters were analyzed to assess the water quality of different sites of Bagmati River. The physical parameter studied were turbidity (turb), total suspended solids (TSS), total dissolved solid (TDS) whereas chemical parameters were water pH (pH), dissolved oxygen (DO), biological oxygen demand, chemical oxygen demand (COD), total phosphorus (TP), heavy metals iron (Fe), manganese (Mn), copper (Cu), cadmium (Cd) and chromium (Cr). Similarly, for biological parameter faecal coliform (FC) was only studied. The summary of observation from the analysis of 14 water quality parameters are shown in Table 2. The unit of all the parameter is expressed in mg/L expect turbidity in NTU and FC in CFU/100 ml.

Table 2: Summary of water quality parameters of Bagmati River at different sampling sites along with average and standard deviation (Std)

Parameters	Sampling Stations										
	BA01	BA02	BA03	BA04	BA05	BA06	BA07	BA08	BA09	BA10	BA11	Average±Std
pH	6.2	6.6	6.9	7	7.2	7.5	7.4	7.2	7.5	7.4	7.1	7.09 ± 0.38
Turb	3	410	370	73	34	450	370	375	600	255	310	295.45±178.99
TSS	12	267	300	101	43	366	568	440	740	234	326	308.82 ± 209.6
TDS	58	105	120	250	230	562	556	474	612	558	422	358.82± 200.4
DO	8	4.3	4.5	5	5.5	2.9	2.5	3	2.3	2.7	2.6	3.9±1.7
BOD	4	35	38	25	23	367	439	363	508	362	427	235.5±196.4
COD	11	117	130	90	74	704	834	592	992	464	656	424±335.5
FC	120	$38x10^6$	$45x10^5$	$20x10^4$	$42x10^4$	$33x10^7$	$78x10^7$	$65x10^6$	$32x10^8$	$32x10^6$	$52x10^7$	$44\times10^7\pm90\times10^7$
TP	0.1	1.36	1.24	3.2	1.8	20.27	25.58	16.4	23.32	13.07	11.69	10.73±9.3
Fe	ND	0.59	0.53	0.41	0.35	0.55	0.58	0.61	0.64	0.38	0.52	0.52±0.09
Mn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Cu	ND	0.015	0.016	0.007	0.006	0.08	0.085	0.1	0.17	0.03	0.07	0.06 ± 0.05
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

The average concentration of the pH recorded in the studied period was 7.09 ± 0.38. Station BA01 from uppermost region were found to be slightly acidic whereas other station has almost neutral pH.

