EFFECT OF TRIBUTARIES ON WATER QUALITY PARAMETERS OF BAGMATI RIVER

In partial fulfilment of the requirement for the award of degree of M.Sc. in chemistry

By

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This is certified that dissertation work entitled **"The Effect of Tributaries on Water Quality Parameters of Bagmati river"** has been carried out by Mr. Narendra Bahadur Rawal, a partial fulfillment for the requirement of the Master Degree of Science in Chemistry under my supervision. To the best of my knowledge, this work has not been submitted for any other degree in any situation.

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I, “Narendra Bahadur Rawal”, hereby declare that the work presented here is genuine work done originally by me and has not been published or submitted elsewhere for the requirement of a degree program. Any literature, date or work done by others and cited in this dissertation has been given due acknowledgement and listed in the reference section.

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DEDICATION

Dedicated to my parents

My father Tek Bahadur Rawal

My mother Rithu Devi Rawal

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ABSTRACT

Unplanned urbanization of Kathmandu city is creating many environmental issues, where worsening of Bagmati river water is one of the serious problems. The water quality of Bagmati river was characterized by collecting the real-time fine-scale data along the Bagmati river in the Kathmandu valley, using multi parameter sensor in winter season. The different physiochemical parameters viz., temperature, pH, conductivity, ORP, DO, salinity, TDS, and turbidity were monitored at 14 different locations from Gokarna to Balkhu. The spatial variation of water quality parameters revealed that the Bagmati river was comparatively less polluted between Gokarna to Tilganga and molecular oxygen present in the water was enough to decompose the organic pollutant. However, the water quality at downstream from Tinkune to Balkhu was degraded drastically making unfit for living organism. Temporal variation of water quality attributed that human activity significantly enhanced pollutants which severely degraded the water quality in the day time. The comparative study of water quality of Bagmati river and its tributaries showed that the chemical composition of the rivers were different from each other. Most of the parameters of all river water exceeded the WHO limit, ORP was positive for Bagmati river water but that was negative for other tributaries, which attributed that the tributaries of Bagmati river was highly polluted. The physiochemical parameters measured at upstream, downstream and at tributaries before mixing into the Bagmati river showed that tributaries and local pollutants from the human activities excessively loaded contaminants into the Bagmati river. The Water Quality Index (WQI) was varied between 25 to 50 for Bagmati river and its tributaries, which suggested that water quality of all rivers in the Kathmandu was bad.

Keywords: Dissolved oxygen, oxidation reduction potential, pH, spatial variation, water pollution.

ABBREVATIONS

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
CCMEWQI	Canadian Council of Ministers of Environment Water Quality Index
EDTA	Ethylenediaminetetraacetic acid
EPA	United States Environmental Protection Agency
FNU	Formazine Nephelometric Unit
ISO	International Organization for Standardization
JTU	Jackson Turbidity Unit
KMC	Kathmandu Metropolitan City
LSMC	Lalitpur Sub Metropolitan City
meq/L	milli equivalent per Liter
mg/ L	milligram per liter
mV	millivolt
µS/cm	micro Siemen per centimeter
µeq/L	micro equivalent per Liter
NSFWQI	National Sanitation Foundation Water Quality Index
NTU	Nephelometric Turbidity Unit
ORP	Oxidation Reduction Potential
OWQI	Oregon Water Quality Index
ppm	parts per million
PSU	Practical Salinity Unit
TDS	Total Dissolved Solid
USGS	United States Geological Survey
WAWQI	Weight Arithmetic Water Quality Index
WQI	Water Quality Index

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CHAPTER 1

INTRODUCTION

1.1 General Background

Water is the most important chemical compound which has essential role in the life processes. One third part of the earth is filled with water among that only least amount is suitable for drinking purpose. Water is used in many purposes such as drinking, bathing, cooking, irrigation, constructions and several other purposes. Contamination of water causes several health problems hence fresh water is needed for healthy life. About a million of people annually dies from waterborne diseases with relates the water problems (like: typhoid, dysentery, cholera etc.) (WHO). Hence preservation of fresh water is important to improve the quality of life.

Basically, there are two types of natural sources of water such as ground water (well, ponds, borehole water, pump) and surface water (lake, river, streams etc.). About 3% of water in earth is suitable for human kind as fresh water on that 0.01% is available for human uses, the percentage availability of fresh water declined due to exponential growth of population, urbanization and the unsustainable consumption of water in agriculture and industries. Water pollution is increased by human activities mainly as indiscriminate disposal of industrial, municipal as well as domestic waste in water channel, river, lake etc., 2 million tons of sewages and other effluents are discharged daily in water. Among them 90% of raw sewage and 70% industrial untreated industrial wastes are dumped into surface water sources (WPP, 2010).

The surface water pollution is the widespread environmental problems in the developing nations. Considering the problems government of such nations makes secure policy management programs for treatment of the domestic sewage effluents, agricultural and the industrial wastes before discharge into environment or in surface water. About 20% of waste water are treated before discharge into the environment and rest of waste water used for other purposes like irrigation or agricultural production. So, the wastes from the industrial production, agricultural fertilizers and the domestic sewages effluents causes a water pollution. The industries and city area are the major source of waste water, the untreated waste water from any sources like domestic as well as industries contains the pathogens and the harmful chemicals which are harmful for human health (Perrine, et al., 2013).

Water quality is often thought of as a matter of taste, clarity and odor, and in terms of other properties which determine whether it is fit for drinking or not. Most of the properties depend on the kinds of substances that are dissolved or suspended in the water. The chemical constituents found in surface water depend in part on the chemistry of precipitation and recharge of water by waste solids and the impurities of metal and ions present in water. Fresh water is a renewable resource whose supply can never be exhausted because it is constantly getting replenished through the global hydrological cycle. However, the supply of fresh water resources may come under threat if used at a rate greater than the normal recharge rate and when highly polluted (Rose, 2002).

1.2 Importance of Bagmati river

The major sources of water in Nepal are glaciers, snow-melt from the Himalayas, rainfall and ground water. Of these, river water is the most significant in terms of potential development. The rivers alone cover about 54 percent of the total water coverage area in the country (CBS, 2002). There are over 6,000 rivers in Nepal with an estimated total length of some 45,000 kilometers (CBS, 2001). These rivers flow through the extensive mountain region and then through the narrow plain terrain is dependent for drinking, bathing and washing, irrigation, fishery, hydro-development etc. Recently, the river course particularly in major urban areas has become the site for urban drainage and waste dumping. During the past few decades an exponential increase in human population, rapid urbanization and industrialization, intensive agriculture have all severely affected the rivers.

The study mainly concerns to the 20 km stretch of the Bagmati river and its tributaries of in the Kathmandu valley. The Bagmati river, which originates about 5 km north from Kathmandu valley, which is an important source of water in Kathmandu valley in various purposes; for daily uses as for drinking, bathing, cooking, industrial manufacturing, irrigation and recreation for about millions people in three major cities of Kathmandu. The few mass of river water uses in various sector 66% for irrigation purpose, 31% for water supply in three municipality of valley and 3% of it for industrial uses (Gautam, et al., 2013).

Bagmati river in Hindu culture worshiped as goddess river that is why number of temples located on its banks. It has various religious and cultural meaning in the Hindu and Buddhist society so worshiped by millions of people from all over the world. Every Hindu wishes that he/she be cremated on the banks of this holy river according to their culture and devotes conduct daily rituals and takes bath in the river to purify the mind (Wikipedia). Bagmati river has important role in hydroelectricity, irrigation and as domestic purpose (about 80% of the water used for domestic water supply in Kathmandu valley). The water of river is highly polluted due to making a dumping site on the bank of river for solid waste, direct contact of domestic outlets on river, the wastes from infrastructure constructions, production from industries and the effluents from agricultural bi products (Paudyal, et al., 2016).

The upstream of the Bagmati river water is good for domestic use (bathing, drinking etc.,) but downstream towards urban area the pollution is increased substantially due to the high population in city area, development of the industrial production and the commercial activities as well as behavior of consumption of water. The rapid developing of nation, lack of waste water treatment facilities, careless behavior, unmanaged drain in municipality and the waste from industries are the main source of water pollution of river and its tributaries. The serious problems arise in the river water quality, by chemical contaminant, pathogens, and including (Mishra, et al., 2017).

Bagmati is the main river of Kathmandu valley its flow along the valley with major six tributaries, Monahara, Dhobikhola, Tukuchsa, Bishnumati and Balkhu khola. Hole of the river basin faces with serious environmental and highly water pollution problems due to highly urbanization in city, unmanaged drains in the river, the bi products of industrial goods, agriculture wastes, solid wastes in the water from domestic kitchens, bodies of dead animals, wastes from the hospitals without safe disposing treatment, dumped solids wastes on side of river, direct contact of wastes from domestic and industries wastes water without effective treatment, resulting the foul odor on the course or on side of river and the state of water in the core area is too bad visibly black in color with filth, smelled badly no chemical test are required to verify its quality(Regmi, et al.,2016).

Figure 1.1: Origin of Bagmati river (left) and Pashupatinath area (right).

Figure 1.2: The dumping site along the course of Bagmati river at Balkhu area.

1.3 Different Water Quality Parameters of Drinking Water

pH

The pH is the main important parameter for water. If the pH of water is greater than 7 then it is basic or alkaline water, and if it is less than 7 normally said as acidic water. According to CDS (Central Bureau of Statistics) in Nepal the normal pH value from 6.5 to 8.5 considered as normal water. The pH is the activity of free movement of hydrogen ion in water. Concentration of free ions of hydrogen and hydroxyl ions are the main parameter to classify the basic class of water, inserting more favorable process to combines with others matters from minerals or by other means, classify various properties of water.

Temperature

Temperature is the another important parameter of the water that defects the hydrodynamic properties of the water. The temperature has the vital roles in the entire properties of water. The temperature alters the density of water by which the isotopes of water alters as according to the rate of temperature fluctuation the properties of water flow and contained other wastes like any kind of solids (suspended and dissolved) or other minerals and ores, not only this the rate of rain fall also depend on temperature of river water or other sources of water. Normally the temperature range for river water is 26^{o} C which is good for other water parameters and for aquatic creatures.

Conductivity

Conductivity is the ability of water to carry current from the free mobile ions presence in the water, the ions may be cations Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and the anions like HCO_3^{-}, SO_4^{2-}, Cl^{-} etc. the ions in water are present from the rock salts, dead and decayed matter from environment (physiological effects on plants or animal, corrosion rates, etc.). The wastewater contained the huge amount of free ions from different sources in the city areas that may be organic or inorganic that's why the conductivity of free ions mobilization in waste water is higher than the reservoir water or free pollutants water. The conductivity of water alters the entire properties of water as change in temperature (APHA, AWWA, WEF).

ORP [Oxidation–Reduction Potentials]

ORP is the chemical phenomenon of the water which is capable to oxidize or reduce other substances by a chemical process involving the losing or gaining of electrons between the molecules that why it is the effective sanitizer of water. Higher potential of oxidation means more effective sanitize it is (AliAl-Samawi, et al., 2016).

Hardness

Water hardness is the capacity of the water to precipitates soaps, calcium and magnesium ions are presents in excess amount. Other polyvalent cations are also present but are in complex from with organic matter, least role in water hardness and difficult to conformed. The total hardness is the sum of calcium and magnesium ions as form of calcium carbonate (APHA).

Water if don't form the lather with soap, is hard water and water if form copious lather with soap, is soft water. Soap consist the salt of sodium with higher fatty acid viz., stearic acid, oleic, palmitic acid etc., having higher solubility with water and hence have better cleansing property. The free calcium and the magnesium ions reacts with salt of sodium;

$$2C_{17}H_{35}COONa + CaSO_4 \rightarrow (C_{17}H_{35}COO)_2Ca + Na_2SO_4$$

(Sodium Stearate) (insoluble salt)

The hardness is generally of two types that's are temporary and the permanent hardness. The bicarbonate salts of calcium and magnesium cause temporary hardness and easily removed by boiling water, the salt of bicarbonate changed into insoluble salt of carbonates or hydroxide, which can be removed by filtration. Similarly, the chloride or the sulfate salts of calcium and magnesium causes permanent hardness. The hardness is the capability of the that dissociate the acids. The sources of such ions in the natural water comes from the rock distortion and the minerals that generates from the decaying process of the plants or by means the natural minerals (Rattan, et al., 2011-2012)

The excess amount the such anions or the cations like calcium, magnesium, strontium, ferrous ion, and manganese ions and the anions viz., bicarbonate, sulfates, chloride, nitrate and silicates, causes the free hardness in the water. The attribution of Ca^{++} and Mg^{++}, in water is significant, the sum of these ions with their respective anions is the total hardness of the water. Hardness greater than the sum of carbonate and the bicarbonate, hardness equivalent to total alkalinity, called carbonate hardness and balance as noncarbonated hardness. And, sum of carbonate and bicarbonate alkalinity less than total hardness, hardness due to carbonate only. The ions like sodium if excess in water also behaves like hardness due to common ion effect, such hardness is pseudo hardness. Hardness represent as mg/L of $Ca\ CO_3$.

The hardness of water was determined by two methods: one is the most accurate process as calculation of hardness and the another is the EDTA Titration Method. The hardness calculation method is used to determine the separate ions concentration of calcium and magnesium. And the another titration method used to determine the combined concentration of both calcium and magnesium ions, ethylenediaminetetraacetic acid as the complexing reagent form the soluble chelated complex with the metal cation and the indicator Eriochrome Black T or Calmagite at pH 10.0 ± 0.1 form a red wine color of solution containing a calcium and magnesium ions. On titrant with the chelating complex solution of EDTA the color of solution changed to blue from red wine color indicating the end point of the reaction. The sharpness of end point increases with increasing the pH of the solution, however the pH cannot increase sharply because of precipitation of calcium carbonate or magnesium hydroxide occurred, often at high pH the dye changed its color. The tendency of precipitation of $CaCO_3$ minimized by making the time duration of 5 minutes before titration. The polyvalent cations interfere the sharp end point of the solution by consumption of EDTA such kinds of interference can reduce by adding the inhibitors before titration, and if the concentration of heavy metals are excess in water at a case the hardness of water determined by non-EDTA method and determine the hardness of water by calculation. Some the end point of hardness of water often interfere by colloidal suspended organic matter, and that can be reduce by evaporating the sample in muffle furnace at 550^{o} Cuntil the organic matter completely oxidized, and then dissolved the residue with 1N solution of HCl and made the pH of solution at 7 by adding 1N solution of NaOH, solution must cool at room temperature before titration as usual procedure. The changing color of solution slow down towards the freezing temperature and also the indicator decomposed when the sampling solution hot (APHA, 2340 C).

Alkalinity

Alkalinity is the another important parameter of water, and it measures the acid neutralizing capacity of water (APHA). It is important because it acts as the acid stabilizer for pH or with basicity of water or buffer against rapid pH changes in water and measured on pH scale. Generally, the water's alkalinity is due to presence of carbonate, bicarbonate and hydroxide of sodium, potassium, calcium and magnesium. Sometimes water's alkalinity often by presence of silicates, borates and phosphates may also contribute to the total alkalinity to small extents. The manner of alkalinity of ions presence in water is in order of:

Hydroxide only (OH^-), Carbonates only (CO_3^{2-}), Bicarbonates only HCO_3^-), Hydroxides and carbonates, Carbonates and bicarbonates.

It is important to know about the alkalinity of water because is usually unpalatable. If used to generate steam, it may lead to deposition of scales and sludge, corrosion etc. Water with low levels of alkalinity (<155 ppm) is more likely to be corrosive. Alkalinity of water is determined by titrating the solution of water against standard solution of acids, HCl, until its pH changes abruptly with using the appropriate indicators, methyl orange and phenolphthalein. The volume of acid consumed up to the end of methyl orange corresponds to the complete neutralization of OH^-, CO_3^{2-} and HCO_3^- ions. As the sample is titrated with standard acid using methyl orange as indicator and alkalinity is calculated in terms of $CaCO_3$ equivalent, alkalinity called as total alkalinity or methyl orange alkalinity. Alkalinity expressed in unit of concentration; meq/L (milli equivalents per liter) or μeq/kg (micro equivalent per kilogram), or mg/L $CaCO_3$ (milligram per liter) which correspond to amount of acid added to titrant.

Dissolved Oxygen

The most important parameter of water quality is dissolved oxygen presence in water. It is the free oxygen gas present in water as dissolved form, it is considered as the essential parameter to assess the water quality, and it reflects the physical and biological condition in the prevailing water. Its presence is vital to sustaining the higher forms of biological life in water (Trivedi, et al., 1986). Oxygen enters in the water by the process of photosynthesis of aquatic biota, and transfer oxygen across the air-water interface. In aquatic environment oxygen is produced by the photosynthesis of algae and plant, and the oxygen is removed by respiration of plants, animals, microorganism, BOD degradation process, sediment oxygen demand, and oxidation (Radwan, et al., 2003; Lin, et al., 2006). The water at noon, have high level of oxygen because plant generate by the process of photosynthesis; once it falls at night, because photosynthesis stops, and plant and other aquatic organism consume oxygen as they respire, decreasing the dissolved oxygen levels (Goa, et al., 2008).

The overall photosynthesis process is represented by the equation:

$$6H_2O + 6CO_2 + \text{light energy} \rightarrow 6O_2 + C_6H_{12}O_6$$

The water (H_2O) together with carbon dioxide (CO_2) and energy from sum transformed into free oxygen (O_2) and organic matter ($C_6H_{12}O_6$). And the respiration process is inverse of photosynthesis: organic matter decomposed to obtain chemical energy contained in it, obtained by combining the organic matter with oxygen:

$C_6H_{12}O_6$ (aq) + $6O_2$ (g) → $6CO_2$ (g) + chemical energy

The DO is required for aquatic life in river, streams, lakes etc. and almost beneficial for water. If the water has deficiency of DO, it signs the pollution of water. As DO level drops below 4-5 mg/L, the life form in the aquatic ecosystem gets affected. The level of oxygen in water also depends upon its physical, chemical and biological activities. The higher level of DO, in water supply makes water suitable for drinking purposes. Water contains the least amount of DO in the range of 10^{-4} M, compared with the atmospheric concentration of oxygen (21%). Any technique used to measure DO must exclude atmospheric oxygen from the analysis or the sample is highly contaminated. DO in addition to biological factors, affected by different physical parameters like turbulence, atmospheric pressure, surface aeration, river flow, estuaries circulation, pH, water depth, seasonal variation, diurnal variation as well as temperature and salinity. The dissolved oxygen decreases in water as temperature and salinity increase, and more dependent on temperature variation than on salinity variation (Pinet, 2006; Sarmiento et al., 2006). If the concentration of biological oxygen demand (BOD) is excess, alternatively the dissolved oxygen level been low.

The rate of oxygen transfer between atmosphere and water depends on the numbers of parameters such as wind speed, turbulence at the interface, air bubbles, etc. Bubbles increases the effective surface area for gas and thus increase air-water fluxes (Falck, et al., 1999; Gao, et al., 2008).

The dissolved oxygen (DO) can be readily, and more accurately measured by the method developed by Winkler, 1888. DO, can also be determined by the use of oxygen sensitive electrodes; and such electrode frequently standardized with known concentration of oxygen, usually useful for polluted water where the concentration of oxygen is quite high. In addition, their sensitivity can be exploited in environment with rapidly- changing oxygen concentrations. The electrode sensor examination of waste water is less accurate or reliable, if the concentration of oxygen is very low, for these reasons, Winkler titration employed for accurate determination of oxygen concentration in an aqueous sample.

Total Chlorine Demand

Chlorine is the powerful oxidizing agent, and easily penetrate inside the cell of microorganism and killing them easily, beneficial use for removing the slime, oxidation of other inorganic species (e.g., ferrous ion, reduce manganese, sulfide and ammonia) and oxidation of organic compounds (e.g., taste-and odor producing compounds) (Haas, et al., 1984; Vasconcelos, et al., 1997). Both, addition and substitution reaction produces organochlorine species (e.g., phenol produce chlorophenols with chlorine), or active chlorine species (e.g., chloramine produced when chlorine react with ammonia). And, chlorine react with naturally occurring organic compounds to produce trihalomethanes (APHA).

As regards the chlorination, there are several mechanisms that occurs simultaneously when chlorine ids added to waste water (Clark, 1998).

A first reaction is hydrolysis:

$$Cl_2 + H_2O \leftrightarrow HOCl + H^+ + Cl^-$$

or:

$$Cl_2 + OH^- \leftrightarrow HOCl + Cl^-$$

A second reaction is ionization:

$$HOCl \rightarrow H^+ + OCl^-$$

Both hypochlorite and calcium hypochlorite, generate the same reactions (Hurudey, et al, 2004). Oxidation of reducing substances by chlorine produces the chlorine demand, and the reaction is proportional to the amount of reducing the present substances.

The waste water also contains the amount of compounds of nitrogen which reacts with chlorine; the most important reaction is that of hypochlorous acid with ammonia:

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O \text{ (monochloramine)}$$

$$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O \text{ (dichloramine)}$$

$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O \text{ (tri chloramine)}$$

The chloramine depends on the pH value, temperature, time contact, and the concentration of each reacting substances. It is important to performing the experiment, to destroy the taste and odors; for ensure the good disinfection (Fisher, et al., 2012; Gilbert, et al.,1990).

Amount chlorine remaining after chlorination is called residual chlorine. The amount of chlorine is considered sufficient if, after a 30min chlorination, the amount of residual chlorine ranges between 0.5 to 1.0mg/L, and the concentration must be 2mg/L on contact time of 15min to achieved an optimum bacteriological effect.

The chlorine demand is a function of chlorine concentration, temperature, contact time and pH. The minimum concentration of chlorine in the range of 1.5 to 2.0 ppm is essential in the drinking water (Monteiro, et al., 2015). WHO guideline for the concentration of chlorine in the range of 0.2 to 0.3 ppm for 30minute contact time. Turbidity have great effect on chlorine demand, it composed both organic and inorganic matter. Turbidity reduced the effectiveness of chlorination through absorption of chlorine species in dirt matter. The Total Organic Carbon (TOC), associated with turbidity, and exert excess chlorine demand. Organic matter was responsible for reacting with the chlorine species in the water, and produces a harmful chlorinated compounds, trihalomethanes, producing unpleasant smell in water.

Total Dissolved Solid

Total dissolved solids (TDS) is defined as all inorganic and organic substances contained in water. In general, TDS is the sum of the cations and anions in water; carbonate, bicarbonate, chloride, fluoride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, and potassium. The organic ions include pollutants, herbicides, and hydrocarbons (Eaton, et al., 2012; Akan, et al., 2007). Total dissolved is a non-specific, quantitative measure of the amount of dissolved inorganic chemicals but does not tell us anything about its nature. TDS is not considered a primary pollutant with any associated health effects in human drinking water standards, but it is rather used as an indication of aesthetic characteristics of drinking water and as a broad indicator of an array of chemical contaminants (Phiri, et al., 2005).