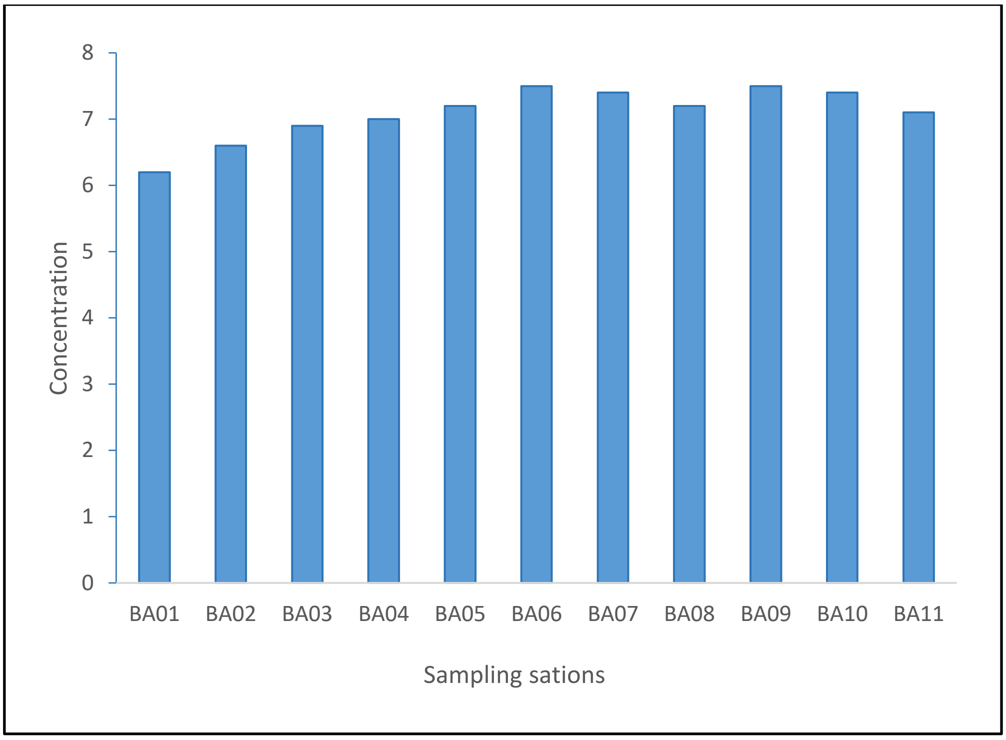

Figure 4: Bar graph showing change concentration in pH in Bagmati River

Turbidity is an optical measurement of water clarity (Wetzel, 2001) and often used to estimate the suspended particles. Similarly, total suspended solids (TSS) and Total dissolve solids (TDS) measure the suspended solids (clay, slits, bacteria, sediment etc.) and dissolved ions (salts) in the water respectively. The average concentration of turbidity recorded was 295.45±178.99. The maximum amount of turbidity, TSS and TDS (i.e 600 NTU, 740 mg/L and 612 mg/L respectively) were found in the water sample collected from the Bagmati - Bishnumati confluence (BA05) whereas sample from Sundarijal (BA01) showed very lowest value (i.e 3 NTU, 12 mg/L and 58 mg/L respectively (Figure 5)). The average concentration TSS and TDS recorded during present study in Bagmati were308.82 ± 209.6 mg/L and 358.82 ± 200.36 mg/L respectively.

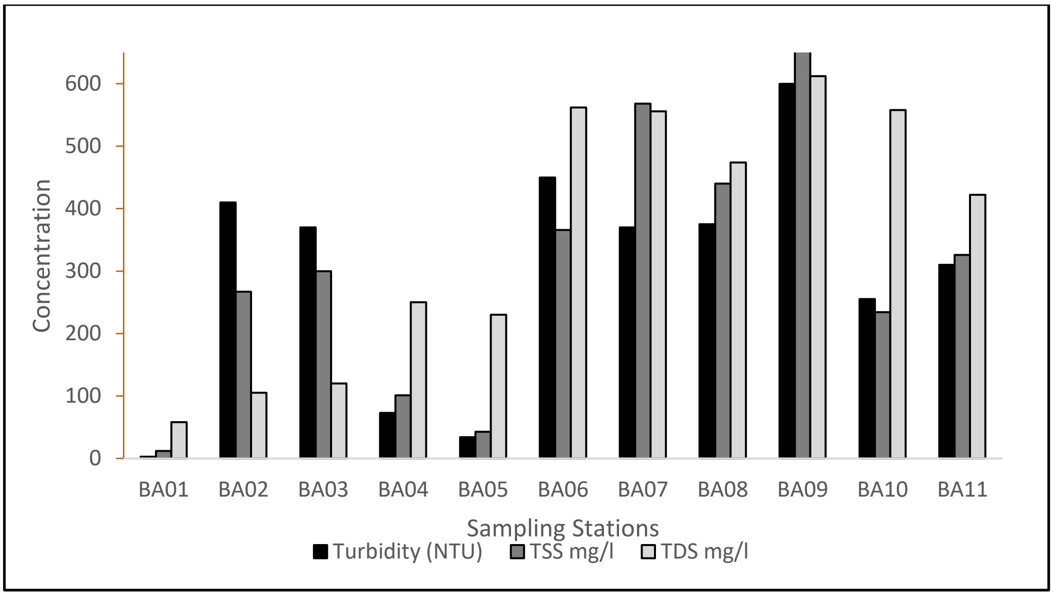

Figure 5: Bar graph showing change in concentration of turbidity, TSS and TDS along the Bagmati River

Maximum amount of DO record in present study was 8 mg/L in the headwater region i.e Sundarijal (BA01) while <50% water samples in the downstream had DO <3 mg/L. The average concentration of BOD and COD was found to be 235.5±196.4 mg/L and 424±335.5 mg/L respectively in the Bagmati River in the present day. In the present study, the concentration of DO record was found to be gradually decreasing from BA05 than the sites above BA04. Meanwhile concentration of BOD and COD increased while moving downstream from station BA05 of the Bagmati River in present study. Maximum of BOD and COD i.e 508 mg/L and 992 mg/L respectively were observed in Bagmati-Bishnumati Confluence (BA09).

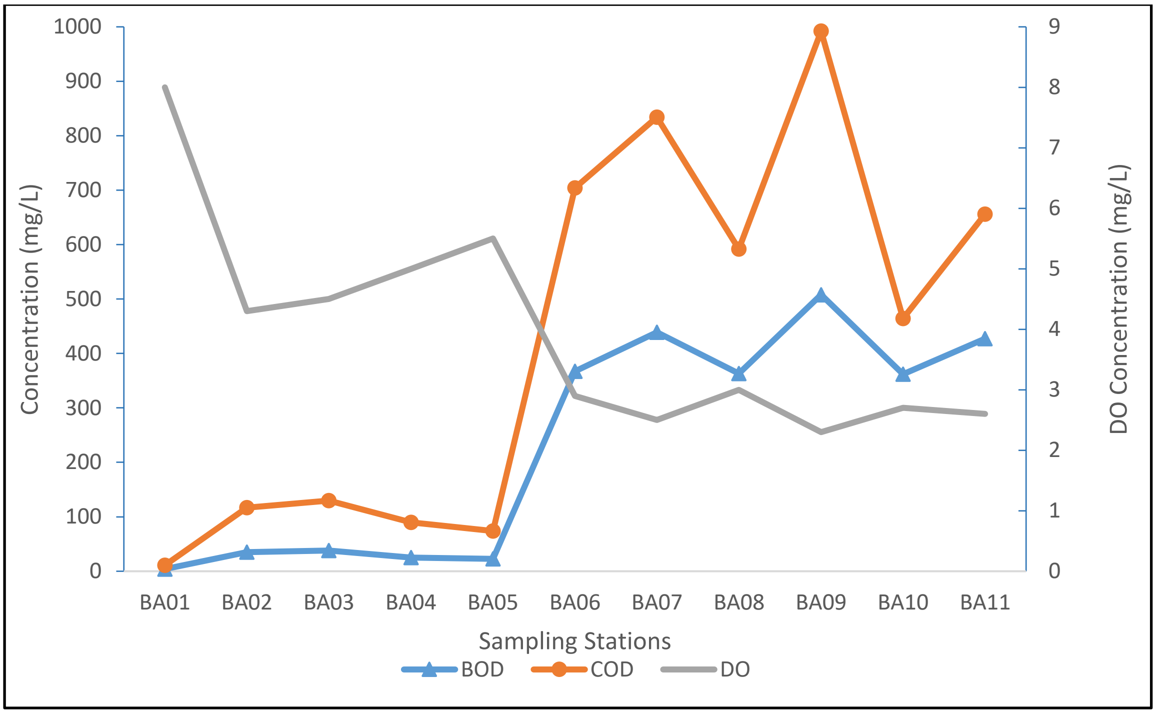

Figure 6: Concentrations of DO, BOD and COD along Bagmati River

Average concentration of total phosphate (TP) in the present study was found to be 10.73±9.3 mg/L. The maximum value recorded was 25.58 mg/L in Manahora –Bagmati confluence (BA07) which is followed by Bagmati-Bishnumati confluence (BA09) i.e 23.32 mg/L. However, the headwater region BA01 (Sundarijal) had less amount of total phosphate i.e 0.1 mg/L.