Turbidity

Turbidity is the amount of cloudiness in the water (Meybeck, et al., 1989). Turbidity can be caused by silt, sand and mud, bacteria and other germs, chemical precipitates. It is very important to measure the turbidity of domestic water supplies, as these supplies often undergo some type of water treatment which can be affected by turbidity (Meybeck, 1998; Von Gunten, et al., 1993). Turbidity of water is an optical property that causes light to be scattered and absorbed, rather than transmitted. The scattering of the light that passes through a liquid is primarily caused by the suspended solids. The higher the turbidity, the greater the amount of scattered light (Birch, et al., 2008). Because even the molecules in a very pure fluid scatter light to a certain degree, no solution will have zero turbidity. The unit of measure adopted by the ISO Standard is the FNU (Formazine Nephelometric Unit) and by EPA is NTU (Nephelometric Turbidity Unit). The other two methods used to test for turbidity and their measurement units are the JTU (Jackson Turbidity Unit) and the Silica unit (mg/L SiO_2) (APHA).

Salinity

The term "salinity" refers to the concentrations of salts in water or soils (APHA). Salinity can take three forms: primary salinity (also called natural salinity); secondary salinity (also called dryland salinity), and tertiary salinity (also called irrigation salinity) (Droste, 1998). Small amounts of dissolved salts in natural waters are vital for the life of aquatic plants and animals. However, high levels of salinity and acidity (if present) are harmful to many plants and animals (Kincannon, 1966). Our water resources generally derived from three sources. Firstly, small amounts of salt (primarily sodium chloride) are evaporated from ocean water and are carried in rainclouds and deposited across the landscape with rainfall (Flood, 2011). Secondly, some landscapes may also contain salt that have been released from rocks during weathering (gradual breakdown), and thirdly, salt may remain in sediments left behind by retreating seas after periods where ocean levels were much higher or the land surface much lower (Henze, 2011).

Primary salinity is caused by natural processes such the accumulation of salt from rainfall over many thousands of years or from the weathering of rocks (Cao, et al., 2015). The small amounts of salt brought by the rain can build up in soils over time (especially clayey soils), and can also move into the groundwater (Turton, 2008). Secondary salinity is caused where groundwater levels rise, bringing salt accumulated through 'primary' salinity processes to the surface (Maguire, 2016). Tertiary salinity occurs when water is reapplied to crops or horticulture over many cycles, either directly or by allowing it to filter into the groundwater before pumping it out for re-application. (Droste, 1998).

Phosphate

Phosphorus occurs naturally in rocks and other mineral deposits (APHA). During the natural process of weathering, the rocks gradually release the phosphorus as phosphate ions which are soluble in water. The phosphate occurs in living and decaying plant and animal remains, as free ions or weakly chemically bounded in aqueous systems, chemically bonded to sediments and soils, or as mineralized compounds in soil, rocks, and sediments (Rosen, et al., 1992).

Phosphorus gets into water in both urban and agricultural settings. Phosphorus tends to attach to soil particles and, thus, moves into surface-water bodies from runoff (Metcalf, et al, 2003). Since groundwater often discharges into surface water, such as through streambanks into rivers, there is a concern about phosphorus concentrations affecting the water quality of surface water**.** Phosphorus is an essential element for plant life, but when there is too much of its concentration in water, it can speed up eutrophication (reduction in dissolved oxygen in water bodies caused by an increase of mineral and organic nutrients) of rivers (Park, et al., 2010).

Sulfate

Sulfates occur naturally in numerous minerals, including barite ($BaSO_4$), epsomite ($MgSO_4 \cdot 7H_2O$) and gypsum ($CaSO_4 \cdot 2H_2O$). These dissolved minerals contribute to the mineral content on surface water. Sulfates and sulfuric acid products are used in the production of fertilizers, chemicals, dyes, glass, paper, soaps, textiles, fungicides, insecticides, astringents and emetics. They are also used in the mining, wood pulp, metal and plating industries, in sewage treatment (Greenwood, et al., 1984). Aluminium sulfate (alum) is used as a sedimentation agent in the treatment of drinking-water. Copper sulfate has been used for the control of algae in raw and public water supplies (McGuire et al., 1984).

Sulfates are discharged into water from mines and smelters and from kraft pulp and paper mills, textile mills and tanneries. Sodium, potassium and magnesium sulfates are all highly soluble in water, whereas calcium and barium sulfates and many heavy metal sulfates are less soluble. Atmospheric sulfur dioxide, formed by the combustion of fossil fuels and in metallurgical roasting processes, may contribute to the sulfate content of surface waters. Sulfur trioxide, produced by the photolytic or catalytic oxidation of sulfur dioxide, combines with water vapor to form dilute sulfuric acid, which falls as "acid rain" (Delisle, et al, 1977).

Ammonia

Ammonia is one of the forms of nitrogen that exist in aquatic environments. Unlike other forms of nitrogen, which can cause nutrient over-enrichment of a water body at elevated concentrations and indirect effects on aquatic life, ammonia causes direct toxic effects on aquatic life. Ammonia is produced for commercial fertilizers and other industrial applications. Natural sources of ammonia include the decomposition or breakdown of organic waste matter, gas exchange with the atmosphere, forest fires, animal and human waste, and nitrogen fixation processes (Sotirakou, et al., 1999).

Ammonia can enter the aquatic environment via direct means such as municipal effluent discharges and the excretion of nitrogenous wastes from animals, and indirect means such as nitrogen fixation, air deposition, and runoff from agricultural lands. When ammonia is present in water at high levels, it is difficult for aquatic organisms to sufficiently excrete the toxicant, leading to toxic buildup in internal tissues and blood, and potentially death. Environmental factors, such as pH and temperature, can affect ammonia toxicity to aquatic animals (Bansode, 2002).

1.4 Literature Review

The effect of pollution on Bagmati river due to the slum activities were studied by Deshar (2013), and suggested that that Bagmati corridor is only and one open spot attractive for slum activities. The latrine effluents in the slum area are directly discharge into the river. The expansion of squatter settlement on the river side seems rapid in 2008 and 2009, however slower in 2010 and 2011, due to sweeping political changes in Nepal, they used to discharge a significant quantity of pollutant to the river, plastics contamination, and sand extraction in the area.

Moreover, Regmi, (2013) suggested that the deterioration of the water quality of the Bagmati river is because of the surface runoff from urban areas and agricultural lands, including industrial discharges. About of 50.9% of the industries in Nepal are located in Kathmandu valley, and they are also the major sources of water pollution along with hospital wastes. Cointreau, et al., (2013) suggested that most of the cities in the developing nations have miserable state of sanitation, inadequate, and unscientific municipal solid waste management practices, which have resulted in environmental problems causing surface and groundwater contamination and serious human health risk. Similarly, Ijjaali, et al., (2014) suggested that in developing countries, very few industrial wastewater treatment units are in place before the effluents are discharge into the environment, which causes severs environmental obstacles.

Amagloh et al., (2009) reported that more than 2.6 billion people (40%) of the world's population lack basic sanitation facilities and one billion people still used unsafe drinking water sources. Even though out of the total population of Nepal an estimated 84% have access to safe drinking water, it was not safe. In rural Nepal, millions of people did not have access to safe drinking water or basic sanitation sources. Only 27% of the population as a whole had access to sanitary facilities.

Adhikari, et al., (2019) determined the effect of tributaries on Bagmati river by sampling water from five different sites such as Pashupati (B-1), Shankhamul (B-2), Kupondol (B-1), Balkhu (B-4), and Jalbinayek (B-5). The water samples B-2, B-3, B-4 and B-5 were less turbid but black in color while water sample B-1 was more turbid but grey in color. The pH of water samples ranged from 6.7 to 7.3. The alkalinity, conductivity and chlorine demand were 60 ppm, 95.7 µs and, 5.44 ppm, respectively for B-1 sample and increased almost continuously from B-2 to B-5 sample. The alkalinity was 360 ppm, conductivity was 862 µs and chlorine demand was 23.7 ppm for the last sample (B-5). The concentration of ammonia in the B-1 sample was only 0.0625 ppm whereas it was 3.32 ppm in the B-5 sample. This revealed that the conductive alkaline pollutants consumed more chlorine than colloidal particles. From the study it is considered that the Bagmati river water contains natural as well as anthropogenic pollutants which is extremely hazardous not only to the people using river water but also for the living organism rely on the river.

During post-monsoon 2013, Paudyal, et al. (2016), analyzed surface water by collecting samples form 34 sites from the Bagmati river and its tributaries within the Kathmandu Valley to assess the river water quality. The physical parameters were measured on site and major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-) and 17 elements in water were analyzed in the laboratory. Conductivity ranged from 21.92 to 846 µS/cm, while turbidity ranged from 2.52 to 223 NTU and dissolved oxygen (DO) ranged from 0.04 to 8.98 mg/L. The ionic and elemental concentrations were higher in the lower section where the population density is high compared to the headwaters. The large input of wastewater and organic load created anoxic condition by consuming dissolved oxygen along the lower belt of the river. Anthropogenic activities like industrial activities, municipal waste water, and road construction besides the river appear to control the chemical constituent of the river water. Overall the river was highly polluted with elevated concentrations of major ions and elements and there is a need for restoration projects.

Shrestha, et al., (2013), carried out to find out the possible impact of Bagmati river water on its nearby ground water resource within Kathmandu valley (KV). River water analysis showed that it was less polluted during winter season as compared to other seasons and got severely degraded as it entered to the urban core. Regression analysis showed that the mean value of ground water parameters like pH, conductivity, chlorides, free carbon dioxide, alkalinity, hardness, nitrate, ammonia, iron, and orthophosphate were decreased from within 50 m to 50-100 m, and 100-150 m distance from the river bank. Microbial analysis of ground water showed that 88% of the samples were contaminated with fecal matter. So the ground water along Bagmati river should could not be used as consumptive purposes without treatment. The finding showed that the ground water was more contaminated along the river banks and towards the urban corridor than the upstream parts which might be due to intrusion of nearby polluted river water.

Shrestha, (2018), collected ten different water samples from Ratuwa river and its tributaries. The correlation matrix shows that color, total dissolved solids (TDS), chloride (Cl), fluoride (F), total phosphorus (TP), total alkalinity (TA), calcium (Ca), magnesium (Mg), sodium (Na), and dissolved oxygen (DO) have a significant effect on the electrical conductivity (EC). Among these parameters, TDS has the highest contribution (39.65%) followed by total alkalinity (23.5%), total hardness (19.9%), chlorine (6.5%), and calcium (5.5%) ions, respectively. However, color, TP, fluoride, and DO have almost 1.45% contribution to the electrical conductivity.

Kannel, et al., (2007) studied the assessment of variation of water qualities, classification of monitoring networks and detection of pollution sources along the Bagmati river and its tributaries in the Kathmandu valley of Nepal. Seventeen stations, monitored for 23 physical and chemical parameters in pre-monsoon, monsoon, post-monsoon and winter seasons, during the period 1993-2003, were selected. They revealed that the upstream river water qualities in the rural areas were increasing affected from human sewages and chemical fertilizers. In downstream urban areas, the river was heavily polluted with untreated municipal sewages. The contribution of industries to pollute the river was minimal. The higher ratio of COD and BOD (3.74 in the rural and 2.06 in the urban) confirmed the increased industrial activities in the rural areas. An increasing trend of phosphorus was detected. The water quality measurement in the study period showed that DO was 4 mg/L and BOD, COD, TIN, TP and TSS above 39.1, 59.2, 10.1, 0.84 and 199 mg/L respectively in the urban areas. In the rural areas, DO was above 6.2 mg/L and BOD, COD, TIN, TP and TSS below 15.9, 31, 0.41, 134.5 mg/L, respectively. The data analysis from 1998 to 2003 at a key stations in the river revealed that BOD was increasing at a rate of 1.8 mg/L in the Bagmati river. A comparative study for the water quality variables in the urban areas showed that the main river and its tributaries were equally polluted. The other comparison showed the urban water quality were significantly poor as compared with rural area.

Thirty groundwater samples were collected and analyzed by Adimalla, et al., (2017) physico-chemical parameters including nitrate concentration. The results showed that, the concentration of nitrate ranges from 14 to 82 mg/L and about 43.3% of these groundwater samples beyond the safe level of 45 mg/L according to Indian guidelines. The higher nitrate contamination is observed in the vicinity Health risks were assessed through oral/ingestion and dermal contact exposure routes for females, males and children population in the study region. Oral exposure was much higher than dermal contacts. For the non-carcinogenic risk, the HI_{Total} values of groundwater in the investigated region varied from 0.313 to 1.976 (mean of 0.941) for males, 0.370 to 2.336 (mean of 1.112) for females and 0.443 to 2.694 (mean of 1.314) for children. The health risk assessment for nitrate divulged that 60%, 57% and 50% of groundwater samples posed a non-carcinogenic health risk for children, females and males, respectively.

Water quality index is the mathematical instrument used to transform immense quantities of water quality data into a single number, which provide a simple and understandable tool for determination of the quality and its possible use of given water bodies (Bordan, 2001; Kannal, et al., 2007). According to the study done in the Bagmati river, the rural areas of the Bagmati river had WQI 64.4 units, which indicates the medium quality of water; however, WQI of urban water was 45.1 units (Kannal, 2007). There is a distinct number of water quality indices viz. Weight Arithmetic Water Quality Indexes (WAWQI), National Sanitation Foundation Water Quality Indexes (NSFWQI), Canadian Council of Ministers of Environment Water Quality Indexes, Oregon Water Quality Indexes, and so on have been formulated by several international and international organization (Tyagi, et al., 2013). The analysis done in the Bagmati river, CCEMEWQI values indicates that the water at most of the sampling had been found poor (0-40) for both the aquatic ecosystems and recreational uses, particularly in more densely populated regions and urban areas. At some sampling sites, i.e. semi-urban areas along the Bagmati river water quality would found to be marginal (45-64), Regmi, et al., (2017).

1.5 Research-Innovation Gap

The Bagmati river is one of the most polluted river comparing, all river over the country Nepal. The researcher starts their work on analyzing the water quality of Bagmati river since 2000 decays. Kannal, et al., 2007; Mishra et al., had done their research work on analysis of water quality parameters and the pollution in the Bagmati river. Pollution rate in the Bagmati river increased due to the unusual handling of the municipal solid wastes, direct dumping of sewages, hospital wastes and harmful chemical, unmanaged settlement on the bank of river. Deshar, 2013; had described the cause of water pollution in Bagmati river. Poudyal et al., 2016; Adhikari, et al., 2017; KC, et al., 2018; Adhikari, et al., 2019: had performed different studied under the cause of pollution on Bagmati river water and its effective factors.

There are many clusters of slum settlement along the river, and there, unsatisfactory waste management facilities in those communities. People generally seem to throw garbage in the river directly. This research tries to unfold some information on how the slum areas, the other developing factors and other sources of pollution that were affecting water quality of Bagmati river.

1.6 Objectives of Study

The research mainly focused in the following general and specific objectives.

General objectives

Determination of water quality of Bagmati river & influence of tributaries on Bagmati river.

Specific objectives

- Determination of physio-chemical parameters of Bagmati river and its tributaries.

- Determination of diurnal and spatial variation of water quality of Bagmati river.
- Determination of pollution level using water quality index (WQI) value.
- Ascertain the influence of tributaries on main river Bagmati

CHAPTER 2

MATERIALS AND METHODS

2.1 Sample collection and storage

The data were collected from 14 observation sites of Bagmati river from Gokarna to Balkhu region. From these data spatial and diurnal variation of river water was determined. The physico-chemical parameters such as pH, conductivity, oxidation-reduction potential (ORP), dissolved oxygen (DO), turbidity, total dissolved solid and salinity were measured on each spot by using digital multi parameter sensor (Hanna HI-9829). The sensor dipped into river water nearly about 1 feet depth from the surface of water.

Further, effect of tributaries on Bagmati river water was determined by collecting data of physico-chemical parameter on the spot and by analyzing water samples in the laboratory. The data was collected from 15 observation sites each from upstream & downstream sites of tributaries in the Bagmati river and each from the five tributaries before mixing into the river. For the laboratory analysis water samples were collected by using BOD bottle possibly from the center of the river stream. The BOD bottles were washed with detergent then by distilled water dried them. The washed BOD bottles were rinsed with sample water before taking water samples. The collected water sample was stored in a cool box and transported immediately into the laboratory. The water samples were stored in a freezer and analyzed within a day as possible. In the laboratory the water quality parameters such as alkalinity, hardness, chlorine demand, ammonia, phosphate, and sulfate were determined by using standard method.

2.2 Measurement of different parameter in Bagmati river water

2.2.1 Physiochemical parameters

The physiochemical parameters of river water were measured in the spot and by using multi parameter sensor which is given in the Table 2.1.

Table 2.1: Instrumentation for measurement of physiochemical parameters of water.

Parameters	Instrument
Temperature (^{o} C)	Hanna, HI-9829
pH	Hanna, HI-9829
Conductivity (µS/cm)	Hanna, HI-9829
ORP (mV[pH])	Hanna, HI-9829
DO (ppm)	Hanna, HI-9829
TDS (ppm)	Hanna, HI-9829
Salinity (PSU)	Hanna, HI-9829
Turbidity (FNU)	Hanna, HI-9829

2.2.2 Chemical parameter of river water

Alkalinity

Alkalinity of water was determined by the titration of water sample against a standard acid using phenolphthalein and methyl orange as indicator. 50ml of water sample was taken in volumetric flask in which 2 drops of phenolphthalein (indicator) was added which was titrated against 0.02M HCl till the color just disappeared. Again 2 drops of methyl orange were added and titration was continued with 0.02M HCl till orange color obtained. The working formula for alkalinity was

$$\text{Alkalinity (mg/L)} = \frac{V \times M \times 1000}{\text{Volume of sample taken}} \times \text{eq. wt. of } CaCO_3$$

Where; V= volume of acid consumed,

M= molarity of acid.

Hardness

The hardness of water was determined by complexometric titration where Ethylene Diamine tetra acidic acid (EDTA) was used as complexing reagent and Erichrome black T (EBT) as indicator. 5 mL of sample water was mixed with 10 mL of distilled water in which 10 mL of buffer solution of pH 9.5 was added. In this mixture 2-3 drop of EBT (indicator) was mixed and titrated with 0.01 M EDTA. The titration was done until the color of the solution changed from wine red to blue and end point was recorded. The working formula for hardness was

$$\text{Hardness (mg/L)} = \frac{V \times M \times 1000}{\text{volume of sample used}} \times \text{mol. wt. of } CaCO_3$$

Where; V= volume of EDTA consumed,

M= molarity of EDTA solution.

Chlorine demand

The starch-iodine titration method, one of the oldest methods for determining chlorine demand and generally is used for total chlorine determination. Chlorine will liberate free iodine (KI) solutions at pH 8 or less. The liberated iodine is titrated with a standard solution of sodium thiosulphate ($Na_2S_2O_3$) with starch as the indicator. The burette was rinsed filled with 0.005N $Na_2S_2O_3$ solutions. 100 mL water sample was taken in 250 mL BOD bottle and standard chlorine water solution of 40 ppm strength was added. After 30 minutes of contact time 2 mL of acetic acid was added followed by 25 mL KI solution (25% solution prepared freshly each time) to the bottle. Instantly the mixture was titrated with standard solution of sodium thiosulfate (0.005 N) using starch solution as indicator.

Ammonia

Phenate method has been used to determine ammonia content in water sample. This method involves addition of phenol solution together with hypochlorite and nitroprusside catalyst to the sample and phenol reacts with ammonia to form indophenols. 25 mL water sample added to of 1 mL phenol solution and 1 mL sodium nitroprusside and 2.5 mL of oxidizing in 250 mL conical flask and mouth of flask was covered with aluminum foil leave to stand for 30 minutes for color development in subdued light. Finally, absorbance was measured at 640 nm wavelength.

Phosphate

25 mL of water sample was evaporated to dryness in a 250 mL conical flask the residue was cooled and dissolved in 1 mL of 70% $HClO_4$. In cooled solution 10 mL distilled water and 2 drops of 1 % phenolphthalein indicator was added and titrated against 1 N NaOH solution until pink color appears and volume was made to 25 mL with distilled water. Then solution was transferred in to 50 mL volumetric flask and added 10 mL of reagent B and maintained to 50 mL and leave for color develop. Absorbance was recorded at 660 nm. Simultaneously distilled water bank was run in the same manner. Process the standard phosphorus solutions of various strengths in a similar way. Plotted a curve between absorbance as a function of concentration of standard phosphorus solutions. phosphorus content of the sample was described by comparing its absorbance with standard curve. From the obtained value phosphate ion concentration was calculated.

Sulfate

50 mL of water sample was taken in to conical flask and 20 mL of buffer solution was added in it. In the flask 0.15 gram of barium chloride was added and stirred up to 1 hour. Volume was marked to 50 mL with distilled water till the blue color develops. Absorbance was recorded at 420 nm. Simultaneously distilled water blank was run in the same manner. Process the standard sulfate solutions of various strengths in a similar way. Plotted a curve between absorbance as a function of concentration of standard phosphorus solutions. phosphorus content of the sample was described by comparing its absorbance with standard curve

2.3 Calculation of Water Quality Index (WQI)

The water quality index is the mathematical parameter used to transform large quantities of water characterization data into a single number, which examines the water quality class (Bordalo, 2001). National Sanitation Foundation Water Quality Index (NSFWQI) was used to calculate the water quality index of Bagmati river as it provides water class for water bodies that are severally polluted (Tyagi, et al., 2013). The weight factor of different parameters used was given in Table 2.2.

The mathematical expression for NSFWQI is provided in equation;

$WQI = \sum_{i=1}^{n} Qi \times Wi$ …………(1)

Where,

Q_i = Sub-index for i^{th} water quality parameter

W_i = weight of the i^{th} water quality parameter

n = number of water quality parameter

Table 2.2: Weight factors for WQI based on NSFWQI.

SN	Parameters	Units	Wt. Factor
1	Temperature	° C	0.1
2	pH		0.11
3	EC	µS/cm	0.25
4	DO	Ppm	0.17
5	TDS	Ppm	0.1
6	Turbidity	FNU	0.08
7	Ammonia	mg/L	0.1
8	Phosphate	mg/L	0.1
9	Sulfate	mg/L	0.1

2.4 Preparation of reagents for determining different parameters

Hardness

- **EDTA Solution, 0.1 M:** 18.6125 g disodium salt of EDTA was dissolved in distilled water in 500 mL standard volumetric flask and it was diluted up to the mark using distilled water.
- **Buffer solution:** 35.5 g ammonium chloride (NH_4Cl) was dissolved in 285 mL of concentrated ammonia solution and finally the solution was diluted to 500 mL by adding distilled water.
- **Erichrome Black T Indicator**: 0.25 g Erichrome black T dye was mixed with 50 mL of methonal.