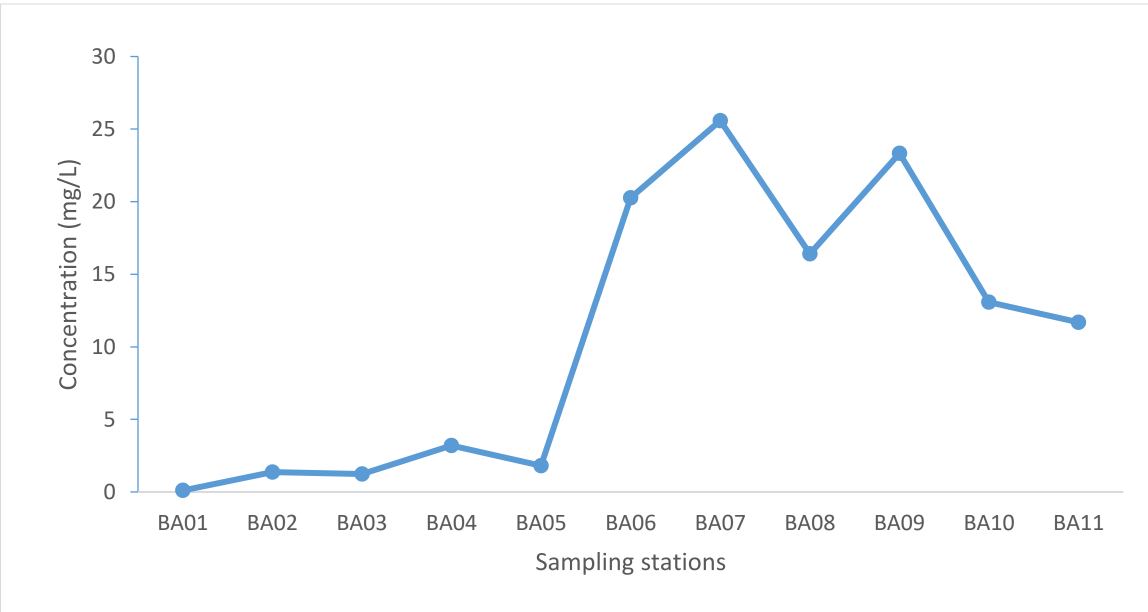

Figure 7: Change in concentrations of total phosphorus along Bagmati River

Fecal coliforms are the biological contamination indicator of water quality for human consumption. The average concentration of faecal coliform recorded in the present study was$44\times10^7\pm90\times10^7$ CFU/100 ml. The highest value of FC was found at Bagmati-Bishnumati confluence (BA09) i.e 32×10^8 CFU/100 ml whereas lowest at Sundarijal 120CFU/100 ml.

In the present study, heavy metals such iron (Fe), manganese (Mn), cadmium (Cd), chromium (Cr) and copper (Cu) was estimated. Among the five heavy metals estimated, only iron and copper were present in detectable amount. The concentrations of Cd, Cr and Mn were found less than detectable amount (<0.001 mg/L). Average concentration of Fe was found to be 0.52±0.09 mg/L which is higher than the guideline provided by WHO i.e 0.3 mg/L. Similarly, average Cu observed was 0.06± 0.05 mg/L which was within guideline provided by WHO i.e 2 mg/L. The mean concentration of Fe and Cu was not detected in first sampling station BA01. The detectable concentration of heavy metals was lower at sampling station of Guheshowri (BA04) and Aryaghat (BA05). Water sample from Bagmati-Bishnumati confluence (BA09) showed the maximum concentration i.e 0.67 mg/L and 0.17 mg/L of Fe and Cu respectively (Figure 8).

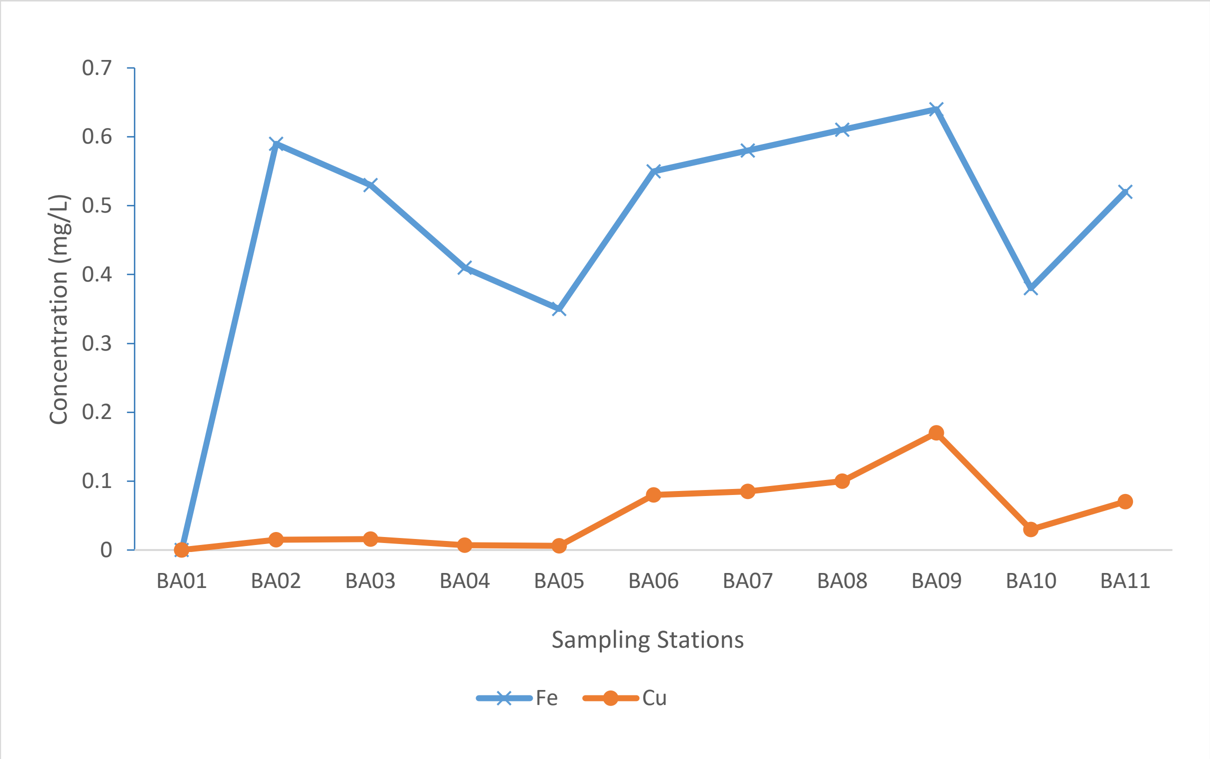

Figure 8: Change in concentration of heavy metals along Bagmati River

4.2 Multivariate Analysis

4.2.1 Correlation Analysis

The Spearman's correlation coefficient was used to explain the interrelationship all the parameters which shows the chemical source of theses parameters. The correlation was derived using statistical software (IBM SPSS statistics 20) for all the studied water quality parameters. The positive correlation ($r > 0.5$) indicates towards single source of elements, whereas negative correlation ($r > -0.5$) indicates the multiple sources of these elements (Kumar *et al.*, 2019).

pH showed the strong positive correlation with the total phosphate and TDS while strong negative correlation with DO at significant level ($p = 0.01$). Similarly, Turbidity showed strong positive correlation with Fe, TSS, Cu and COD at significant level ($p = 0.01$). Again, TSS show strong positive relation with all the parameters except DO and pH. Similarly, DO shows negative correlation with all parameters BOD and COD. Meanwhile, BOD and COD showed the strong positive correlation with TP, TSS, TDS and Cu (Table 3). TP showed the strong positive correlation between with pH, TSS, TDS, BOD, COD, Cu and Fe at significant level ($p = 0.01$). Similarly, Fe showed the strong positive relation with Turb, TSS and Cu. Likewise, FC showed the strong positive correlation with pH, TDS, TSS, COD, BOD, TP, and Cu at significant level ($p = 0.01$).