Alkalinity

- 0.02M HCl

  250 ml 0.02M HCl solution was made from standardized 1M HCl solution through serial dilution.

Chlorine demand

- 200 ppm chlorine water solution

  5000 ppm stock solution of chlorine water was diluted to 200 ppm solution by dilution method.
- 0.015M $Na_2S_2O_3$ solution

  1.248 g of $Na_2S_2O_3$was dissolved in distilled water (pH 6.8) in a volumetric flask (500 ml) and volume was made up to the mark by adding distilled water. Further this solution was diluted to 0.015M solution by dilution method.
- 1M $K_2Cr_2O_7$ Solution

  Firstly, 100 ml 1M $K_2Cr_2O_7$ solution was prepared by taking 4.90 g $K_2Cr_2O_7$ in volumetric flask and volume was made up to mark by adding distilled water then 0.01M solution of $K_2Cr_2O_7$ was prepared by dilution method.
- 25% and 10% KI solution

  25% and 10% of KI solution were prepared by taking 25 g and 10 g KI in different 100ml volumetric flask.
- Starch solution

  1 g starch was dissolved in 100 ml water and boil for 15 minutes.

Ammonia

- **Phenol solution (10%):** 10 mL liquefied phenol was mixed with 90 ml ethyl alcohol.
- **Sodium nitroprusside (0.05%):** 0.5 g sodium nitroprusside dissolved in 100 mL ammonia free water and stored in amber bottle.
- **Alkaline citrate solution:** Dissolved 20 g of tri-sodium citrate and 1 g of sodium hydroxide in 100mL volumetric flask with ammonia free water.
- **Sodium hypochlorite (4% fresh)**

  The 4% sodium hypochlorite were taken from available solution of 4% sodium hypochlorite solution.
- **Oxidizing solution**

  100 ml citrate solution was mixed with 25 ml sodium hypochlorite (4% fresh) and volume was made up to 125 ml in 250 ml volumetric flask.
- **Stock ammonia solution**

  0.855 g NH_4Cl was dissolved in 250 ml volumetric flask and diluted up to the mark with distilled water.

Phosphate

- **Preparation of stock solution:** 2.194 g of anhydrous potassium di- hydrogen phosphate was dissolved in deionized water and marked up the volume to 500 ML. 10 mL of this solution and distilled water was added to make 1L of stock solution containing 1 mg P/L. standard phosphorus solutions of various strengths from 0.0 to 1 mg P/L at intervals of 0.1 mg P/L were made by diluting the stock solution with distilled water.
- **1 N NaOH:** 10 g NaOH was dissolved in 250 mL volumetric flask with distilled water and volume was marked.
- **1% phenolphthalein indicator:** 1 g phenolphthalein powder was added to 50 ml of 95 % ethanol and stirred well.
- **Reagent A:** 1.0 g of ammonium molybadate and 0.02 g of potassium antimony tartrate were taken in 100 mL volumetric flask. 16 mL of concentrated sulfuric acid was added slowly and diluted with distilled water up to the mark.
- **Reagent B**: 0.88 g of ascorbic acid was dissolve in 1 L of reagent A.

Sulfate

- **Buffer Solution A:** 30 g magnesium chloride ($MgCl_2.6H_2O$), 5 g sodium acetate ($CH_3COONa.3H_2O$), 1.0 g potassium nitrate (KNO_3), and 20 mL acetic acid (CH_3COOH; 99%) were dissolved in 500 mL distilled water and volume marked up to 1L.
- **Buffer Solution B (required when the sample SO_4^{2-}<10 mg/L):** Dissolve 30g magnesium chloride, 5 g sodium acetate, 0.111 g sodium sulfate, and 20 mL acetic acid (99%) in 500 mL distilled water and make up to 1L.
- **Dry Barium Chloride ($BaCl_2$) crystals**
- **Stock Sulfate Solution:** 0.1479 g of anhydrous sodium sulfate was dissolved in distilled water to make the volume 1 L. This solution contains 100 mg sulfate/L (i.e., 1 mL=100µg SO4 $^{2-}$). Prepared standards of various strengths (preferably from 0.0 to 40.0mg/L at the intervals of 5 mg/L by diluting this stock solution). Above 40mg/L accuracy decreases and $BaSO_4$ suspension lose stability.

CHAPTER 3

RESULT AND DISCUSSION

The water quality of Bagmati river was characterized and influence of tributaries on Bagmati river was determine by collecting data from different sites along Bagmati river & its tributaries in Kathmandu valley. The different sites were chosen as accordance to their regional importance and considering the range of data collection making the distances variations along Bagmati river.

3.1 Spatial variation of water quality parameters along the Bagmati river

The spatial variation of the physiochemical parameters of water was carried out by sampling water from 14 different locations as in Table 3.1 The data of physiochemical parameters were logged in every 6 second. The data was collected on different day and time in winter season. The average and standard deviation of all the measured parameters were tabulated in Table 3.2.

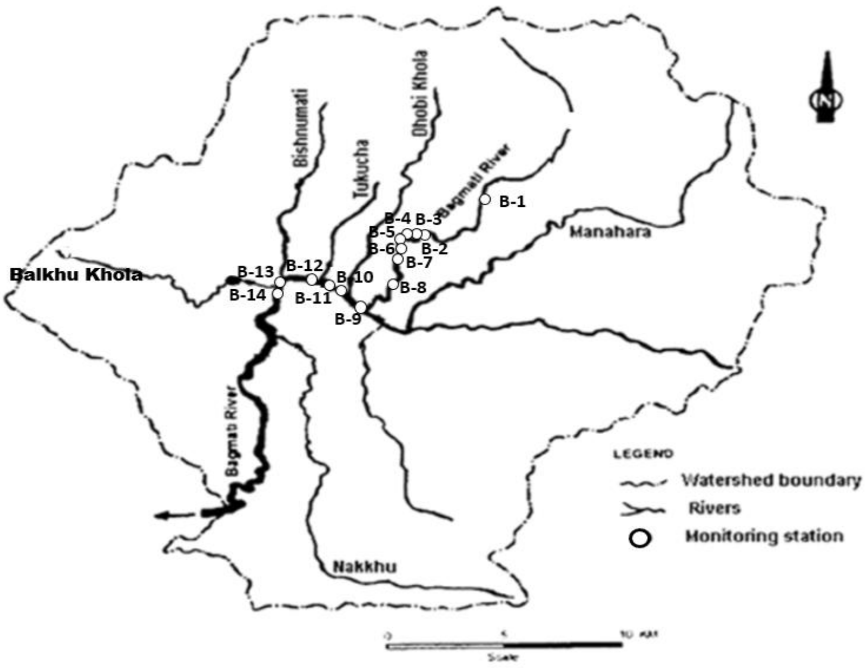


Figure 3.1: Outline of Bagmati river and location of sampling sites

Table 3.1: Water quality data monitoring stations along the Bagmati river.

Sample name	Observation site
B-1	Gokarna
B-2	Upstream of Guheshwori Wastewater Treatment Plant
B-3	Downstream of Guheshwori Wastewater Treatment Plant
B-4	Guheshwori Temple
B-5	Gaurighat
B-6	Pashupatinath Temple (Aryaghat)
B-7	Tilganga
B-8	Tinkune
B-9	Shankhamul
B-10	Dhobikhola
B-11	Thapathali
B-12	Tukuchakhola
B-13	Bishnumatikhola
B-14	Balkhukhola

Table 3.2: Water quality parameters along Bagmati river at 14 Observation sites.

Sample number	Temp. [°C]	pH	Conduct. [μS/cm]	ORP [mV]	TDS [ppm]	Salinity [PSU]	DO [ppm]	Turb. [FNU]
B-1	12.76 ±0.24	7.06 ±0.6	133.83 ±1.29	68.32 ±15.62	67.02 ±0.7	0.06 ±0.005	7.22 ±0.58	51.18 ±10.63
B-2	10.73 ±0.64	6.96 ±0.07	193.59 ±14.92	40.64 ±18.92	96.77 ±7.46	0.09 ±0.01	7.04 ±0.59	814.53 ±201.21
B-3	9.34 ±0.02	7.02 ±0.02	163.2 ±1.13	73.08 ±6.3	81.6 ±0.54	0.08 ±0.0005	6.92 ±0.23	596.56 ±56.11
B-4	13.06 ±0.03	7.09 ±0.07	204.55 ±0.8	77.43 ±1.22	102.35 ±0.5	0.1 ±0.0004	6.79 ±0.11	424.39 ±27.64
B-5	13.07 ±0.15	7.01 ±0.05	227.92 ±10.76	76.31 ±8.82	113.93 ±5.41	0.11 ±0.0053	6.83 ±0.64	355.42 ±44.242

Sample number	Temp. [°C]	pH	Conduct. [µS/cm]	ORP [mV]	TDS [ppm]	Salinity [PSU]	DO [ppm]	Turb. [FNU]
B-6	11.77 ±0.9	7.2 ±0.03	485.28 ±2.86	25.8 ±6.38	242.61 ±1.41	0.24 ±0.0014	7.92 ±0.38	
B-7	12.31 ±0.05	7.17 ±0.02	470.09 ±44.96	-30.95 ±8.61	235.09 ±22.47	0.23 ±0.0224	1.07 ±0.53	412.32 ±236.02
B-8	15.38 ±0.07	7.3 ±0.01	870.92 ±9.11	-47.48 ±2.54	435.49 ±4.57	0.43 ±0.0	0.36 ±0.01	674.26 ±79.86
B-9	15.2 ±0.12	7.33 ±0.01	708.44 ±23.62	-24.4 ±2.19	354.24 ±11.84	0.35 ±0.01	3.12 ±0.77	741.06 ±117.62
B-10	14.39 ±0.04	7.41 ±0.01	859.56 ±19.34	-76.24 ±4.97	429.74 ±9.65	0.43 ±0.01	0.75 ±0.27	652.11 ±22.01
B-11	14.95 ±0.08	7.40 ±0.01	728.06 ±24.14	-114.4 ±21.55	364.04 ±12.08	0.36 ±0.01	0.49 ±0.25	538.87 ±64.67
B-12	14.78 ±0.06	7.41 ±0.01	862.4 ±7.41	-64.27 ±5.30	431.12 ±3.56	0.43 ±0.0	5.52 ±0.33	501.00 ±18.99
B-13	14.57 ±0.04	7.50 ±0.01	917.39 ±14.09	-45.70 ±6.81	458.75 ±7.06	0.46 ±0.01	0.39 ±0.13	574.19 ±21.60
B-14	13.78 ±0.12	7.56 ±.0.01	927.72 ±3.71	-71.93 ±16.23	463.84 ±1.89	0.46 ±0.0	6.38 ±0.43	366.07 ±18.89

3.1.1 Temperature

Temperature plays a vital role on chemistry and biological reactions in water. The water temperature is a physical property expressing how hot or cold water is, whether from the air, sunlight, another water sources or thermal pollution. A small increase in temperature may lead to the fluctuation in chemical or biological reactions in water, change the taste and odor, and reduces the solubility of gases. Water temperature affect nearly every other water quality parameter, and is an important factor to consider when assessing water (Trivedi, et a., 1986).

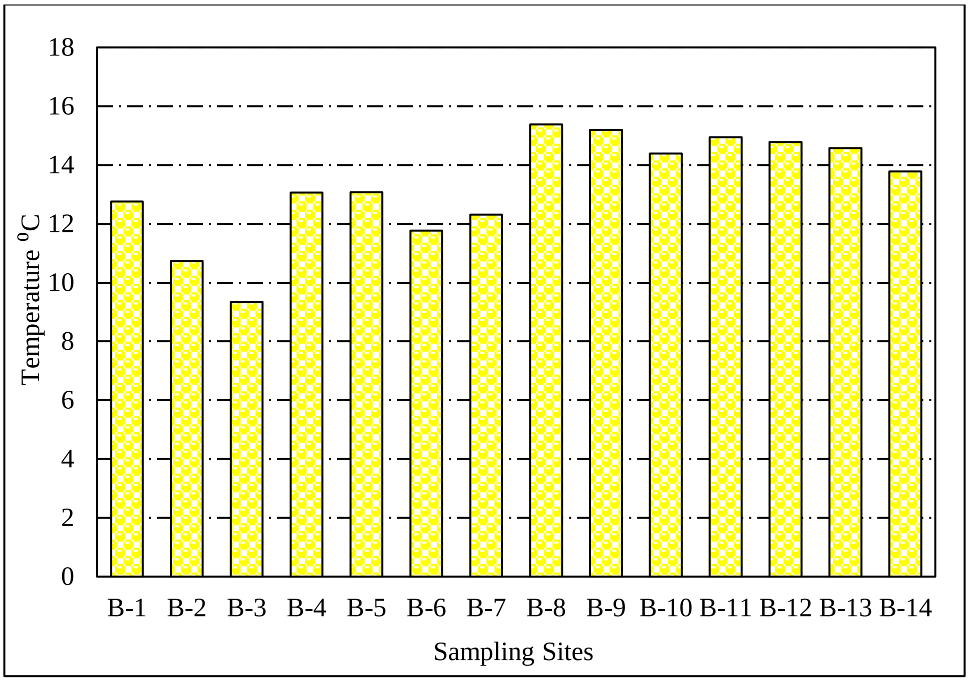


Figure 3.2: Spatial variation of temperature along the Bagmati river from Gokarna to Balkhu site.

The observed temperature varied from 9.0-15.5 ^{0}C as shown in Figure 3.2. Thus, variation in temperature was due to of weather during observation day time not by the thermal pollutants, and hence effect of temperature on water quality was in significant. The temperature of B-3 sample was low because of the rainy day nevertheless the overall sampling temperature seems to be similar at all station of sampling. The temperature variation, illustrate that slightly changing proportion rate of pollution by organic dirts. B-8 site (15.38^{o}C), having high temperature showing that there is possibility of downgrading of other physical and chemical parameters. The linear downgrading of temperature at, B-11 (14.95^{o}C to B-14 (13.78^{o}C) was monitored by effect of tributaries water temperature as well as atmospheric temperature. The increase in temperature from B-6 (11.77^{o}C) to B-9 (15.2^{o}C) indicates that the heavy load of ionic wastes which leads to much more decompositions of organic and inorganic wastes.

3.1.2 pH

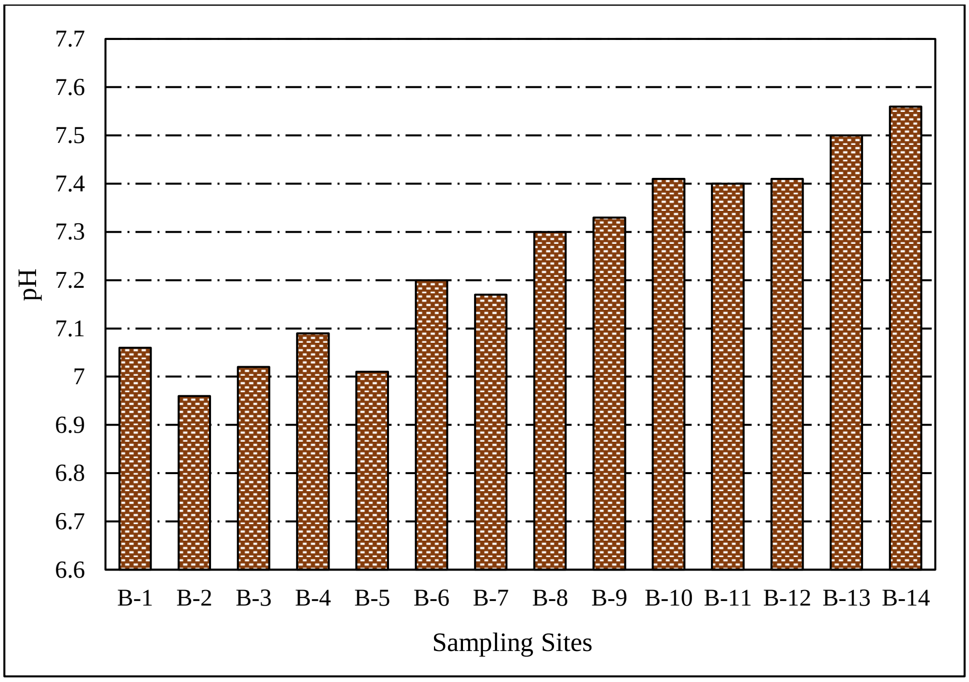


Figure 3.3: Spatial variation of pH of Bagmati river from Gokarna to Balkhu.

The pH is an important parameter of water and frequently used to test water's chemistry. The pH is the physical constituents of water that measures the acidic or alkaline property of water. The pH of all over the examine sample were found normal in all sampling stations. As shown in Figure 3.3, the pH value at B-1 site (7.06) was neutral, at B-2 site the pH decreased to 6.96, and but almost same at all sampling stations till B-5 (7.01). From B-6 site (7.2) the pH value increased, due to mixing of municipal drainage at Tilganga area and almost the pH raised linearly to B-14 site (7.56) as shown in Figure 3.3. The linear increasing in the pH value from site B-5 (7.02) to B-8 (7.3) may be due to unmanaged waste dumping side on the bank of river, the drainage from house, municipal and hospital wastes, mismanaged of slum activity around the area of Tilganga to Tinkunya and becoming more alkaline toward the downstream at Sinamangal. The pH linearly increased from B-9 (7.33) site to B-14 (7.56), there might be loading of organic wastes and waste water from the tributaries, slum area at Thapathali, unmanaged dumping of municipal wastes, wastes from market. The higher load of alkaline salt of bicarbonate and carbonates from high residential area and waste water through drainage (KC et al., 2018).

3.1.3 ORP (Oxidation-Reduction Potential)

It is the measurement of water to oxidized or reduced the other components and promotes biological reactions in water. The study suggested that disinfection is the real chlorine performance [Frederick, 2003].

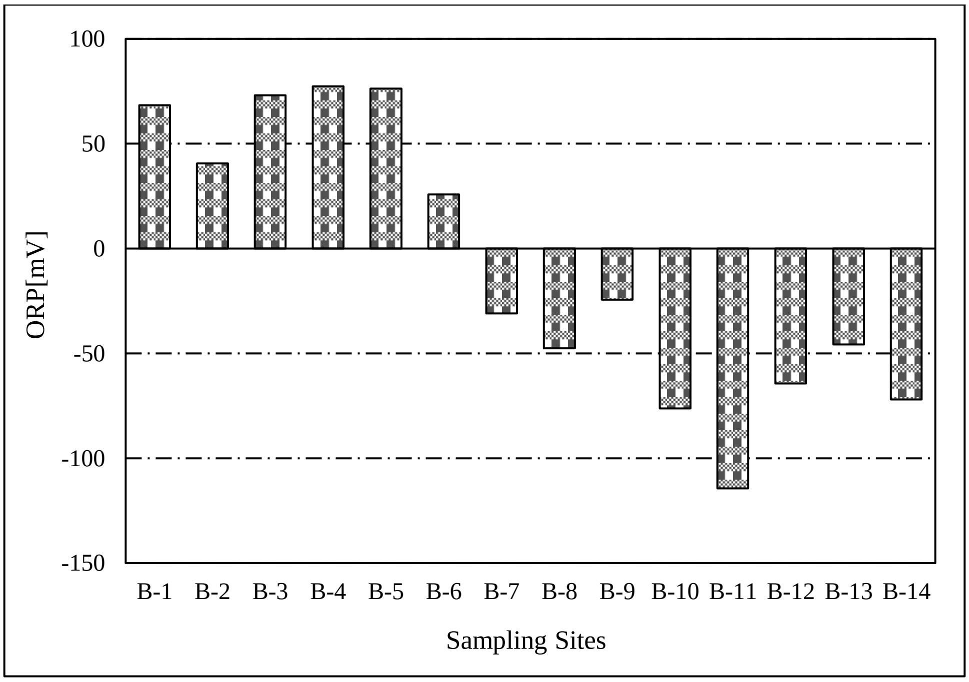


Figure 3.4: Spatial variation of ORP along Bagmati river from Gokarna to Balkhu.

Matters from health perspective, amount of chlorine is not necessarily as important as its effectiveness. Thus, ORP is the critical water quality parameter which measures the water disinfection potential, and used in wastewater treatment plants [Suslow, 2004; Goncharuk et al., 2010]. Higher the value of oxidizing agent (generally oxygen) increase the ORP value and decrease its value when reducing agents (carbon and hydrogen containing compounds) are presence. The value range from +50 to +250 mV of ORP, was suitable for degradation of organic compounds with free oxygen and nitrification process. The range of ORP value from -50 to +50 mV is suitable for denitrification process and the range of value from -50 to -250 mV, suitable for biological phosphorus release and sulfide formation. The oxidation-reduction of Bagmati river was quite good at the upstream before B-6 site, the value ranged from+25.8 to +77.43 mV. The, B-1 site (Gokarna) have ORP value +68.32 mV which indicates the less pollution rate and available excess free oxygen in water which is quite good for aquatic ecosystem. At the B-2 sampling site before the water treatment plant it decreased to +40.63, indicating the slightly contamination by some reducing substance by various sources: wastes from temple area, municipal wastes, agriculture bi products and fertilizer, discharges from houses and hospitals, wastes from industry, overall decrease the ORP value. Later on treating the solid as well as the liquid wastes in water treatment plant, again the value of ORP raised from B-3 (73.08 mV) to B-5 (76.31 mV) sampling stations. On mixing the drain waste below the Aaryaghat, wastes from hospital as well as the slum area contributes the organic as well as inorganic solid and liquid wastes and decreased ORP value to -47.48 mV at B-8 site (Tinkune). The ORP almost decreased from B-9 site (-24.4 mV) to B-11site (-114.84 mV) the sulfide formation was more pronounced so the odor of river water was malodorous. The heavy load of organic solid and wastewater mixed from the tributary Dhobikhola, the slum area at Thapathali, dumping of municipal wastes contributes reducing compounds resulting more polluted water.

3.1.4 Conductivity

Electrical conductivity or simply conductivity of water is a measure of the ability of an aqueous solution to carry electric current, due to dissolved salt in water. The conductivity was less than 227.92 µS/cm till B-5 and increased almost linearly from B-6 (485.28 µS/cm) to B-9 sites (708.44 µS/cm) shown in Figure 3.5. The observed conductivity shows that upper side of river had less effluence of domestic and industrial discharges, later linear increased in conductivity indicates enhancing the dissolves substances on river due to municipal wastes from the residential area and manufacturing corridor on the bank of river. The conductivity increased linearly as the domestic and industrial discharges increased from B-9 to B-14 sites (927.72±3.71 µS/cm) almost in excessive way (Figure 3.5). This shows the continuous increments of organic and inorganic solid and liquid wastes from slum activities, sewages, drains, hospitals, markets and so on and hence increased the salt concentration along the river towards the down basin river water.