Table 3: Correlation analysis of overall water quality parameters of Bagmati River

Parameters	**pH**	**Turb**	**TSS**	**TDS**	**DO**	**BOD**	**COD**	**TP**	**Fe**	**Cu**	**FC**
pH	1.00										
Turb	0.49	1.00									
TSS	0.64*	0.83**	1.00								
TDS	0.96**	0.55	0.71*	1.00							
DO	-0.80**	-0.51	-0.79**	-0.89**	1.00						
BOD	0.72*	0.71*	0.94**	0.81**	-0.89**	1.00					
COD	0.77**	0.75**	0.95**	0.85**	-0.89**	0.99**	1.00				
TP	0.89**	0.56	0.81**	0.92**	-0.86**	0.86**	0.88**	1.00			
Fe	0.39	0.92**	0.87**	0.46	-0.49	0.70*	0.72*	0.58	1.00		
Cu	0.73*	0.77**	0.96**	0.82**	-0.89**	0.94**	0.95**	0.87**	0.81**	1.00	
FC	0.75**	0.69*	0.93**	0.80**	-0.88**	0.99**	0.98**	0.85**	0.68*	0.93**	1.00

Note:

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

4.2.2 Cluster Analysis

Hierarchical cluster method was used for the clustering the sampling sites using Ward Linkage which is represented as dendrogram Figure 9.

In this study, all the tested parameters were used to cluster 11 water sampling stations from the study area. From 11 sampling points, 2 statistically classified clusters were obtained with low distance criterion between 0 and 5 as shown in Figure 9. The result obtained from the cluster analysis showed that 10 samples fell within cluster 1 (C1) whereas only 1 sample lies in cluster 2 (C2). Again, cluster 1 could be divided into two sub cluster in which first sub cluster (C1a) was clustered with 7 sampling stations (BA01, BA02, BA03, BA04, BA05, BA08, and BA10) whereas second sub cluster (C1b) contained 3 sampling stations (BA06, BA07 and BA10). From the cluster analysis it indicated that the water quality in almost all the stations were similar but at confluence of Bagmati and Bishnumati is different and highly contaminated.

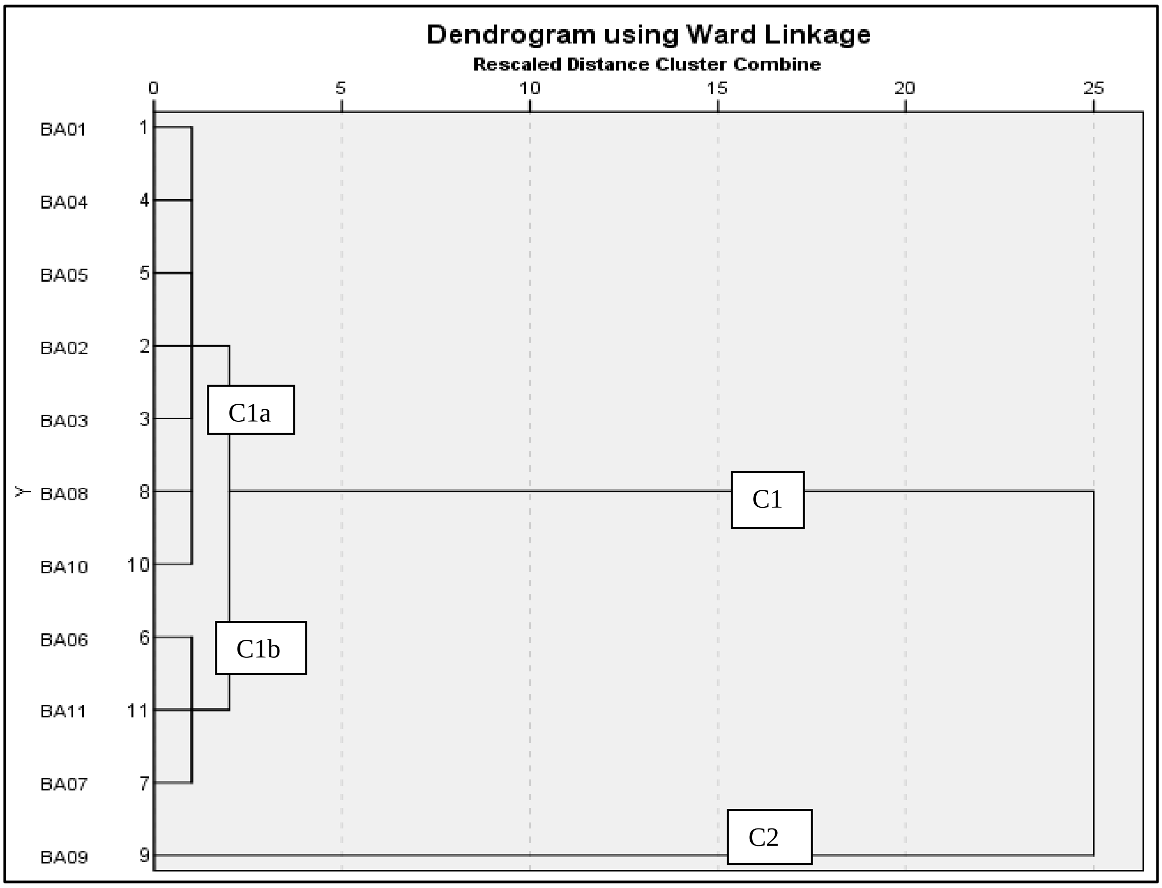

Figure 9: Hierarchical cluster analysis based on the water quality parameters

CHAPTER 5: DISCUSSION

5.1 Water quality parameters

Among 11 stations sampled BA09 station is near to waste transfer, dumping site and crematorium and receives the suspended particles from Bishnumati River which could be the reason for maximum value of turbidity, TSS and TDS. Again, BA09 station is near the shantytown and landless people who often use the river as a free dumping site (Baniya *et al.,* 2019). The mean concentration of TDS and turbidity was found to be higher than the previous study conducted by Paudyal *et al.,* (2016). The pervious study by Bhandari *et al.,* (2017) recorded the mean value 208.8 mg/L of TSS at pre monsoon which is lower than the present study.

DO is important water quality indicators in the river system (Kannel *et al.,* 2007). The value range of DO from 6.5 mg/L to 9.5 mg/L is most suitable to support aquatic organisms (fishes) (Wetzel, 2013). From the current value, only station BA01 i.e near origin of Bagmati River is suitable to support fishes. In the figure 6, there is trend of increase in DO and decrease in BOD and COD in station BA04 (Guhyeshowri) and BA05 (Aryaghat). This might be due to effectiveness of wastewater treatment plant. The dumping of the waste from the nearby fruit market, runoff from agricultural, untreated sewage and waste transfer station might be the cause for high BOD and COD. Both BOD and COD level in all the samples exceed the WHO standard for portable water i.e 6 mg/L and 10 mg/L respectively in the present study. The present recorded value of BOD and COD is more than 5 times lower than the previous study by Baniya *et al.,* (2019). This might be difference of the sample collection period and the dilution due to the rainfall prior to water sample collection.

Among 11 sampling stations, sample from Manahora –Bagmati confluence (BA07) observed high value of total phosphate it might be contributed by runoff from the agricultural land. The development of the graph (Figure 7) shows that the TP had risen after the sampling station BA05. This also shows the effectiveness of wastewater treatment plant located at BA04 station. Since all the stations below high TP this might be due to the domestic waste and agricultural runoff from catchment area which area main source of phosphorous. The study by Pandey and Devkota, (2016) in Tinahu River of Butwal which also flow in city area had low TP (0.32 mg/L) than this study.

In the previous study by Bhandari *et al.,* (2017) samples from Sundarijal were free of faecal coliforms but faecal coliforms were found in the samples analyzed. This might be increase of activities of visitors which is also supported by latest study by Poudel *et al.,* (2021). Water samples from down streams had very high levels of faecal contamination as pervious study by Kannel *et al.,* (2007) concluded that Bagmati River in core rural areas was affected from untreated human sewage chemical fertilizers and dense population. Results of the current study supports the previous studies as well.