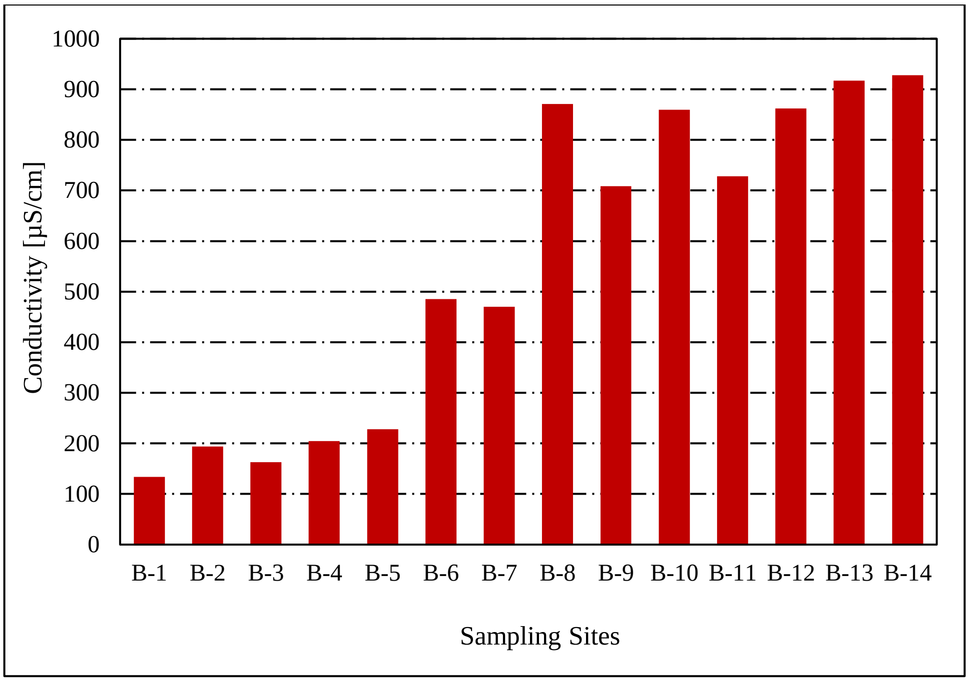


Figure 3.5: Conductivity measurement along Bagmati river from Gokarna to Balkhu.

3.1.5 Turbidity

The turbidity of water is due to presence of clay, silica, microscopic organism, organic and inorganic material from rock, waste material from building the infrastructure, agricultural site, the solid as well as liquid wastes from slum area, the untreated wastes from market etc. The turbidity was the measure of cloudiness of water unclear because of mixing of other waste materials in water. The turbidity measurement along the Bagmati river was ascertain by using the multi parameter sensor. Different station of sampling was examined in which the turbidity ranges from 51.22 FNU to more than 300 FNU all over the examined site.

The sampling site B-1 (51.18 FNU) seem to be consisted of less effluent, industrial wastes and the other contaminants. The drastically change in turbidity was examined at B-2 site (814.53 FNU) there might the pollution through municipal wastes and developing the Bagmati corridor infrastructure, muddy water was the cause of high turbidity. Again, there was highly changed in turbidity at B-3 (596.56 FNU) to B-5 site (355.42 FNU), due to treatment of water. The turbidity almost increased from B-7 (412.32 FNU) to B-9 site (741.06 FNU); indicating that the squatter settlement, mixing the waste water through the drainage downside of Aryaghat, developing corridor, huge pollution through municipality, accumulation of clay and dirty soil, increases the turbidity in Bagmati river. And decreased at each sampling site from B-10 (652.11 FNU) to B-14 site (366.07 FNU) but slightly increased at B-13 site (574.19 FNU) as shown in Figure 3.6, because of the effect of tributary Bishnumati was more pronounced as well as the local pollution from the dumping sites and slum activities are the major sources of dissolved matter in water (solid as well as liquid wastes). The turbidity almost decreased from B-9 (741.06 FNU) to B-14 sampling site because of settlement of dissolved salt & organic compounds as well as soil particles on the surface of river containing the decomposed organic matter.

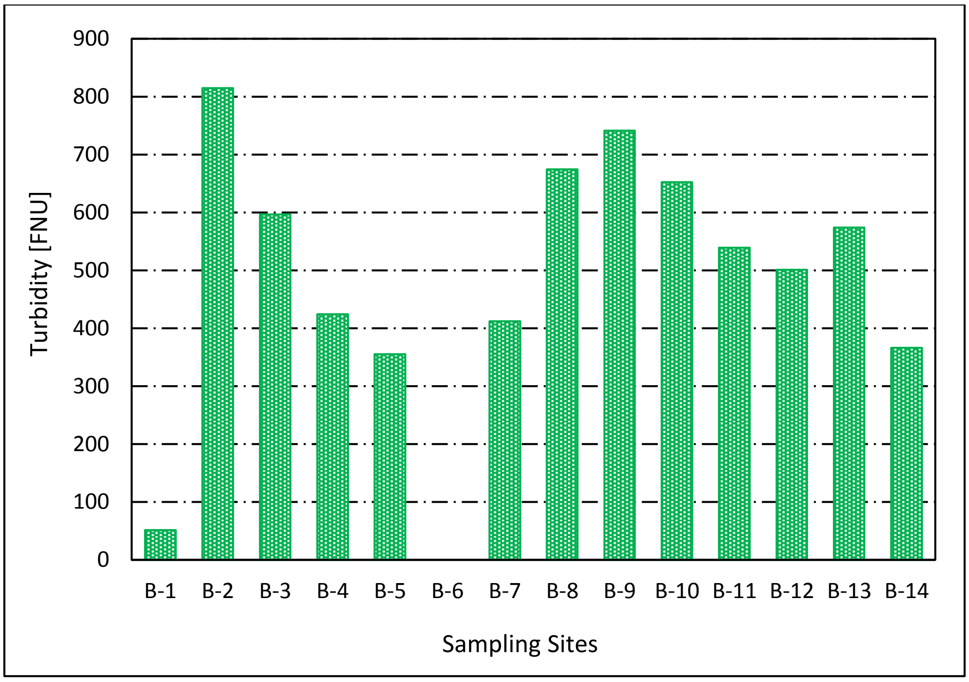


Figure 3.6: The turbidity measurement along Bagmati river (Gokarna to Bakhu).

3.1.6 DO (Dissolved Oxygen)

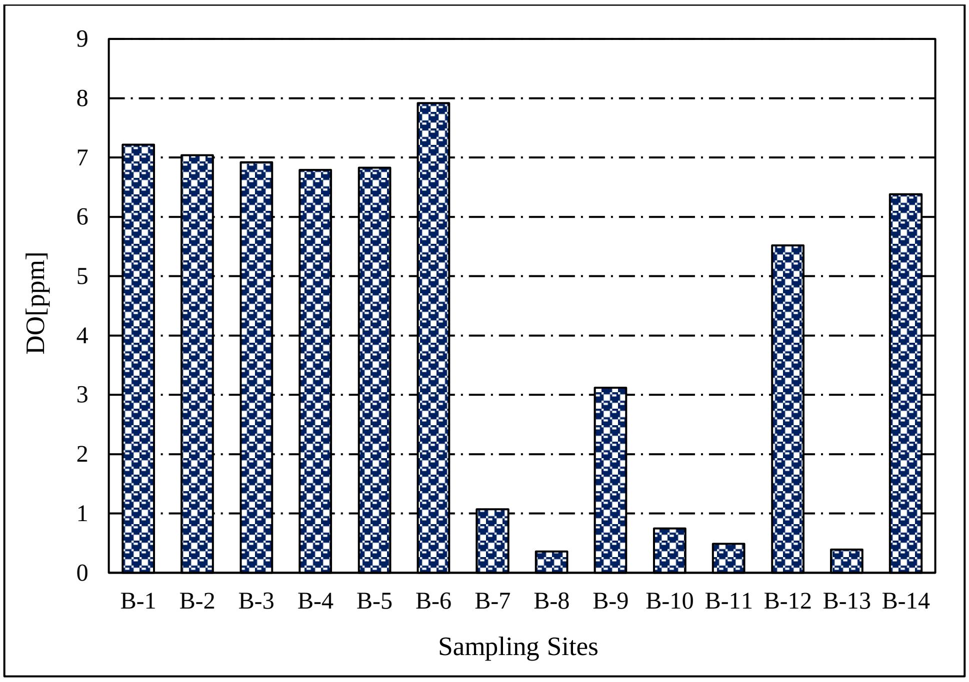


Figure 3.7: Variation in DO along the Bagmati river (Gokarna to Balkhu).

Oxygen is one of the most important factors in any living ecosystem. Its presence is vital to sustaining the higher form of biological life in water (Trivedi, et al., 1986). The main sources of DO are atmosphere, and photosynthesis by aquatic plants and oxygen producer organisms. The level of oxygen in water depends upon surface area exposed, physical, biological, and biochemical activities. Decay of organic matters in water caused by either chemical process or microbial action on untreated sewages or dead vegetation can severely reduce dissolved oxygen. Dissolved oxygen was the important factor in determining of water quality. As DO drops below 4-5 ppm, the life form in aquatic ecosystem gets affected. The upstream of Bagmati (from B-1 to B-6) was within the range of acceptable limits (4-8 ppm), indicating that there was less amount of organic substances in the river water which consumes less amount of molecular oxygen. Whereas towards the downstream from Tilganga (B-7 site, 1.07 ppm) to Bishnumati (B-13 site, 0.39 ppm) were heavily polluted, the microbial decomposition of organic material utilized the molecular oxygen which drastically decrease DO in water, [Okeke, et al., 2013]. This shows that the DO continuously decreased towards the downstream basin of Bagmati river. Bagmati river was heavily polluted by inner city area of high residential area inside ring road. Each of the tributaries were extremely polluted, the outlets of household, drainages, municipal sewages, industrial solid as well as liquid wastes causes the de-oxidation of water and hence did not eco-friendly for aquatic phenomenon. Increased in DO concentration was observed at B-9 site (3.12 ppm), B-12 site (5.52 ppm) & B-14 site (6.38 ppm) as shown in Figure 3.7. The tributary Monahara (6.42 ppm) increased the DO concentration at B-9 site, but tributary Tukucha (B-12 site) and Balkhukhola (B-14 site) shows that the tributaries were less pollutant from organic wastes or the photosynthesis process during the day time enhance the oxygen content in water or self-purification increased the DO concentration.

3.1.7 Salinity

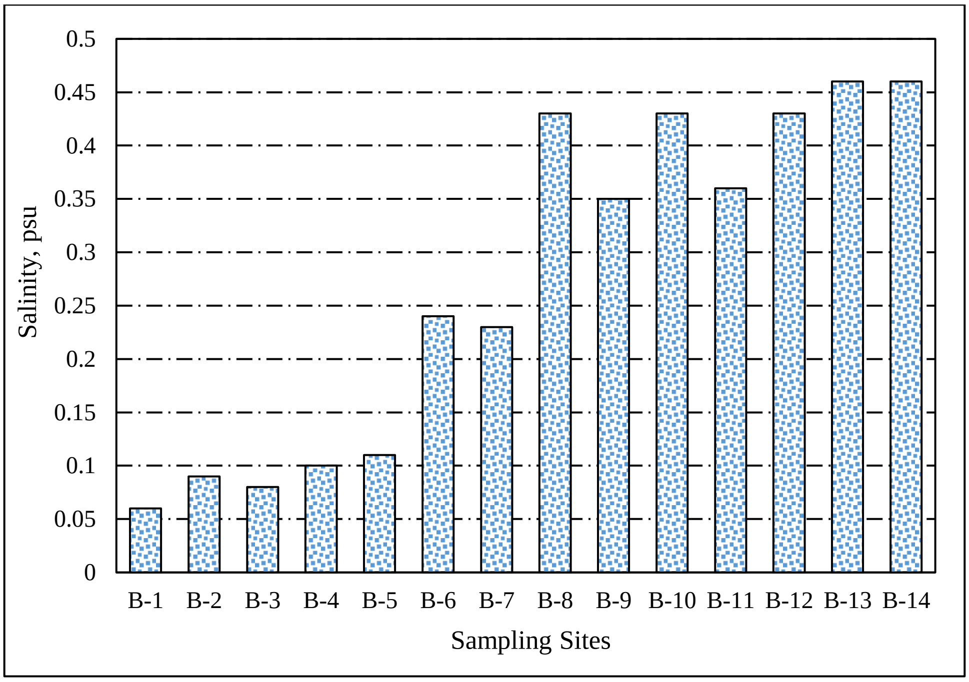


Figure 3.8: The Salinity variation along Bagmati river (Gokarna to Balkhu).

The salinity, refers to the concentrations of salts in water or soils. Small amounts of dissolved salts in natural waters are vital for the life of aquatic plants and animals. However, high levels of salinity and acidity are harmful to aquatic plants and organisms. The salts are the sources that enhancing generally the chloride compositions in water, generally sodium chloride, or it may from the rock minerals. The dirt from the industrial and the untreated municipal wastes, waste products from industrial sectors are some sources for contributing the salt composition in river water. The salinity along Bagmati river showed almost linearly increasing in concentration towards the down basin of Bagmati river, indicates the heavy load of salts composite wastes from highly urbanized residential area, and run off of the agricultural wastes, hospitals and industrial discharges etc. were responsible for contributing the higher salt containing wastes. From downward of Gokarana (B-1 site, 0.06 PSU), developing city area, domestic and industrial outlets are directly connected with stream of Bagmati river and that's contribute the higher value of salts in river water and continuously increasing salinity till B-9 site (0.35 PSU) to B-14 site (0.46 PSU) as shown in Figure 3.8. The heavy waste loads from the municipal waste products drain, sewage, kitchen wastes as well as effluents from latrine increases almost the salinity along the river till Balkhu. The tributary Dhobikhola (B-10, 0.43 PSU), Tukucha (B-12, 0.43 PSU), and Bishnumati (B-13, 0.46 PSU) contributes excess salt concentration in Bagmati river as shown in Figure 3.7.

3.1.8 Total Dissolved Solid (TDS)

Total dissolved solids are natural pollutants in the river water and it impart the color, alkalinity, and conducting nature of water. The most desirable value of TDS was 500 mg/Land the optimum value of 1000 mg/L was acceptable (NDWQS). A higher value of TDS was harmful to those who are victim of kidney and heart diseases (Al-hadithi, M 2012). The current study shows the TDS was low about 67.02±0.70 ppm at Gokarna (B-1 site) and increased almost in all stations of sampling till Aryaghat (B-6 site), enhanced drastically at B-7 site (Tilganga 242.6±1.41 ppm) and two folds increased at B-8 site (435.49 ppm) as shown in Figure 3.9. The variation in the TDS value along the individual Bagmati river before mixing with its tributary shows that the downstream of river continuously contaminated from inflow of municipal wastes and industrial discharge, anthropogenic activity across the river (Malla et. al., 2015) and the bi-products from the industries are enriched in salt concentration [McCArhey, 2008).

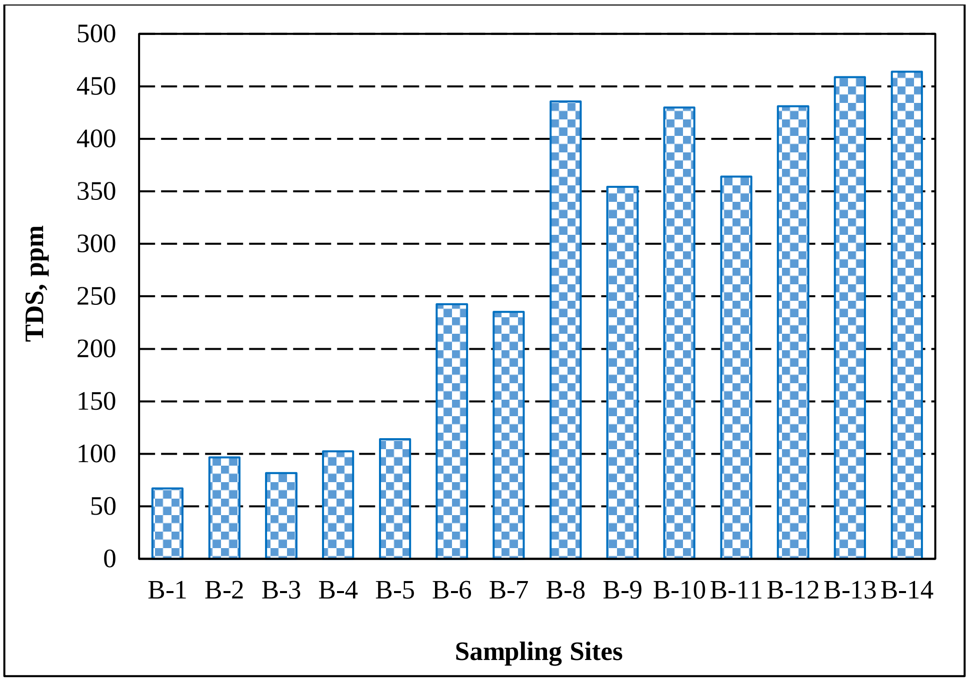


Figure 3.9: TDS measurement along Bagmati river.

The low level of TDS at B-9 (354.24 ppm) site as shown in Figure 3.9, shows that the Monahara tributary decreased the TDS then increased almost linearly till B-14 site (463.84 ppm). Each of the tributaries contributes the excess dissolved solid in Bagmati river.

3.2 Temporal variation of water quality parameter at Bagmati river

The diurnal variation in the Bagmati river was done with the interest of the micro state change in the pollution rate in the river. The study was conducted at the winter season of December 2019, because of the dry season the water in the Bagmati river seem to consist much pollutants. The water quality in the Bagmati river were deteriorated from several decades, as per head capita the ratio of pollution is increasing linearly from year to year (Kannel, 2007). The human activities: along the river side making the dumping area, using the river water as the source of daily use (for bathing, washing, etc.) upward the city area are also the cause of pollution. Many anthropogenic activities like disposal of industrial and domestic wastes, agriculture, construction of roads and buildings, deforestation were some factors of pollution in river water (Gibbs, et al., 1967; Gaillardet, et al., 1999; Zhang, et al., 1999; Vorosmatry, et al., 2010). Moreover, Bagmati river and its tributaries extremely used as the dumping sites for solid wastes, outlets for domestic sewages, and industrial and agricultural effluents, slum dwellers without any restrictions from government, due to demand of new road channel, uncontrolled and mismanaged growth of urban population are affecting the riverine ecology.

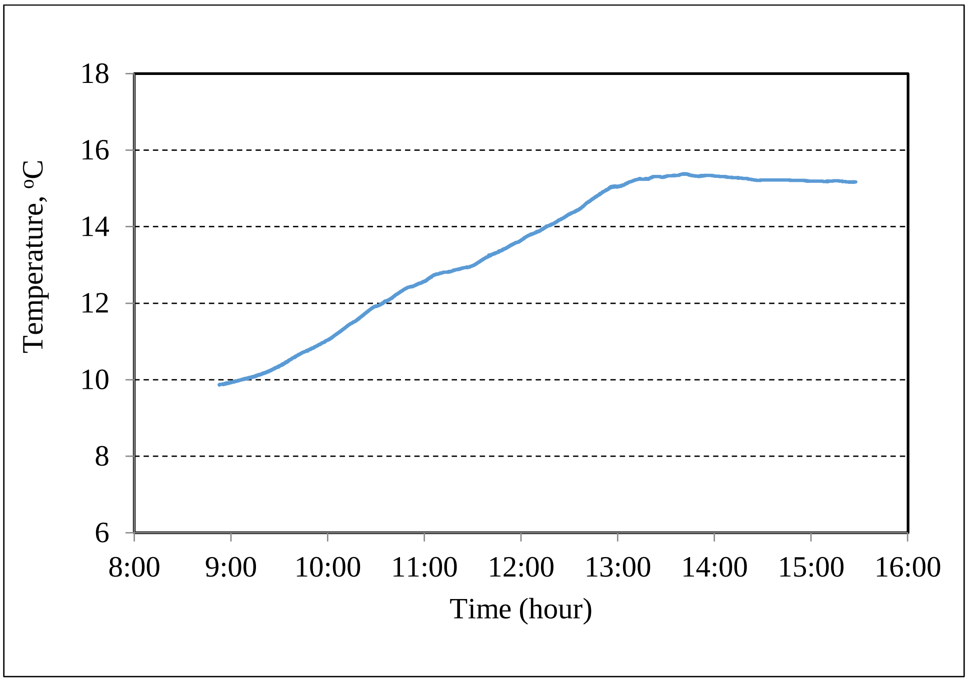


Figure 3.10: The temporal variation in water temperature at Sankhamul site.

The temperature variation with the time shows the distinct variation in water temperature. The water temperature could be affected by sunlight or solar energy, from atmospheric temperature and turbidity in water. At the starting time the thermal heat from sunlight was weak or the atmospheric temperature is too low, the heat transform from water to its surrounding, makes the water temperature low around 10^0C at 9 am. Later on with time the thermal temperature from sun and the atmospheric temperature begin raised up with increasing the turbidity (the suspended solid absorb heat from solar radiation, then transferred from the particle to surrounding water molecule, and increases surrounding water temperature) in water and the temperature of water increased linearly till 15^0C at 13:00 to 14:00 P.M as shown in Figure 3.10. And almost same till the atmospheric temperature remains same. Here the variation in water temperature was more pronounced accordingly with the time during winter season.

The water quality parameter of pH and conductivity shows the linear relationship with variation in time. At initial phase the pH was 7.38 and conductivity 614 µS/cm at 9:00 am as shown in Figure 3.11, which increased linearly to 7.6 and 850 µS/cm at 10:00 am, and remained almost constant from 11:00 am to 14 pm and decreased again slowly with time. The high value of pH and conductivity shows that the water is almost have alkaline toward the downstream from Sinamangal, because of high bicarbonate production from inner city area and high organic inputs from household. Hence, the variation in the value range of pH and conductivity in day time was considered as due to the effect of human activities i.e., the discharge of domestic and industrial effluents into the water.

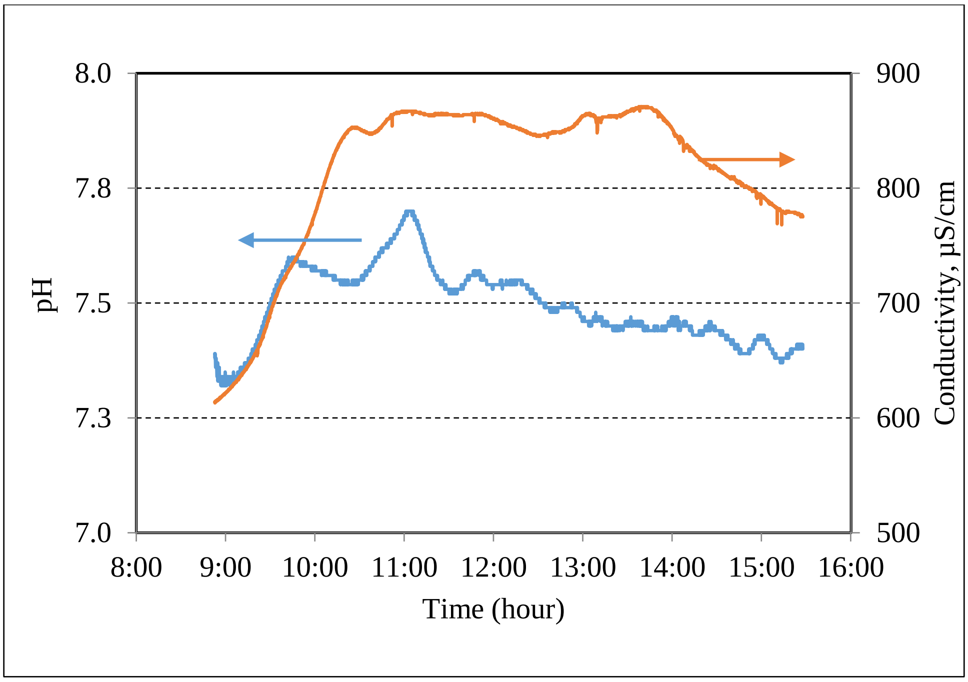


Figure 3.11: The temporal variation in pH and conductivity at Sankhamul.

The effluents from the latrine, the slum activities at the Sinamangal, direct mixing of sewages into river, drainage, the outlets drains are the major causes of variation in pH and conductivity along the day time.

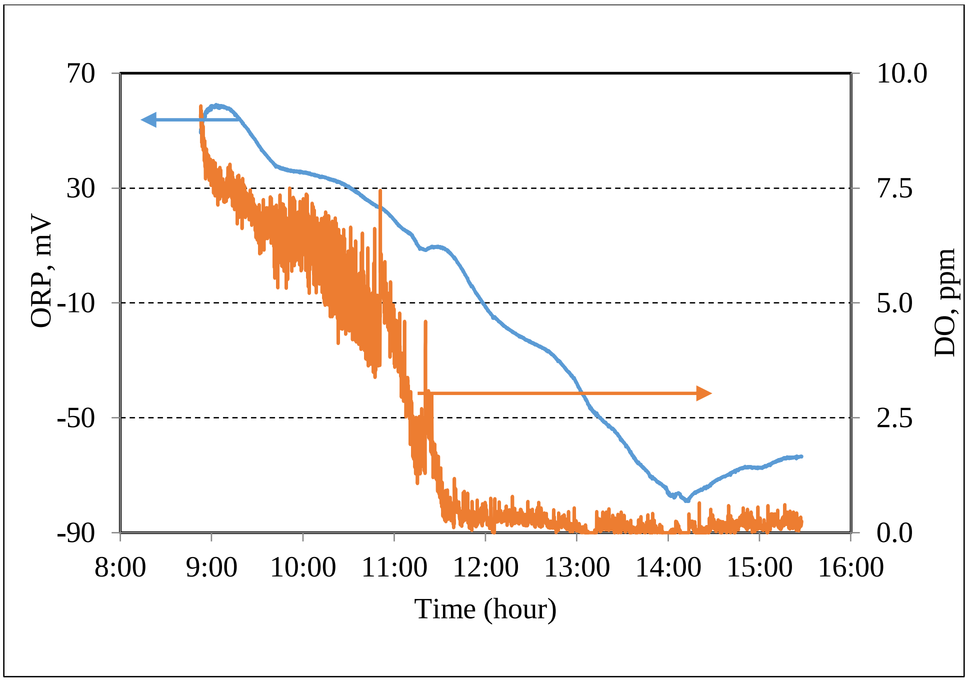


Figure 3.12: Diurnal variation of water quality parameters, ORP and DO at Shankhamul site.

The variation in DO and ORP was distinct the concentration of both parameters were higher at morning time, at 9 am. The DO had concentration of about 8 ppm, which indicating the cleanness of water, however with time it decreases continuously and almost to 0 ppm at 11:30 am as shown in Figure 3.12. This was the indication of presence of anaerobic microorganism which used the molecular oxygen of water to decompose the organic matter and produced sulfide, nitride etc. as bi products. The molecular oxygen or oxygen gas in water produced by the photosynthesis of aquatic plant and algae (Martinez-Tavera, 2017). The river detonated by heavy chemical wastes, the decomposition of contaminated soil that's the reason there was no chances to grow the phytogenic plants to increase DO concentration. Also the ORP at initial phase had a positive value 50 mV and decreased linearly with the time and is nearly -80 mV at 14:00 pm (Figure 3.12). Both the results of DO and ORP shows that with time the reducing component in the river was attribute in high ratio this may be due to the presence of oxygen reducing microorganism inside the soil, clay or high surface pollution inside river water. The high ORP value indicates, presence of an oxidizing agents, and low ORP value indicating the presence of reducing agents like; nitrites, ammonia, sulfides, organic substances capable to reduce (Goncharuk et al., 2010). The result shows that at day time anoxic condition formed, the fermentative bacteria forms large variety of volatile acids of nitrogen and sulfur containing compounds, by converting the nitrogen and sulfur containing organic compounds to acid, (AliAL-Samawi, 2016). From the result, the human activities are countered as the major sources to decrease DO concentration drastically by producing the volatile compounds at day time in Bagmati river.

3.3 Water quality parameter of Bagmati river and its tributaries

3.3.1 The physiochemical properties

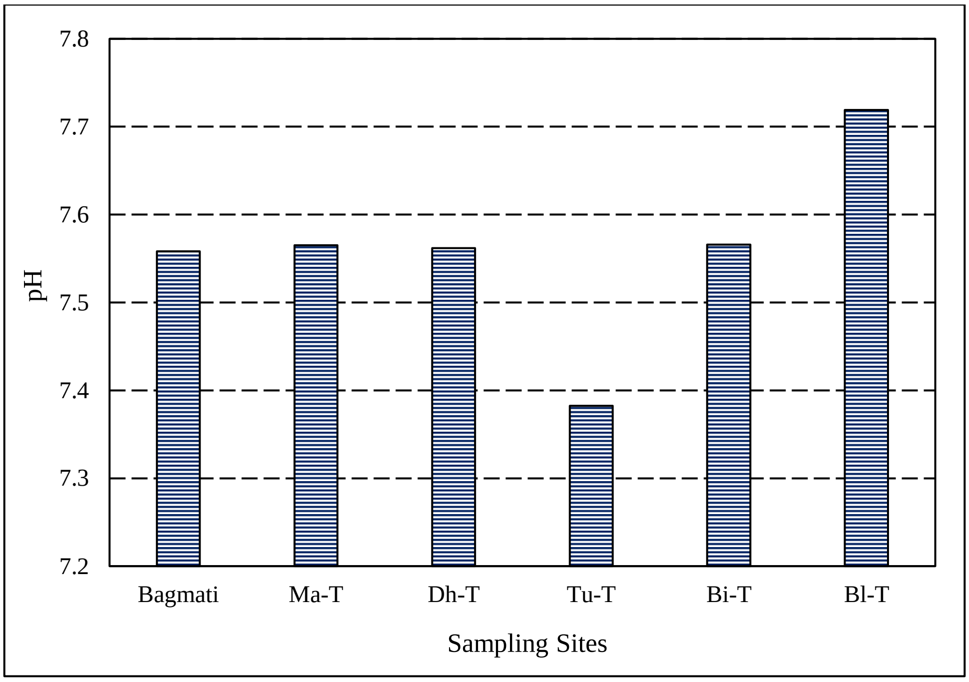
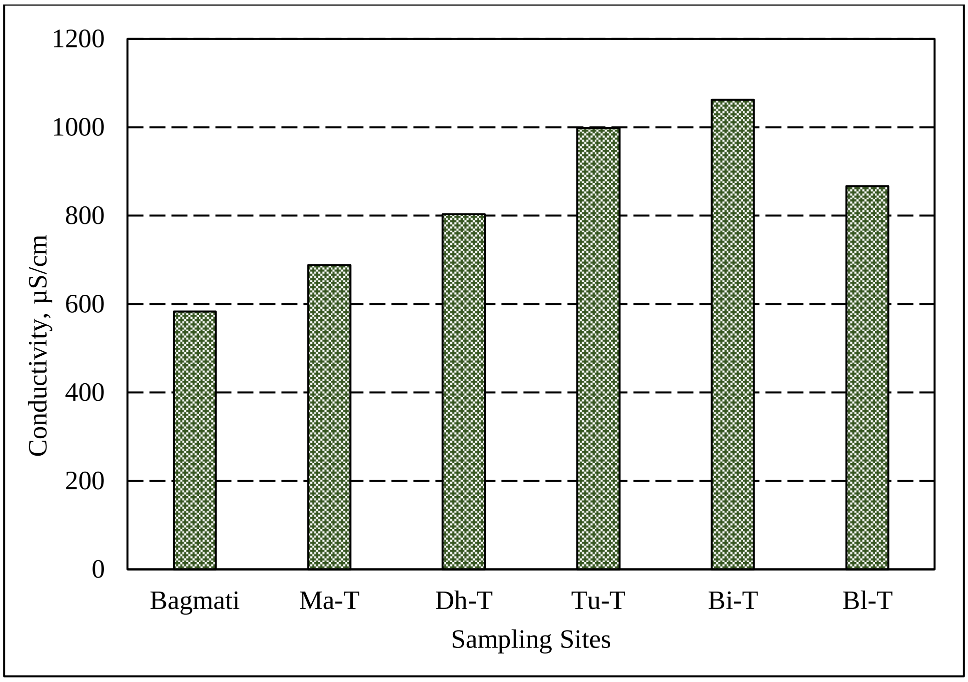


Figure 3.13: The pH of Bagmati river water and its tributaries.

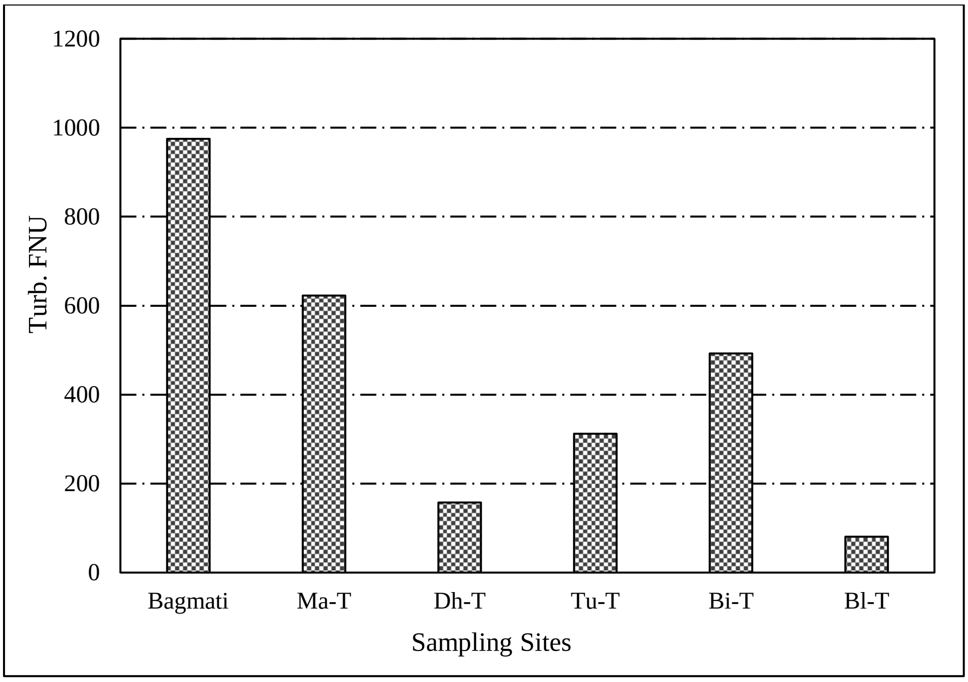
The pH is the important parameter of water, which represents the ionic constituents in water. The pH of Bagmati- 7.55, Monahara- 7.56, Dhobikhola- 7.56, Tukucha- 7.38, Bishnumati- 7.56 and Balkhukhola- 7.71 was observed. This shows that water of Bagmati and its tributaries river were alkaline in nature. The higher pH value of Balkhukhola indicates the higher contribution of weak bases of carbonate or bicarbonate salts as compared to other tributaries as shown in Figure 3.13.

The electrical conductivity attributes the amount of dissolved salts presence in water like carbonates and bicarbonates from soil, ammonical compounds from domestic sewages, microbial decomposition of organic matter, slum activities etc. The concentration of conductivity was linearly increased of each tributaries as Bagmati river- 583.147 µS/cm, Monahara- 688.406 µS/cm, Dhobikhola- 803 µS/cm, Tukucha-

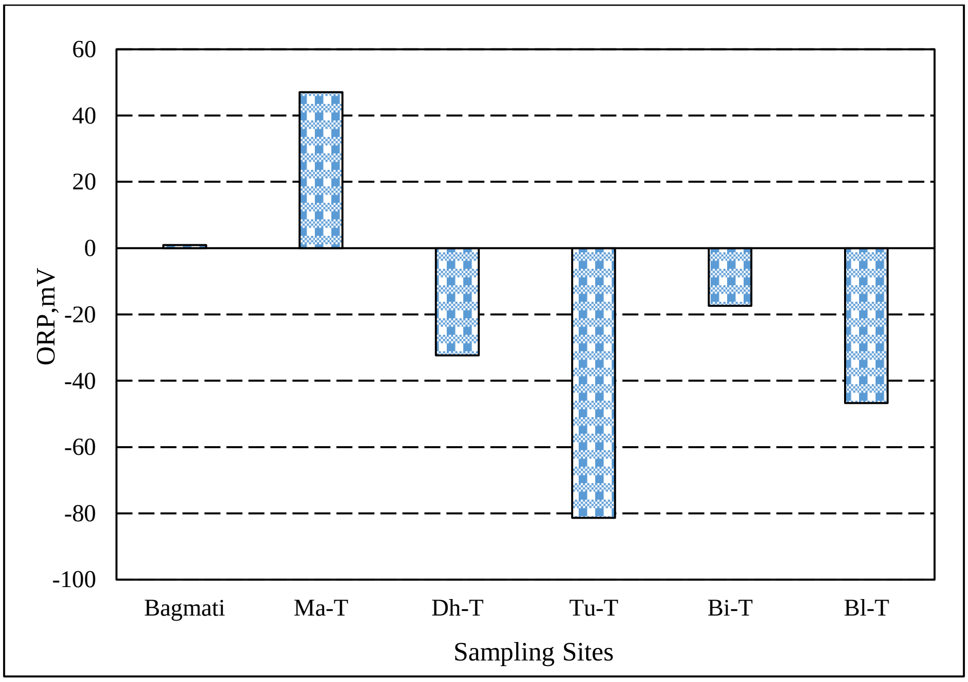
998.434 µS/cm, Bishnumati- 1061.975 µS/cm, but the Balkhukhola- 867.213 µS/cm indicates that excess pollutant from local pollution. Slightly increase in pH but sever increase in conductivity was due to presence of weak bases from carbonate and bicarbonates salts. The plotted data was shown in Figure 3.14 (a).



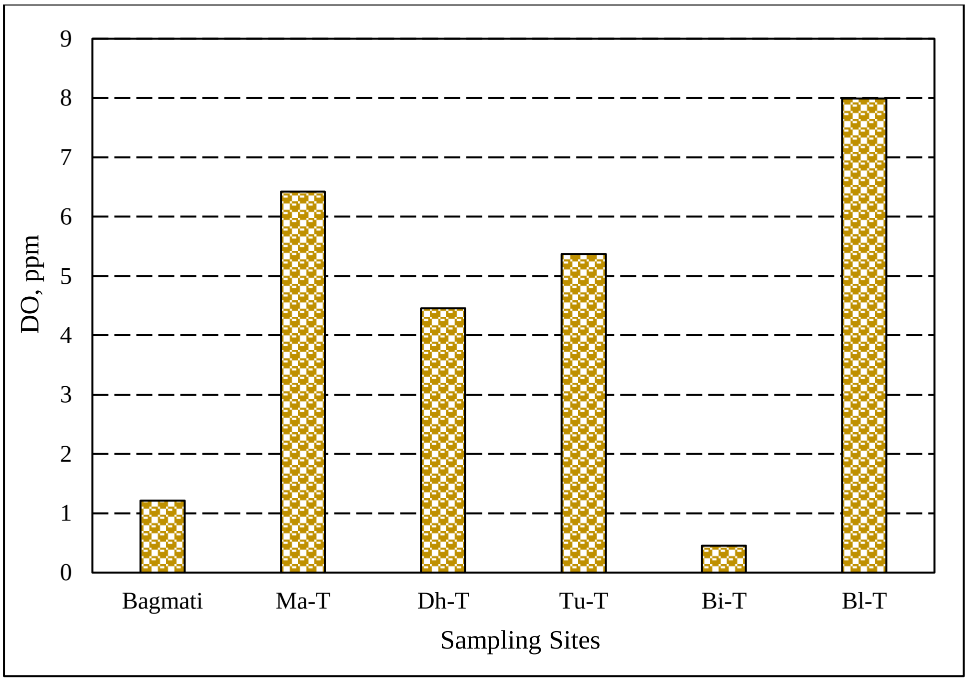
(a)


1200
1000
800
600
400
200
0
Turb. FNU
Bagmati
Ma-T
Dh-T
Tu-T
Bi-T
Bl-T
Sampling Sites

(b)


60
40
20
0
-20
-40
-60
-80
-100
ORP,mV
Bagmati
Ma-T
Dh-T
Tu-T
Bi-T
Bl-T
Sampling Sites

(c)



(d)

Figure 3.14: Water quality parameters of Bagmati river water and its tributaries (a) conductivity, (b) turbidity, (c) ORP, (d) Dissolved Oxygen.

Turbidity increases in water as the dissolved matter in water increases. The turbidity increases as the microbial decomposition of organic matter increases. The Bagmati river (975.043 FNU) show the excess turbidity in water (excess organic wastes from slum area, municipal sewages and drainage etc. decomposed by microorganism present in soil). Tributary Monahara (622.740 FNU), attributes the second rank in contributing dissolved matter in river water. The low turbidity of Dhobikhola (157.226 FNU) and Blkhukhola (80.546 FNU) was due to lack of decomposition of organic matter from microorganism in soil. Tukucha (312.425 FNU) and Bishnumati (492.463 FNU) as shown in Figure 3.14(b), had increasing value of turbidity may be due to decayed wastes from inner city area.

The ORP is the major component of water, which was directly related with the biological reaction in water. More positive the ORP value better be the water quality due to presence of oxidizing agents (mainly oxygen) and be the favorable condition for living aquatic biotas. The ORP value of Bagmati river was 0.97 mV as shown in Figure 3.14(c) this indicates that carbonaceous compounds were excessively mixed from heavy urban area and they may be high organic decomposition occurred by fermentative bacteria. The ORP of Monahara (+47.029 mV) was quite good, free molecular oxygen in water is sufficient for decomposition of organic matter indicating less pollutant by organic substrates. The excess negative value of ORP at Tukucha (-81.38 mV) shows the sulfide formation and biological phosphorus release from the wastes in water. The oxidation reduction potential of Bishnumati (-17.35 mV), Dhobikhola (-32.37 mV) and Balkhukhola (-46.71 mV) as in Figure 3.14(c), attributes the suitable condition for denitrification process in water by decomposition of organic matters.

The dissolved oxygen is the vital component of water and higher the DO value is good for aquatic biota as well as better water quality. The free molecular oxygen as consumed by microorganism to decompose the organic matter so the DO concentration was lower at Bagmati main stream (1.22 ppm) shown in Figure 3.14(d). As the ORP value, the concentration of DO was higher at Monahara tributary (6.42 ppm), which shows the cleanness of water. Dhobikhola had 4.46 ppm, Tukucha (5.37 ppm) which was quite good or in acceptable limit. Increased in DO concentration may be due to the photosynthetic process at day time. The Bishnumati had low DO concentration (0.45 ppm), the reducing compounds enhancing from inner city, dumping of organic disposable and non-disposable (solid and liquid wastes), industrial effluents and slum activities generates enormous wastes on tributary and was responsible in decreasing DO concentration. The Balkhukhola had higher DO concentration (7.99 ppm) comparing with other tributaries as shown in Figure 3.14(d). As it flows a short distance om its origin, the least load of organic wastes, household sewages, bi-products from industrial area, and no more decomposition of organic wastes by microorganism results the higher concentration of DO in tributary. Overall DO concentration was quite good accordingly as Balkhukhola, Monahara, Tukucha, Dhobikhola, Bagmati (main stream), and Bishnumati respectively.

3.3.2 Chemical parameter of river water

The result of chemical analysis was tabulated in Table 3.4.

Alkalinity

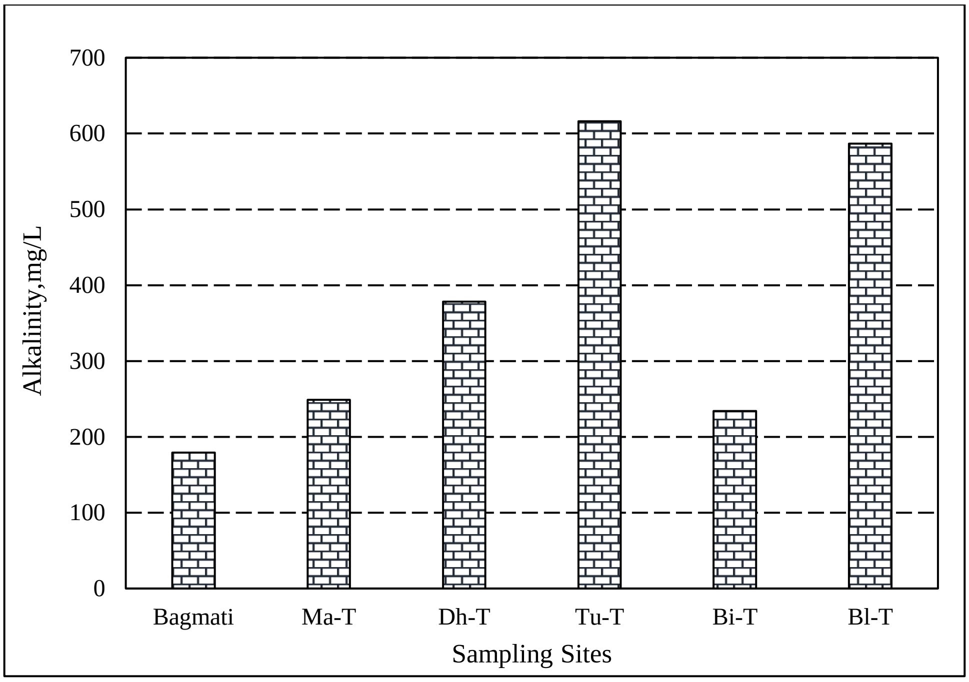


Figure 3.15: Alkalinity of Bagmati river water and its tributaries .