In case of tested heavy metals, the concentration of Fe and Cu was not detected BA01 station as this station has very less anthropogenic disturbance. Though station BA04 and BA05 lies in urban area, the concentration of metals was found to lowered than other station of urban area (beside station BA01). This may be due to wastewater treatment plant. Similar kind of result was also seen in pervious study by Paudyal *et al.,* (2016). Average concentration of iron and copper in the present study is higher than pervious study by Bhatt *et al.,* (2014) and Paudyal *et al.,* (2016). Similarly, the average concentration of Cu in this study (0.06 mg/L) is found to be very high than other rivers like Indrawati (0.0033mg/L), DudhKoshi (0.0021 mg/L) (Tripathee *et al.,*2016) and Gandaki (0.0018 mg/L) (Pant *et al.,* 2020). Anthropogenic inputs (industrial and domestic effluent) might be reason for the high concentration of Cu in the Bagmati River since it is highly polluted river.

5.2 Multivariant analysis

5.2.1 Correlation analysis

pH and DO showing negative correlation which concludes increase in pH decreases the DO. Similarly, Turbidity showed strong positive correlation with Fe and TSS which recommend having the same source in the water. Again, TSS show strong positive relation with all the parameters except DO and pH. This concludes that BOD, COD, TP, Fe, Cu and total coliform increases the TSS concentration in water and suggest for same source. The strong correlation between COD and BOD is due to contamination of organic matter (Vega *et al.,* 1998). Since, BOD and COD both showed the strong positive correlation significant level ($p= 0.01$) with TP, TSS, TDS, Cu (Table 3) and faecal coliform indicating towards anthropogenic pollution like mixing of untreated wastewater directly to Bagmati River (Kannel *et al.,* 2007)

5.2.2 Cluster analysis

The cluster obtain based on sites and parameters shows that cluster C2 is highly polluted than C1a and C1b i.e C1a> C1b> C2 (increasing order of pollution level). C1a was found to be clustered with the samples having low concentration of pollution indicating parameters (BOD, COD, TSS, Turbidity, TDS, TP, total coliform, Fe and Cu). This indicates towards the similar ongoing process affected by similar processes and sources for water parameters (Pant *et al.*, 2018). Meanwhile samples in C1b are high concentration than C1a. Since C2 is clustered with sample station BA09 which has very high concentration of pollution indicating parameters

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the present water quality study, the concentration of the parameters such as COD, BOD, FC, Fe and Cu in Bagmati River exceeded the guideline of WHO. Among the 14 parameters, 5 parameters were found to have high concentration than in previous study. TDS and turbidity were also higher than the previous study. The value of BOD and COD was found to be 5 times lower than the previous study. Similarly, faceal coliform showed higher concentration and even the head water region (BA01) was also found to be contaminated with faceal coliform. Among the five heavy metals studied in present study, values detected for Fe and Cu were >0.001 mg/L whereas Cd, Cr and Mn were not detected. The high concentrations of most of the parameters were remarkably present in the downstream especially Bagmati-Bishnumati (BA09) confluence. The high correlation found between these parameters suggested the same source of parameters. Cluster analysis also indicated that the core urban area of the Bagmati River was heavily polluted. The water sample BA05 after the wastewater treatment plant at Guheshowri showed lower concentrations of than other urban area. Hence, it is suggested that treatment of wastewater should be done before mixing in the Bagmati River. However, the attempts made by *Bagamati Sarsavai Abhiviyan 2074* is found to very less effective in reducing the pollution level of Bagmati River. The present status of the water suggests for an ecological restoration of this Holy River with a continuous and sincere effort by the concerned authorities.

6.2 Recommendations

Based on the present study, the recommendation for the further study can be listed below:

- The seasonal variation in the water quality parameters should be studied in other to complete the monitoring.
- There is urged to study other parameters which determine the water quality too.
- The tributaries of the Bagmati River also plays role in pollution so, the study suggest to further study the water quality of it.
- Further study suggested for the government law enforcement, policies etc, to the NGOs and social campaigner for creating awareness etc. for cleaning and restoring Bagmati.
- Addition of the more wastewater treatment plant is required in Bagmati which can reduce the pollution.

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APPENDIX

Appendix 1: Photographs

 

Photograph 1: Water sample collection and onsite testing

 

Photograph 2: Performing laboratory analysis of water samples.