Alkalinity is the important parameter of water, and it measures the acid neutralizing capacity of water (APHA). It is important because it acts as the acid stabilizer for pH or with basicity of water or buffer against rapid pH changes in water and measured on pH scale. Generally, the water's alkalinity is due to presence of carbonate, bicarbonate and hydroxide of sodium, potassium, calcium and magnesium. Sometimes water's alkalinity often by presence of silicates, borates and phosphates may also contribute to the total alkalinity to small extents. The low level of alkalinity (<155ppm) was corrosive for water, and greater the value (<155ppm) contribute for scaling. The alkalinity of Bagmati river was 179.34 mg/L as shown in Figure 3.15, no more ionic salts in water almost water is loaded by organic wastes. The tributary Monahara had 248.88 mg/L alkainity slightly more ionc salts presence in water, Dhobikhola (378.20 mg/L) have high load of carbonates, bicarbonate, nitride salts. The Tukucha (616 mg/L) had high value of alkalinity which shows that over other tributaries it contributes the excess ionic constituents and salts from the heavy city area (industrial as well as chemical wastes, sewages etc.). Bishnumati (234.24 mg/L) had almost same alkalinity as Monahara shows least pollutants from inorganic salts. From Figure 3.15, the Balkhukhola (586.82 mg/L) had high alkalinity value the ionic salts from hospital area, outlets of household, drains, dumpig site organic and inorganic wastes hugly increases the ionic constituents in water.

Hardness

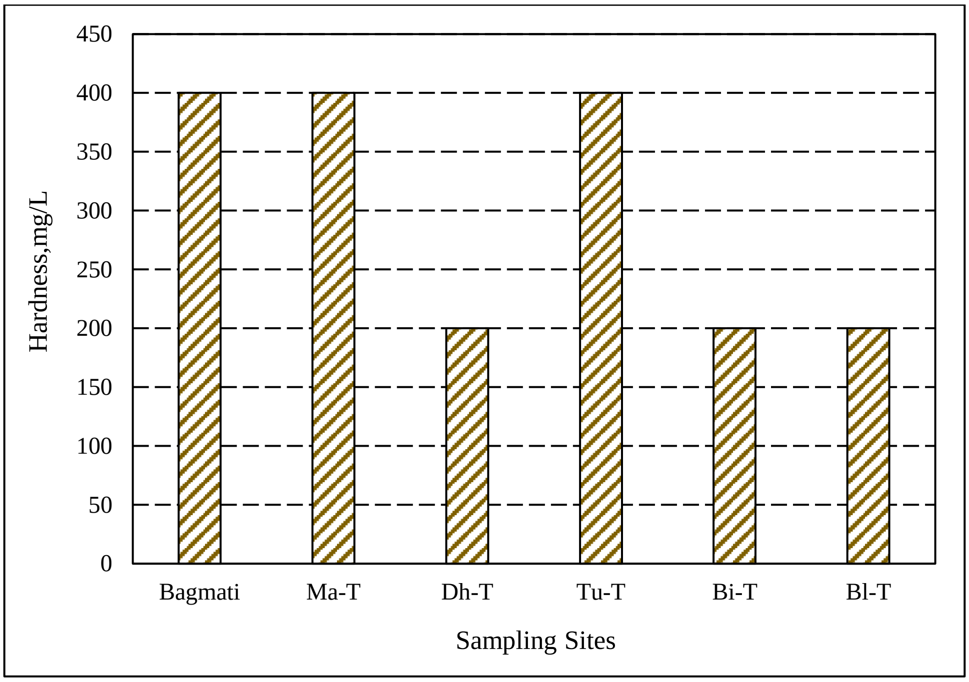


Figure 3.16: The hardness of Bagmati river water and its tributaries.

The hardness value more than 200 mg/L was hard water. The water along Bagmati river and its tributaries was observed as hard water. The hardness of the main stream Bagmati at Sankhamul location was found 400 mg/L shown in Figure 3.16. Similar value of hardness was obtained for tributaries Monahara (400 mg/L) and Tukucha (400 mg/L), which shows two times hard water compared with Dhobikhola (200 mg/L), Bishnumati (200 mg/L) and Balkhukhola (200 mg/L). The result attributes the Bagmati, Monahara and Tukucha water were loaded with excess amounts of carbonate and bicarbonates salts of calcium and magnesium, and less hardness value attributes the least contains of carbonate and bicarbonate salt of calcium and magnesium.

Chlorine Demand

The chlorine demand is the function of chlorine concentration, temperature, pH and contact time. Chlorine species reacts with organic matter and produce chlorinated compounds, trihalomethane, which produce unpleasant smell in water. The chlorine demand value of Bagmati (22.80 ppm), Monahara (26.97 ppm), Dhobikhola (31.14 ppm), Tukucha (32.18 ppm), Bishnumati (35.31 ppm), and Balkhukhola (36.87 ppm) was shown in Figure 3.17 increased linearly towards lower basin of Bagmati river. The result shows that the tributaries enhancing he chlorine demand value of river water. Increasing order of chlorine demand shows that there was formation of chlorinated compounds like trihalomethane by decomposing the organic matter by chlorine species, from many sources like the kitchen outlets, latrine effluents etc.

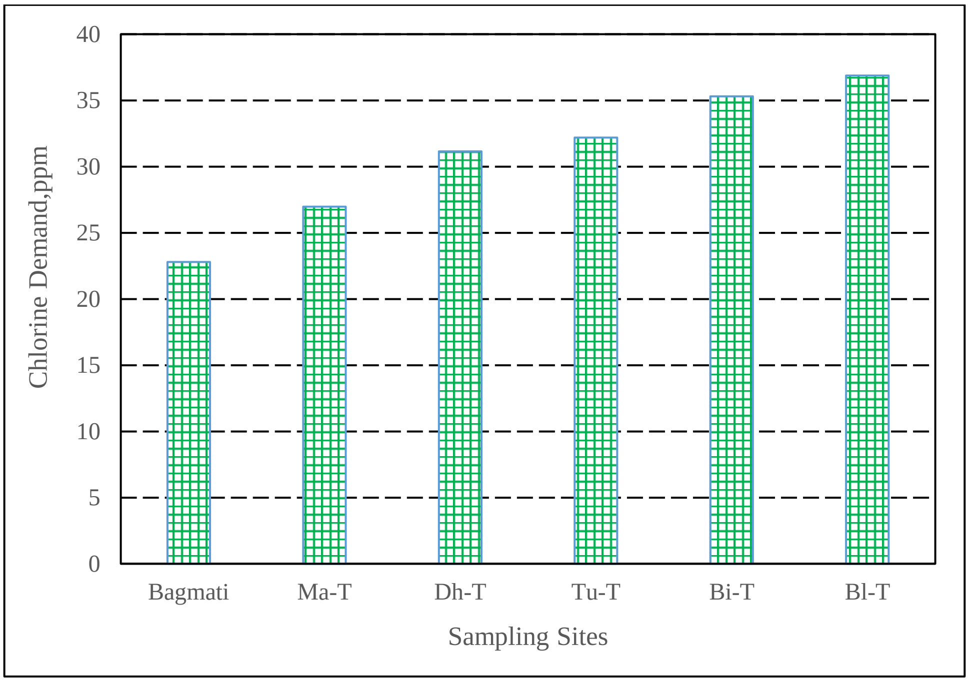


Figure 3.17: Chlorine demand of Bagmati river water and its tributaries.

Ammonia

The excess concentration of ammonia in water was toxic or harmful for aquatic life. Ammonia content in water may be from commercial fertilizer, decomposition of organic matter, animal and human wastes etc. Excess ammonia concentration in water leading to toxic build up internal tissue and blood, and potentially death.

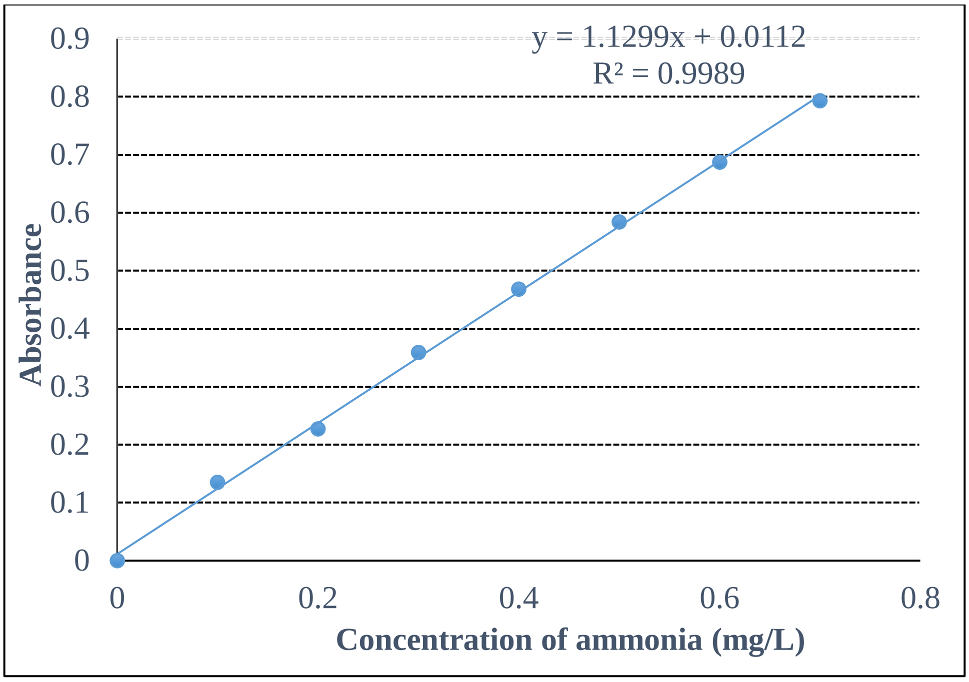


Figure 3.18: Calibration curve for standard ammonia solution of different concentration.

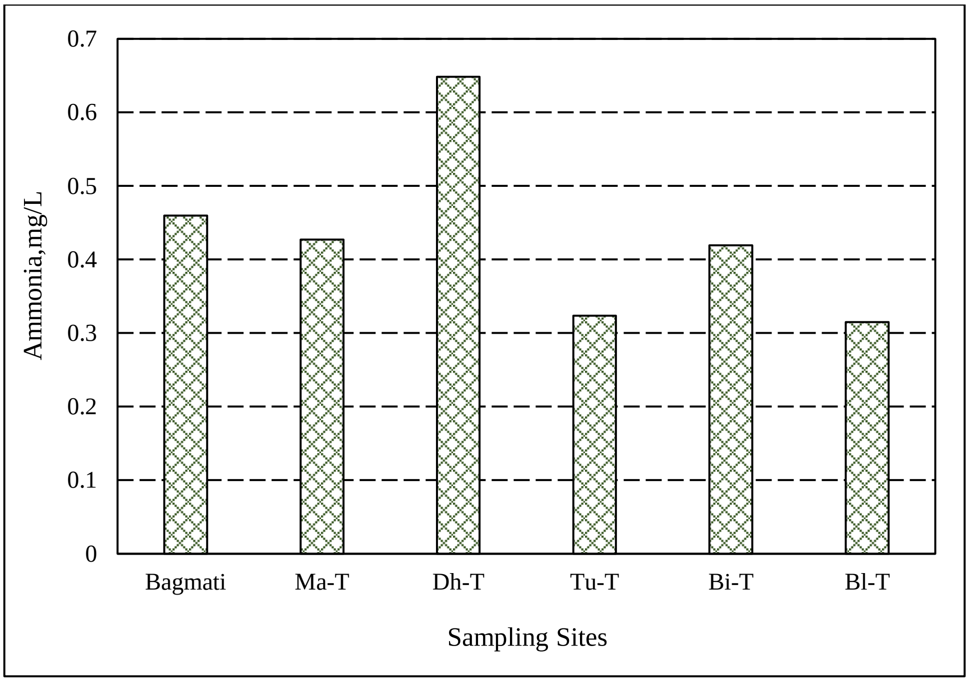


Figure 3.19: The ammonia concentration of Bagmati river water and its tributaries.

The ammonia concentration of Bagmati river (0.46 mg/L), Monahara (0.43 mg/L), Dhobikhola (0.65 mg/L), Tukucha (0.32 mg/L), Bishnumati (0.42 mg/L), and Balkhukhola (0.32 mg/L) was observed as shown in Figure 3.19. The result attributes the excess ammonia concentration n Bagmati and its tributaries river which did not good for aquatic biota. Nitrification process was more pronounced at all sampling location.

Phosphate

The calibration curve for determination of phosphate concentration in known strength of solution by spectrophotometric method was shown in Figure 3.20.

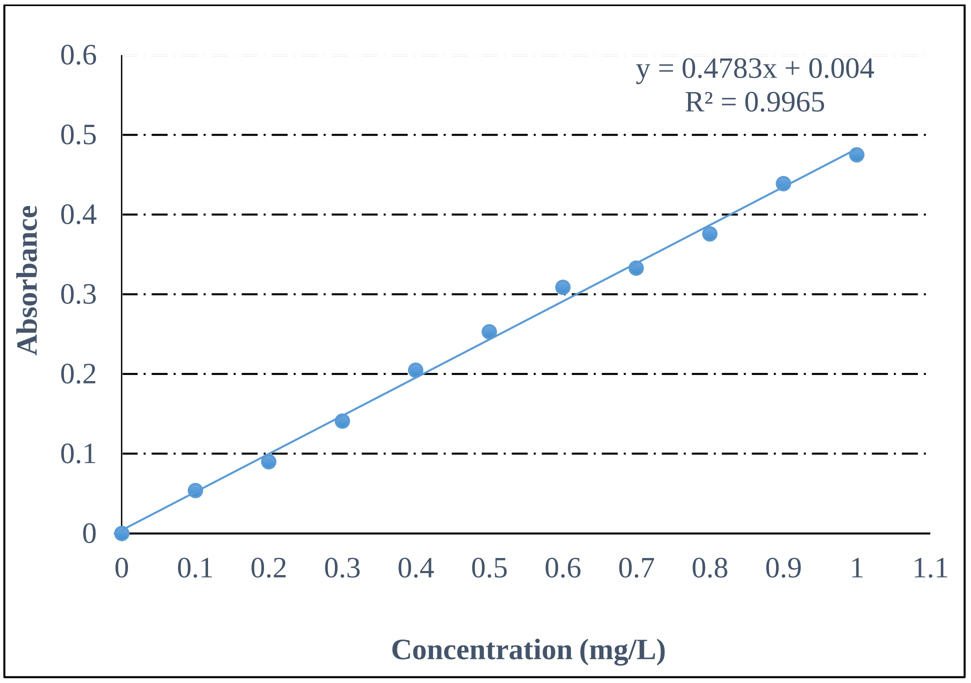


Figure 3.20: Calibration curve for standard phosphate solutions.

Phosphorus is the vital nutrients for living organism but its excess value promotes the eutrophication process in water. Higher the phosphate concentration (above 0.1 mg/L) was not suitable for aquatic biota. More over the phosphate concentration of Bagmati and its tributaries river was found more than acceptable limit. The Bagmati river (0.56 mg/L), Tukucha (0.55 mg/L), and Bishnumati (0.57 mg/L) as shown in Figure 3.20, had higher phosphate concentration from rock salts and other mineral deposition in soil, dead and decaying plant, and fossils. The phosphate concentration of Monahara (0.19 mg/L) was slightly good comparing with other tributaries, and eutrophication process was immunes. The Dhobikhola (0.33 mg/L) and Balkhukhola (0.32 mg/L) illustrate the increasing of phosphate concentration as from industrial wastes, municipal sewages and application of chemical fertilizer.

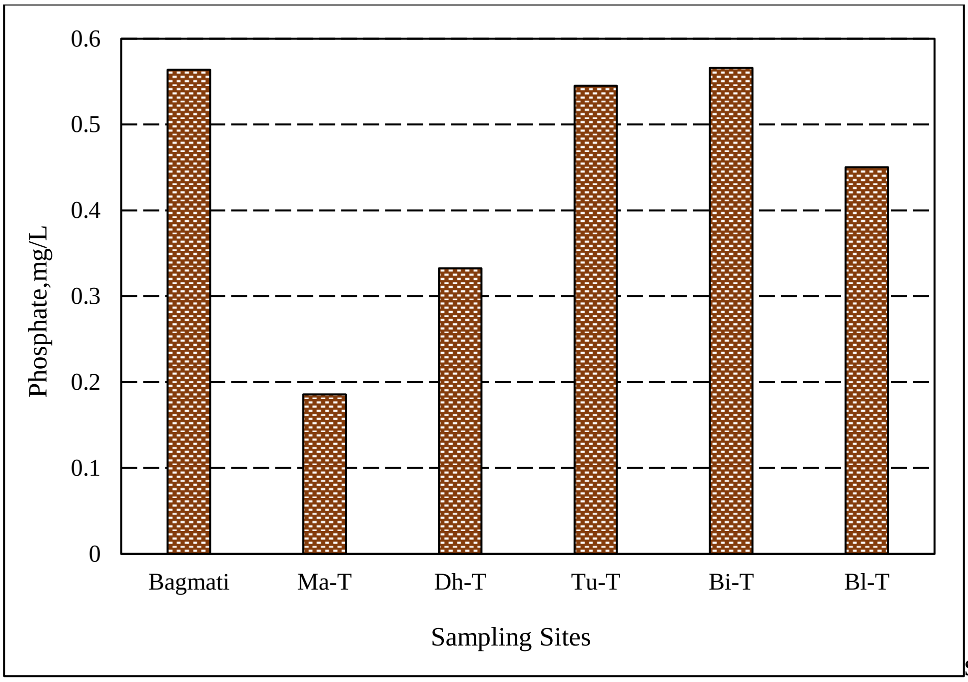


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Figure 3.21: The phosphate concentration of Bagmati river water and its tributaries.

Sulfate

Figure 3.22, represents the calibration curve for different known strength of sulfate solution which was used to determine the sulfate concentration of tributaries. The sulfate concentration of Bagmati river and its tributaries was shown in Figure 3.23, The higher sulfate concentration was observed at Dhobikhola (33.28 mg/L) and Bishnumati (30.94 mg/L). the sulfate concentration of Bagmati river (14.84 mg/L) was higher than Monahara (11.09 mg/L) and Tukucha (12.19 mg/L) and slightly lower than Balkhukhola (17.23 mg/L). The minimum sulfate concentration of tributaries indicates low contaminant through mines and industrial

bi products (paper mills, textile and tanneries) and least effluents discharged from other sources.

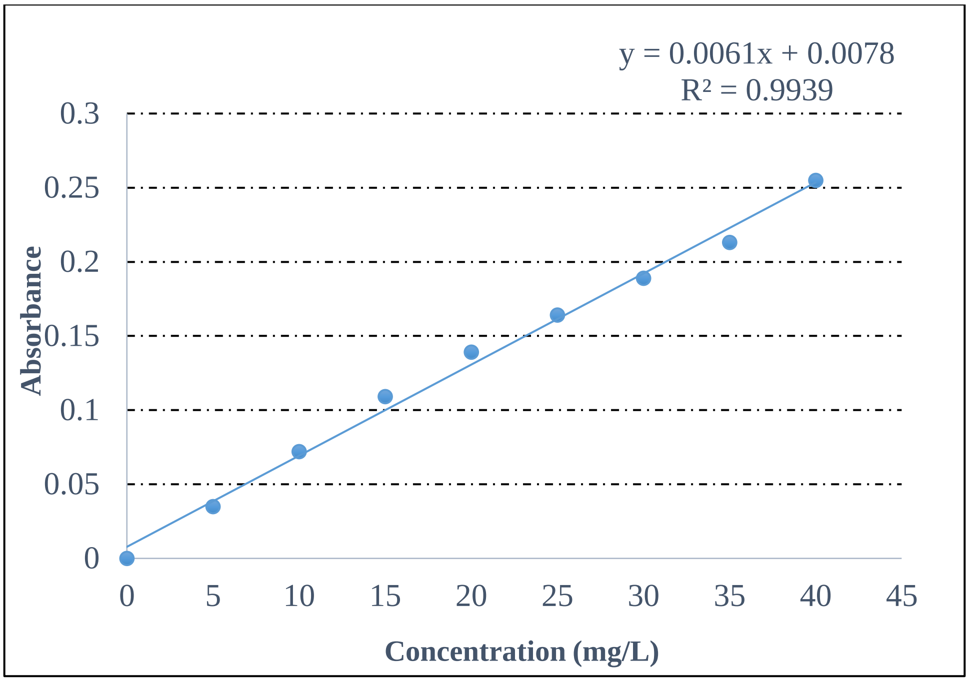


Figure 3.22: Calibration curve of different strength of standard sulfate solution.

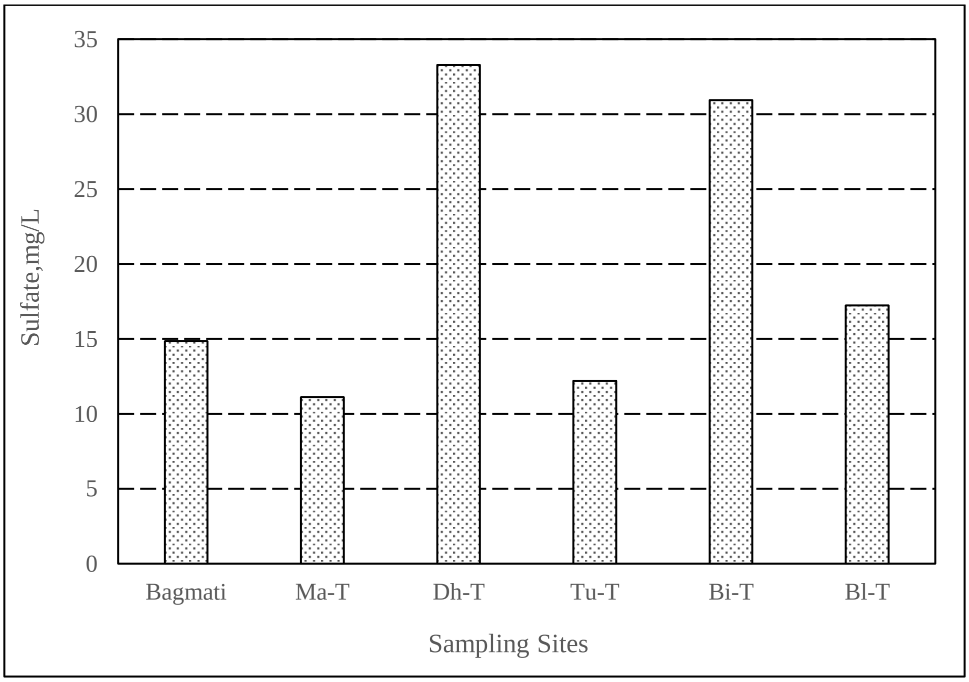


Figure 3.23: Sulfate concentration of Bagmati river water and its tributaries.

3.4 Effect of tributaries on Bagmati river water quality

The effect of tributaries on Bagmati river was analyzed by collecting data from each tributaries and upstream and downstream sites of each tributary in Bagmati river. The data of upstream was considered the river before the confluence of tributaries and data of downstream was consider effect of tributaries on Bagmati river.

The pH of Bagmati river and its tributary was nearly neutral in all the sampling site. The pH was higher at the Monahara tributary (7.56) and almost same in its upstream (7.56) and downstream (7.58) as shown in Table 2. There was slightly decrease in pH towards downstream of Monahara to upstream of Dhobikhola (7.47). But towards downstream of Dhobikhola (7.52) indicates the increase in pH value as shown in Table 2. by the effect of tributary. Tukucha tributary (7.38) decreased the pH value towards downstream (7.41). Bishnumati (7.57) increased the pH of river water toward downstream (7.50) and Balkukhola (7.44) increased pH at downstream (7.56) as shown in Table 2. The pH along the down basin of Bagmati was effects by its tributary with containing the alkaline solid and liquid waste.

The conductivity measurement of tributary river of Bagmati shows the distinct variation. The upstream (688 μS/cm) and downstream (719 μS/cm) of Monahara tributary (583 μS/cm) had high conductivity value, increase towards downstream shows the decomposition of organic wastes in maximal ratio. As shown in Table 2, the EC decreased linearly from downstream of Monahara to upstream of Dhobikhola (509 μS/cm), the slum activities and scatter settlement at Thapathali were be the source of increasing the solid and liquid wastes in river water. The tributary Dhobikhola had high conductivity (803 μS/cm) given in Table 2. The weak salts from domestic and industrial effluents were enriched in water. Towards downstream (741 μS/cm) increased in EC attribute the effect of tributary. The EC decreased towards upstream of Tukucha (537 μS/cm), Tukucha (998 μS/cm) had higher EC value shows the higher contaminant of water by weak bases. The effect of tributary was pronounced and increased EC at downstream (862 μS/cm). There were observed the decrease in EC along the river, but certain affects were observed at sampling locations. Bishnumati (1062 μS/cm) increase the conductivity towards downstream (917 μS/cm). But the effect of Balkhukhola (867 μS/cm) was not cleared, the EC increased linearly towards downstream (928 μS/cm) from upper stream (903 μS/cm).

The turbidity is due to presence of dissolved solid and liquid particles in water. The stream of Bagmati river was extremely polluted towards down basin side after mixing tributaries. The excessive turbidity in water was observed at Monahara tributary (975

FNU) because the excessive load of dissolved particles of organic wastes, chemical enrichments and dissolved clay soil in water tributary enhance the turbidity towards downstream (674 FNU). On increasing the liquid organic wastes turbidity increased at upstream of Dhobikhola (852 FNU) as shown in Table 2, but the settlement of suspended solid particles or by the effect of tributary turbidity was decreased to 464 FNU at downstream of Dhobikhola. Similarly, at all case of examination at Tukucha (312 FNU), Bishnumati (492 FNU), and Balkhukhola (81 FNU) as shown in Table 2 affects the property of Bagmatiri river in some extent. In each sampling location the upstream value of turbidity decreases as mixing the tributaries.

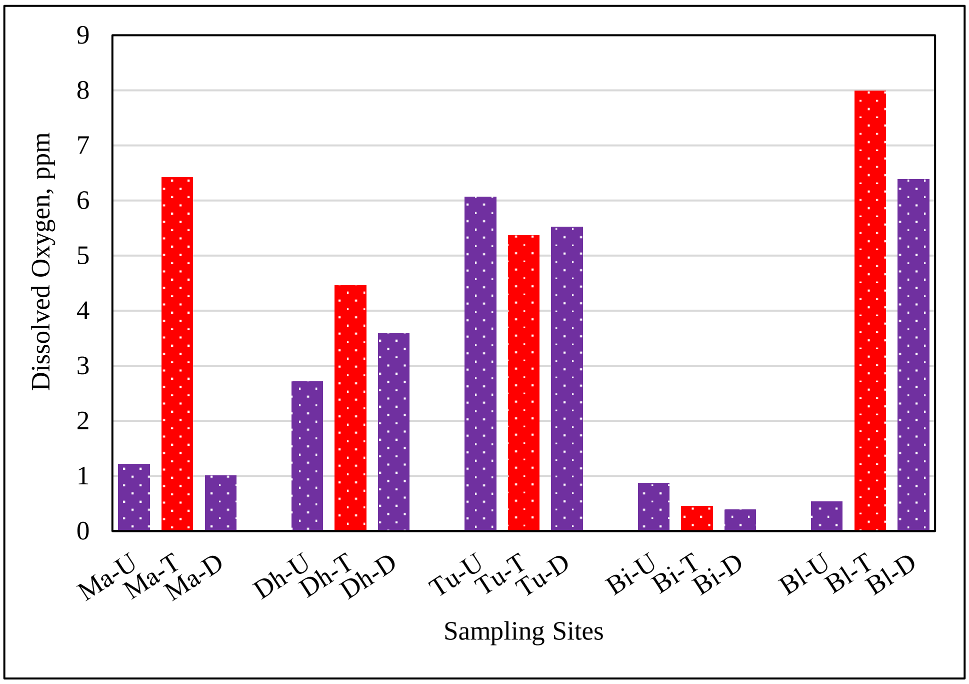


Figure 3.24: Effect of tributaries in DO concentration along the Bagmati river.

The DO level of upstream of Monahara tributary was 1.22 ppm, the tributary had 6.42 ppm, and it was 1.01 ppm at downstream given in Figure. 3.24. The DO concentration increased at upstream of Dhobikhola (2.71 ppm), the tributary had 4.46 ppm and was slightly increased at downstream of Dhobikhola (3.59 ppm), the effect of tributary was pronounced and hence increased DO concentration. The concentration almost increased linearly through the downstream of Dhobikhola to upstream of Tukucha (6.07 ppm) which shows that de-oxidation of river water occurred in less amount. On mixing the Tukucha tributary (5.37 ppm), DO was slightly decreased at downstream (5.52 ppm). Drastically decreased in DO concentration at upstream of Bishnumati (0.87 ppm) might be due to addition of deoxidant components from slum areas, sewages, household waste generation at Thapathali and Teku area. The Bishnumati tributary had 0.45 ppm DO, it was the most pollutant tributary among others, due to absence of appropriate sanitary dumping site, KMC had been placing its solid waste along the Bishnumati and thickness of waste buried along the river corridor depleted the DO concentration and the tributary affects the DO concentration at downstream (0.39 ppm). The DO slightly increased at upstream of Balkhukhola (0.53 ppm), high value of DO (7.99 ppm) at tributary and the tributary increased the DO contains towards downstream.

Alkalinity is the acid neutralizing capacity of water. Generally, water alkalinity is due to presence of carbonate and bicarbonate salts of calcium, sodium, magnesium etc. in water. The higher value of alkalinity at Tukucha (616.1 mg/L) and Balkhukhola (586.82 mg/L) had no more effect towards there downstream as shown in Figure 3.25. The increasing alkalinity value from upstream of Monahara (179.34 mg/L) to downstream of Balkhukhola (417.24 mg/L) might be due to increasing ionic salts from tributaries river and local pollution on river side.

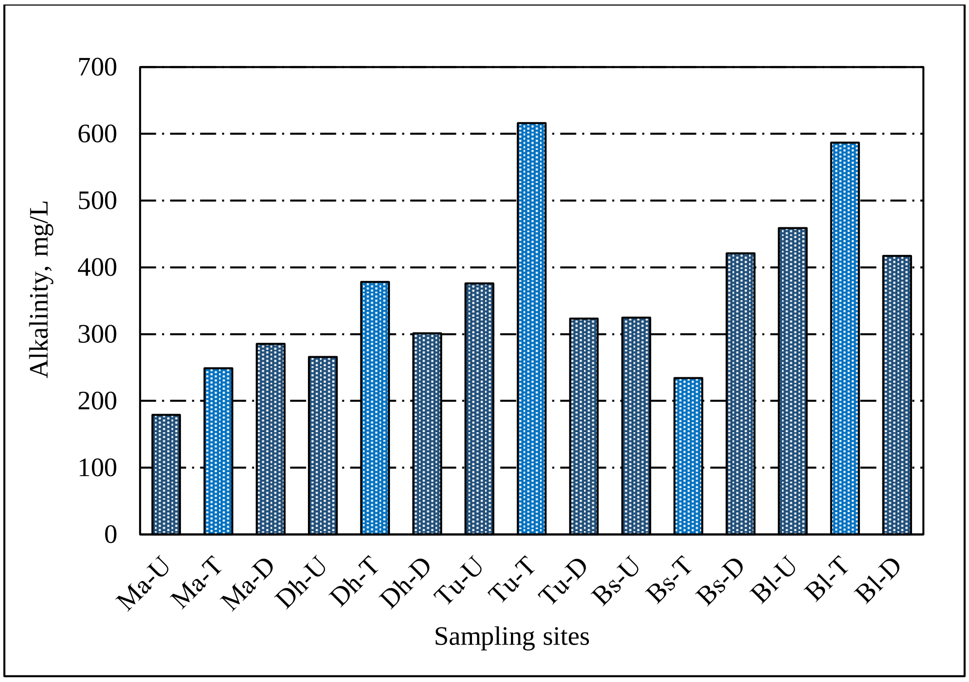


Figure 3.25: Effect of tributaries in alkalinity along the Bagmati river.

Increase in alkalinity value at upstream of Bishnumati (324.52 mg/L) to its downstream (420.90 mg/L) may be due to increasing ionic salts from municipal dumping sites. The Dhobikhola (378.20 mg/L) increased the alkalinity value towards downstream (301.34 mg/L) from its upstream (265.96 mg/). Overall the tributaries affect the stream of Bagmati river.

The hardness of Bagmati river (400 mg/L) was of Monahara was quite similar with the tributary (400 mg/L) but it decreased at the downstream of tributary (200 mg/L) the decrease in the hardness value indicates that there had been decoposition metal ions into the sand (surface settelment) at bank of river. The slum areas, generate solid wastes, disposing household wastes, and dumped haphazardly openly into vacant land be the source of metal ion in river water. The linear increased in the hardness from downstream of Monahara (200 mg/L) to upstream of Dhobikhola (600 mg/L) and similar hardness at downstream (600 mg/L) of Dhobikhola and Dhobikhola had observed 200 mg/L, no effects by tributary. The Hardness decreased from downstream of Dhobikhhola to Tukucha upstream (200 mg/L), the tributary (400 mg/L) had no effect, and 200 mg/L at downstream almost similar water flows along the river as shown in Figure 3.26.

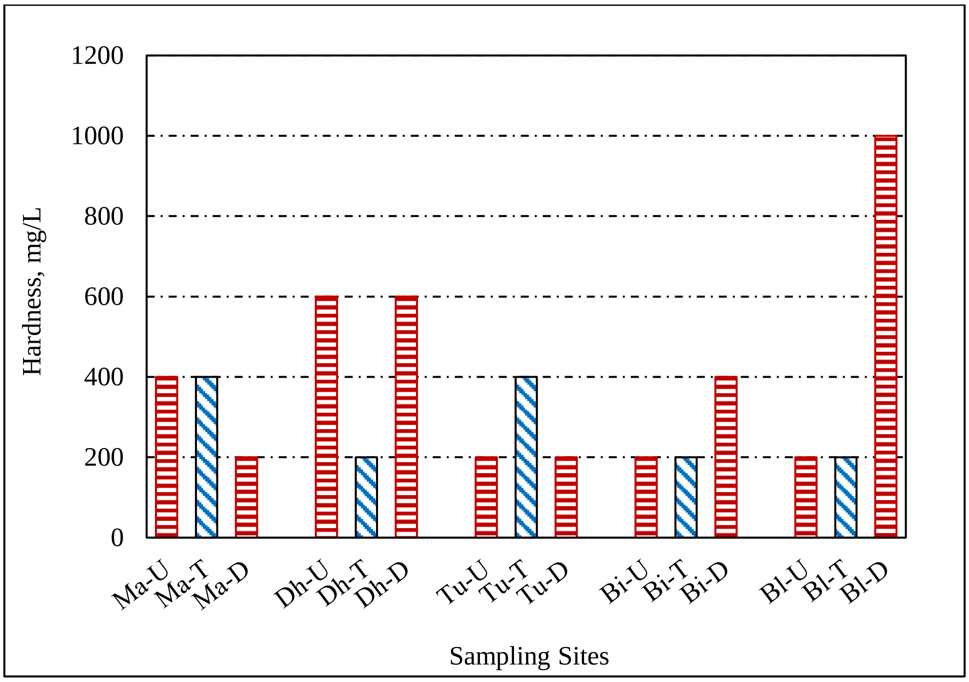


Figure 3.26: Effect of tributaries in Hardness of water along the Bagmati river.

The Tukucha (400 mg/L) was one of most pollutant tributary, flows containing black dirty water in small volume with Bagmati river, that's why effect of tributary was minimal. The upstream of Bishnumati (200 mg/L), and Bishnumati (200mg/L) had same hardness value but increased two times at its downstream (400 mg/L), may be due to dumping sites, and drainage from municipality increased the metal ions. The upstream of Balkhukhola and tributary had same value of hardness 200 mg/L, but drastically increased at downstream (1000 mg/L) because the downstream parts hugely used as dumping yard, slum activities, decomposing organic wastes and decayed matter.

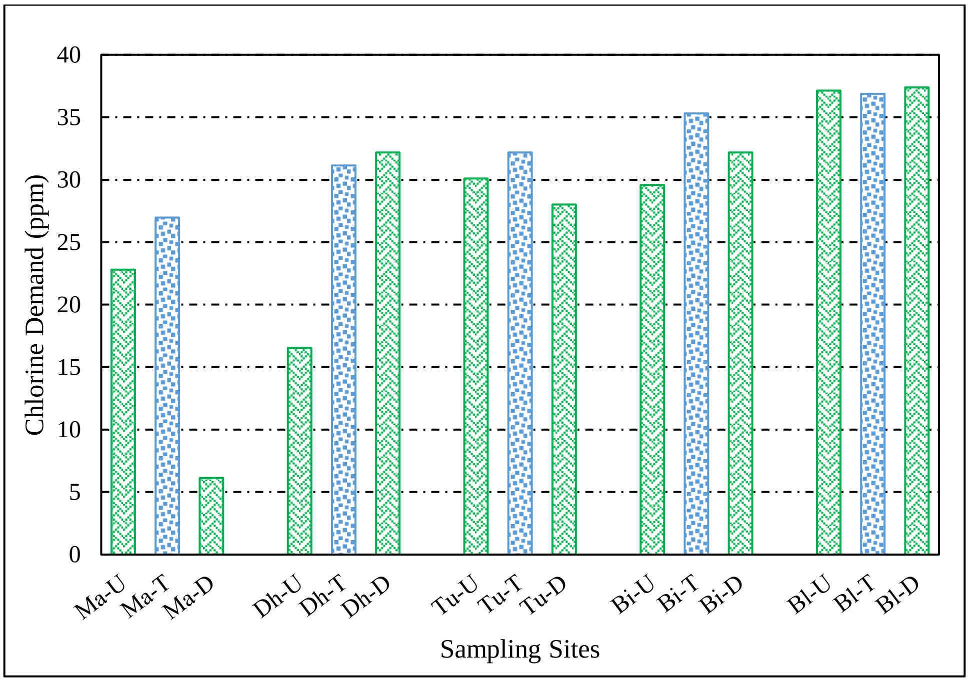


Figure 3.27: Effect of tributaries in chlorine demand along the Bagmati river.

The effect of tributaries in chlorine demand value along Bagmati river was shown in Figure 3.27. The chlorine demand at upstream of Monahara was 22.80 ppm, at Manhara 26.97 ppm, and at downstream was 6.13 ppm. The upstream of Dhobikhola had 16.54 ppm comparatively good, but the Dhobikhola was highly polluted/ turbid than Bagmati river and its value was 31.14 ppm, downstream (32.18 ppm) due to deposition of chlorinated compounds in soil. The upstream of Tukucha had value of 30.10 ppm, and Tukucha had (32.18 ppm), but the downstream had 28.01 ppm, chlorine demand value was not according increased. The chlorine demand was almost constant at upstream of Bishnumati (29.58 ppm), but the most polluted Bishnumati had 35.31 ppm chlorine demand, and polluted by large scale of organic wastes and increased the chlorine demand value at downstream (32.18 ppm). The dumping site of Kulashwor vegetable and fruit market are responsible for wastes of organic matter on river so chlorine demand at upstream of Balkhukhola had higher value 37.13 ppm, the tributary Balkhukhola (36.87 ppm) was also contained huge amount of organic wastes from vegetable market, the street fruit suppliers, wastes from hotel and restaurants increased the chlorine demand value. There are no chances to had less organic wastes toward downstream of Balkhukhola, 37.39 ppm which had highest chlorine demand of Bagmati river.

Unlike other forms of nitrogen, which can cause nutrient over-enrichment of a water body at elevated concentrations and indirect effects on aquatic life, ammonia causes direct toxic effects on aquatic life. Ammonia is produced for commercial fertilizers and other industrial applications. Natural sources of ammonia include the decomposition or breakdown of organic waste matter, gas exchange with the atmosphere, forest fires, animal and human waste, and nitrogen fixation processes. When ammonia is present in water at high enough levels, it is difficult for aquatic organisms to sufficiently excrete the toxicant, leading to toxic buildup in internal tissues and blood, and potentially death.

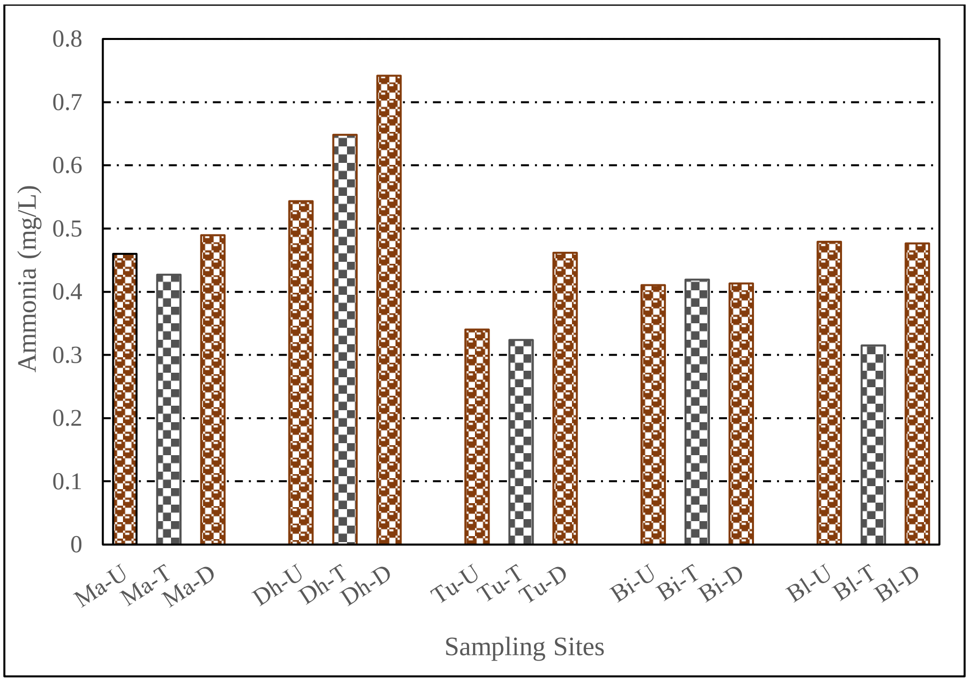


Figure 3.28: Effect of tributaries in ammonia concentration along the Bagmati river.

The upstream of Monahara (Bagmati river) had 0.46 mg/L, Monahara (0.43 mg/L), and 0.59 mg/L at downstream attributing the more decomposition of organic wastes along the sampling site but the concentration was in minimal of WHO ratio. The ammonia concentration increased linearly towards Dhobikhola upstream (0.54 mg/L) the outlets of kitchen, latrine and the human activities at bank of river were be the source of waste organic matter. The highly turbid Dhobikhola contained a maximum ammonia concentration among others and was observed 0.65 mg/L, the dumping of despoil municipal wastes below the bridges (at Babarmahal, Anamnagar, Maetedevi etc) accountably increased nitrogen contained wastes in water and the downstream of

Dhobikhola had maximum ammonia concentration (0.74 mg/L), the settlement of decomposed organic matter results in nitrification. The overall study accompanied, the Dhobikhola had maximum range of ammonia and was not eco-friendly for aquatic organism (EC standard, 0.5 mg/L). The Tukucha upstream (0.34 mg/L) and Tukucha (0.32 mg/L) had almost constant ammonia concentration but drastic changed at downstream (0.46 mg/L) indicates the haphazardous from the dumping side of Thapathali, and latrine effluents increases ammonical compounds in water. The upstream of Bishnumati (0.41 mg/L), Bishnumati (0.42 mg/L), and downstream (0.41 mg/L) shows almost same ammonia concentration as shown in Figure 3.28 above. Upstream of Balkhukhola (0.48 mg/L) and downstream (0.48 mg/L) had no effect by tributary (0.32 mg/L). Overall the ammonia concentration in Bagmati River was observed in same ratio but the small fluctuation was examined at middle region between Sankhamul and Balkhu outlet.

The sulfate concentration increased from upstream of Monahara 14.84 mg/L, to downstream of Dhobikhola (32.66 mg/L). The constant variation between downstream of Manahara to upstream of Dhobikhola indicates that the excessive pollution in water as shown in Figure 3.29 below.

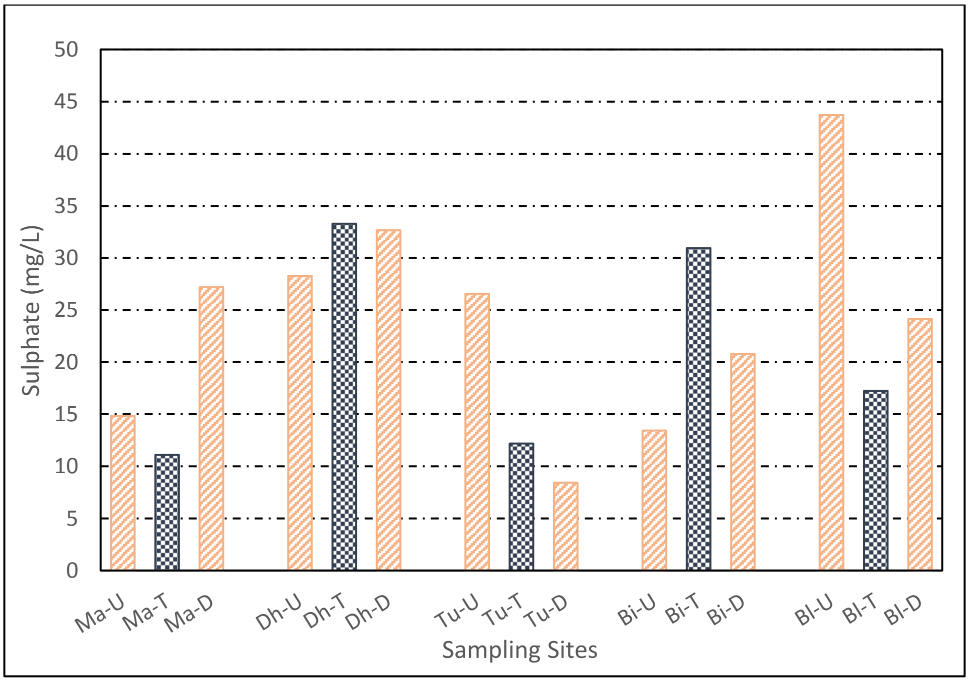
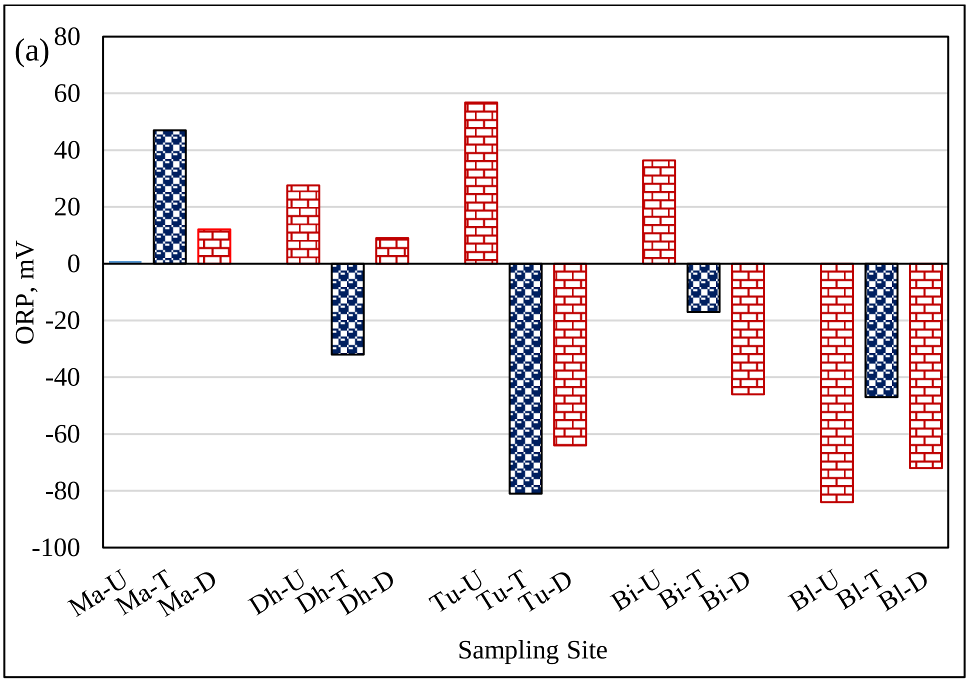
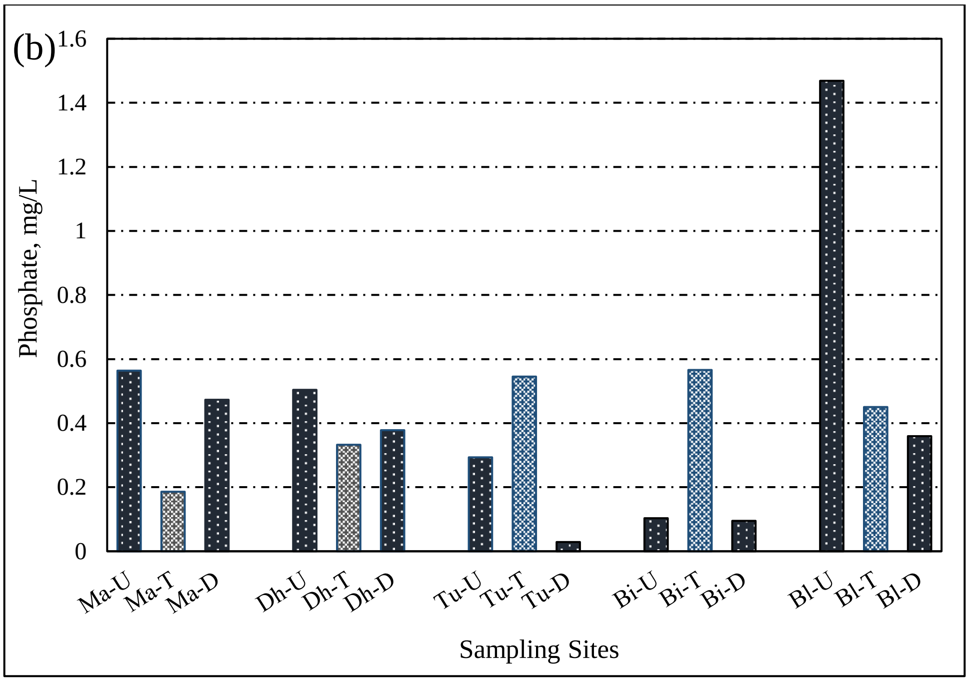


Figure 3.29: Effect of tributaries in sulfate concentration along the Bagmati river.

The Dhobikhola (33.28 mg/L) contribute the large amount of sulfate concentration on Bagmati river. The sulfate concentration between downstream of Dhobikhola, to upstream of Tukucha was found to be linearly decreased (26.56 mg/L), no sulfate from outsource were added along Bagmati river, the Tukucha had low sulfate concentration (12.19 mg/L), no more sulfate contribution from natural minerals only the market byproducts, and industrial wastes are responsible for contributing sulfate in water. Again the concentration increased till upstream of Bishnumati (13.44 mg/L) to its downstream (20.78 mg/L), tributary (30.94 mg/L) was responsible for contributing sulfate on Bagmati river in second rank with Dhobikhola as given in Figure 3.29. The natural resources (rock, fossils etc.), municipal wastes, and industrial untreated waste water are the major factors to increase sulfate concentration in water. The slum activities (between kuleshwor to Balkhu before the bridge), despoil organic wastes from market at kuleshwor, dumping site, sewage from drain at the bank of river are some sources for sulfate contribution in Bagmati river. The higher concentration of sulfate at upstream of Balkhukhola (43.72 mg/L) indicates that the sulfide formation was enhanced by decomposition of organic matter, fertilizers and the industrial wastes, and was decreased after mixing tributary (17.23 mg/L) towards its downstream (24.14 mg/L). But, sulfate concentration increased from upstream of Monahara (Bagmati river) to downstream of Balkhukhola, attributes the influence of tributary effect on Bagmati river and increased in sulfate concentration after mixing tributaries.





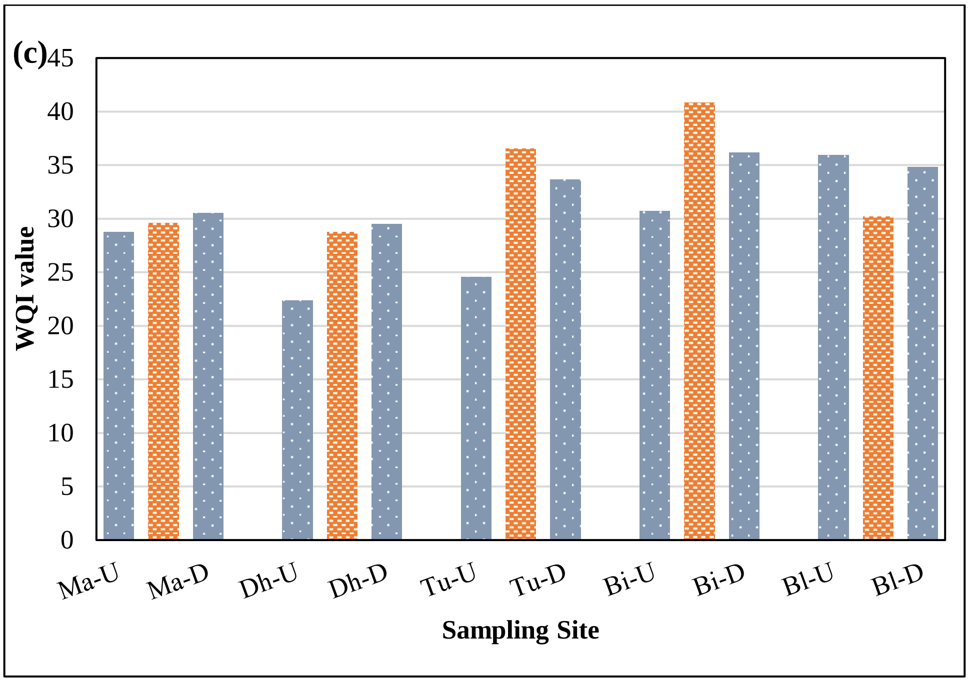


Figure 3.30: Effect of tributaries in (a) ORP, (b) phosphate, (c) WQI of water along the Bagmati river.

The ORP at Monahara tributary (+47 mV) was quite good comparing with the other tributaries, its upstream had +0.97 mV (Bagmati river from Pashupatinath side), after mixing of Monahara tributary the ORP increased to +12.41 mV at its downstream. The in Figure 3.30(a), shows ORP increased linearly towards the downstream of Monahara and it was 27.6 mV at upstream of Dhbikhola. The Dhobikhola tributary (-32 mV) was extremely polluted because of heavy load of wastes from residential area, and it decreased the ORP towards downstream of tributary (9.04 mV). The effect of tributary was clearly visualized. The ORP increased linearly from downstream of Dhobikhola to upstream of Tukucha (+56.8 mV), these value shows that the ORP of river water was almost same, the influence of tributary shows the least effect to the certain extent. Tukucha tributary had high negative value of ORP (-81 mV), addition of high amount of reducing compounds from the upper part of tributary (Bagbazar to Tripureswor), the wastes from the market and the industrial sectors declined the ORP value of tributary. The tributary decreased ORP value towards downstream (-64 mV). Tukucha is small tributary and hence had small proportion of effect on stream of Bagmati. The upstream of Bishnumati (36.4 mV) had quite good ORP value but it decreased towards downstream (-46 mV) of Bishnumati tributary (-17 mV) as shown in Figure 3.30(a). The ORP decreased through downstream of Bishnumati to Balkhu site; the dumping site and the discharges from hospital, wastes from vegetable market, wastes from slum area and the construction site were some sources that enhance the reducing compounds in Bagmati river. The upstream of Balkhukhola (-84 mv) shows the industrial sectors and the market area were contributing the organic and inorganic carbon containing wastes. The tributary Balkhukhola had -47 mV ORP value and it decreased the ORP towards downstream (-72 mV) illustrating the continuous enrichment of reducing compounds in water. The excess negative value of ORP was due to disposable and non-disposable solid and liquid wastes from municipal wastes, and slum activities.

One of the vital nutrients for living organism, including plants, is phosphorus. However, when its value exceeds the process of eutrophication also boosts, which result in decline of DO level. The sufficient level of phosphate is 2 mg/L for river (Fadiran et al., 2007), but when this limit exceeds the growth of plant can occur. As shown in Figure 3.30(b), the phosphate concentration at Monahara tributary was 0.19 mg/L, lower than upstream 0.56 mg/L (Bagmati river), and at downstream (0.47 mg/L). It was (0.50 mg/L at upstream of Dhobikhola, but decreased to 0.38 mg/L at downstream after mixing tributary (0.33 mg/L). Almost decreased towards upstream of Tukucha (0.029 mg/L), but tributary (0.55 mg/L) had high value unless its effect cannot be accounted towards downstream (0.03 mg/L). Slightly increased at upstream of Bishnumati (0.10 mg/L), Bishnumati (0.57 mg/L) had highest phosphate concentration over all tributary, but at downstream (0.10 mg/L) had no effect by tributary. Huge increased in phosphate concentration at upstream of Balkhukhola (1.47 mg/L), the tributary had 0.45 mg/L, but the concentration could not increase towards downstream (0.36 mg/L) as an expected limit (Figure 3.30b). The increasing concentration of phosphate along the riverside was due to the dumping of municipal solid wastes, direct discharge of industrial and domestic sewage into the river. Overall the Bagmati river and its tributaries water were not good for drinking purpose and eco-friendly for aquatic biota, WHO guideline for drinking water was 0.10 mg/L, that's the reason a well treatment was necessary to adequate the aquatic ecosystem.

3.5 Water quality index of Bagmati river and its tributaries

Table 2.2 shows the weight of water parameter based on its impact on water quality. Nine parameters were taken into consideration while calculating WQI. The Figure 3.30(c) illustrate, the current WQI value along the Bagmati river and its tributaries. The water quality index along Bagmati river after and before mixing tributaries was calculated by monitoring the 15-stations sampling Sites (three- point sampling was done in each spot: upstream, tributary, and downstream) given in Table 3. At Sankhamul sampling site the effect of tributary result in increased the WQI value at downstream of Monahara (30.53) in some extent. The tributary Dhobikhola (28.75) also increased the WQI value at its downstream (29.49) comparing with its upstream (22.36). Tukucha was most turbid/polluted tributary but had 36.54 WQI value greater than its upstream (24.56) and), almost increased its WQI value towards downstream (33.64). Comparing with others the tributary Bishnumati have quite good WQI value (40.85) and increased the WQI value of upstream (30.7) towards its downstream (36.17) as shown in Figure 3.30(c). No more changed was observed between downstream of Bishnumati to upstream of Balkhukhola (35.95) as observed in chemical analysis. The slight decreased in WQI value at downstream downstream (34.83) was due to effect of tributary. The excess polluted Bagmati river from Pashupatinath side was equally polluted to Dhobikhola and Monahara tributary. Therefore, the water quality of Bagmati river and its tributaries falls on the class of bad water quality, according to the National Sanitation Foundation Water Quality Index

CHAPTER 4

CONCLUSIONS

The physical and chemical parameters of Bagmati was analyzed from upstream at Gokarna to downstream at Balkhu. The overall, water parametrization shows a downgrading water quality from upstream site to downstream with significant detonating the water quality. The water quality was comparatively less polluted at upstream from Gokarna to Tilganga sites. The concentration of DO was found more than 5 ppm, quite enough to oxidize organic compounds. However, extremely polluted from Tilganga to Balkhu sites and had almost zero concentration of DO at most of the site suggesting no possibilities of survival of living organism. Where the degrading of ORP value attributed the suitable conditions for sulfide formation, which might generate malodorous order into river water. The drastic change in water quality from Tilganga to Sankhamul before mixing tributaries represented that the addition of untreated domestic and industrial waste water from high residential area of inner city to the Bagmati river was responsible to change the water quality. The result of diurnal variation at Sankhamul site showed a distinct variation in physical parameters of water. As the pH and conductivity increased with time but DO and ORP decreased with time till evening. The DO decreased from 9 ppm to zero and ORP from about 40mV to -80mV at late morning to afternoon and remained constant till evening. The upper Bagmati river was less polluted, waste water from domestic and industrial sectors was treated before discharging in the river. The physical and chemical aspect of the river is deteriorating as it flows through the core city area.

The water quality of five tributaries of Bagmati river inside Kathmandu Valley attribute that all the rivers were massively polluted. The effect of tributaries was analyzed by comparing upstream and downstream water quality of tributaries along the Bagmati river. The effect of tributaries on Bagmati river was pronounced in increasing the pollutants in water. The conductivity of main stream increases after mixing tributaries at Balkhu site (928 µS/cm) which was 688 µS/cm before mixing tributaries. The ORP of the river decreased to -72 mV at Balkhu site whereas it was 0.97 mV at Sankhamul. Similarly, the salinity increased to 0.46 PSU (at Balkhu) from its beginning 0.34 PSU (before mixing tributaries) this shows tributaries are the main source of the salt concentration in Bagmati river. The DO varies differently and was found in low concentration in the region between Sankhamul to Balkhu which attributes the higher load of wastes from tributaries creates the anoxic condition along Bagmati river inside valley. Almost all the parameters such as alkalinity increased from 179 mg/L to 417.24 mg/L, hardness from 400 mg/L to 1000mg/L, chlorine demand from 22.80 ppm to 37.39 ppm, sulfate from 14.84 mg/L to 24.14 mg/L, phosphate from 0.56 mg/L to 1.45 mg/L, and ammonia 0.46 mg/L to 0.47 mg/L before mixing to after mixing of tributaries in the Bagmati river. The human activities enhanced the pollutants in the river and were responsible for degrading the river water quality. The excess inadequate management of solid waste aggravating the problems in the river water along with flies and mosquito could lead to different health issues.

4.1 Further work and Recommendation

- In this study, data was collected in winter season only. Hence, further study could be done by collecting data from different seasons. The parameters determined in this study was enough to characterize the water quality but detail chemical analysis of water is necessary to determine the characteristic of pollutants in water sample. Further, the detonating water quality create the serious problem for both aquatic plants and organisms, hence, it is necessary to monitor the water quality of the Bagmati river at regular time interval,

Base on the study following points were considered as recommendations:

- Public awareness regarding the environmental problem could be necessary to prevent haphazard dumping of wastes into the river. Strict rules regarding proper management of sewage and industrial discharges could be rewarding.
- The care must be taken to these sources of water to protect aquatic animals. These water sources need appropriate treatment from the Government or any stakeholder for better environment.
- Spreading public awareness about solid waste management and 3R's (reduce, reuse, and recycle) of solid waste among slum-dwellers.
- As the generation of organic waste is enormous, composting facilities should be encouraged, and feeding of cattle can be done, reduce organic waste in slum area.

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APPENDICES

Table 1: Sampling locations of tributaries along Bagmati river.

Sample name	Observation site
Ma-U	Manahara upstream
Ma-T	Manahara tributary
Ma-D	Manahara downstream
Dh-U	Dhobikhola upstream
Dh-T	Dhobikhola tributary
Dh-D	Dhobikhola downstream
Tu-U	Tukucha upstream
Tu-T	Tukucha tributary
Tu-D	Tukucha downstream
Bi-U	Bishnumati upstream
Bi-T	Bishnumati tributary
Bi-D	Bishnumati downstream
Bl-U	Balkhukhola upstream
Bl-T	Balkhukhola tributary
Bl-D	Balkhukhola downstream

Table 2: The physiochemical parameters of tributaries along Bagmati river.

Sample Location		Temp. [°C]	pH	mV [pH]	ORP [mV]	EC [µS/cm]	TDS [ppm]	Sal. [psu]	D.O. [ppm]	Tub. FNU
Ma-U	Av	12	7.56	-32	0.97	688	344	0.34	1.22	623
	SD	0.1	0.01	0.3	3.63	47	23.5	0.02	0.46	30
Ma-T	Av	9.7	7.56	-31	47	583	294	0.29	6.42	975
	SD	0.2	0.09	5	19.1	89	36.4	0.04	0.74	170
Ma-D	Av	13	7.58	-33	12.1	719	360	0.35	1.01	674
	SD	0.1	0.01	0.7	9.39	48	23.9	0.02	0.65	71
Dh-U	Av	12	7.47	-26	27.6	509	254	0.25	2.71	852
	SD	0.1	0.01	0.5	4.88	7.4	3.7	0	0.17	32
Dh-T	Av	12	7.56	-32	-32	803	402	0.4	4.46	157
	SD	0	0	0.1	2.57	0	0.5	0	0.18	2.7
Dh-D	Av	13	7.52	-30	9.04	741	370	0.37	3.59	464
	SD	0.1	0.01	0.3	1.51	4.3	2.21	0	0.42	25
Tu-U	Av	14	7.51	-29	56.8	537	268	0.26	6.07	710
	SD	0.1	0.01	0.3	3.63	47	23.5	0.02	0.46	30
Tu-T	Av	15	7.38	-22	-81	998	499	0.5	5.37	312
	SD	0	0.01	0.3	11.4	47	23.2	0.02	0.33	11
Tu-D	Av	15	7.41	-24	-64	862	431	0.43	5.52	501
	SD	0.1	0.01	0.4	5.3	7.1	3.56	0	0.33	19
Bi-U	Av	14	7.42	-24	36.4	709	355	0.35	0.87	747
	SD	0	0.01	0.3	4.02	2.9	1.51	0	0.41	34
Bi-T	Av	14	7.57	-32	-17	1062	531	0.53	0.45	492
	SD	0	0.01	0.2	19.2	9.1	4.6	0	0.18	28
Bi-D	Av	15	7.5	-28	-46	917	459	0.46	0.39	574
	SD	0	0.01	0.3	6.81	14	7.06	0.01	0.13	22
Bl-U	Av	15	7.72	-25	-84	903	451	0.45	0.53	572
	SD	0	0.01	0.4	27.5	13	6.36	0.01	0.38	17
Bl-T	Av	12	7.44	-41	-47	867	434	0.43	7.99	81
	SD	0	0.02	1.1	19.3	1.3	0.7	0	0.54	9.7
Bl-D	Av	14	7.56	-32	-72	928	464	0.46	6.38	366
	SD	0.1	0.01	0.7	16.2	3.7	1.89	0	0.43	19

Table 3: Chemical analysis of Bagmati river and its tributaries.

Sample	Alkalinity (mg/L)	Hardness (mg/L)	Chlorine Demand (ppm)	Sulfate (mg/L)	Phosphate (mg/L)	Ammonia (mg/L)	WQI value
Ma-U	179.34	400	22.8032	14.843	0.5639	0.4599	29.58
Ma-T	248.88	400	26.9721	11.093	0.1859	0.4270	28.73
Ma-D	285.48	200	6.1275	27.1875	0.4730	0.4895	30.53
Dh-U	265.96	600	16.5498	28.2812	0.5040	0.5433	22.36
Dh-T	378.2	200	31.1410	33.2812	0.3326	0.6483	28.75
Dh-D	301.34	600	32.1832	32.6562	0.3780	0.7418	29.49
Tu-U	375.76	200	30.0988	26.5625	0.2933	0.3402	24.56
Tu-T	616.1	400	32.1833	12.1875	0.5453	0.3237	36.54
Tu-D	323.3	200	28.0144	8.4375	0.0289	0.4617	33.64
Bi-U	324.52	200	29.5777	13.4375	0.1033	0.4105	30.7
Bi-T	234.24	200	35.3099	30.9375	0.5659	0.4192	40.85
Bi-D	420.9	400	32.1833	20.7812	0.0950	0.4131	36.17
Bl-U	458.72	200	37.1339	43.7187	1.4687	0.4791	35.95
Bl-T	586.82	200	36.8733	17.2343	0.4503	0.3150	30.19
Bl-D	417.24	1000	37.3944	24.1406	0.3594	0.4765	34.83

Table 4: WQI classification value.

WQI Value	Rating of water quality
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Bad water quality
0-25	Very bad water quality