PHYSICO-CHEMICAL, NUTRIENTS AND BACTERIOLOGICAL WATER QUALITY OF MBAGATHI RIVER, KAJIADO COUNTY, KENYA

BY

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DECLARATION

This research thesis is my original work, and has not been presented for any award or a degree in any other University.

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DEDICATION

I dedicate this work to God the Almighty, my loving parents, Mr. William Koikai and Mrs. Nancy Koikai, and my sisters Edith Nkini, Agnes Lasoi and Cynthia Natasha, for their invaluable support and encouragement throughout my education.

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ACRONYMS AND ABBREVIATIONS

α	Alpha
ANOVA	Analysis of Variance
BGLB	Brilliant Green Lactose Bile
BOD	Biological Oxygen Demand
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
˚C	Degrees Celsius
CM	Centimetre
GIS	Geographic Information System
Km	Kilometers
LULC	Land Use and Land Cover
M	Meter
Mg/L	Milligrams per Litre
Ml	Millilitre
Mm	Millimetre
MPN	Most Probable Number
NTU	Nephelometric Turbidity Unit
Ppm	Parts Per Million
PPEs	Personal Protective Equipment's
TC	Total Coliform

TDS Totally Dissolved Solutes

WHO World Health Organization

WRA Water Resource Authority

ABSTRACT

Monitoring of water quality is important to determine the use of that water in different sectors. Water pollution negatively impacts on human health, through exposure to disease causing pathogens in water and chemical toxicants via the food chain. The broad objective of this study was the assessment of the physico-chemical, nutrients and bacteriological contamination of Mbagathi River. The specific objectives included: to determine the physico-chemical parameters of water quality, to determine the bacteriological contamination of Mbagathi River, and assessment of the land use changes and land cover impacts on water quality along the river. The design used was longitudinal. The parameters measured were temperature, pH, turbidity, total dissolved solids, biological oxygen demand, chemical oxygen demand, nitrates, phosphates; as well as total coliforms and fecal coliforms. Water samples were collected in three sampling sites along the river, once every month for a period of four months. Temperature, pH, turbidity and total dissolved solids (TDS), were measured on site using portable meters. Water samples for biological oxygen demand (BOD), chemical oxygen demand (COD), nitrates, phosphates; as well as total coliforms and fecal coliforms were analyzed in the Water Resources Authority Laboratory in Nairobi. Data collected was analyzed using one-way Analysis of Variance (ANOVA) to test for significant differences at $p \leq 0.05$ between the different sampling points. Where significant differences were found to exist, Post-Hoc Tukey's test was used to separate means. The Pearson correlation was also employed to find the relationship among the water quality parameters at the different sampling sites. The land use changes were assessed for the forest area, water area, cultivated areas and built-up areas. Results showed that temperature (20.0±2.94 - 20.50±3.11), pH (7.27±0.11 - 7.53±0.05), TDS (423.00±8.16 mg/l - 487.0±8.29 mg/l), BOD (3.88±1.14 mg/l - 10.45±3.47mg/l) and nitrates (23.50±2.04 mg/l - 62.70±5.06 mg/l) were within the acceptable set standards for drinking by WHO. However, turbidity (2.72±1.09 NTUs - 105.33±4.68 NTUs), COD (15.90±4.04mg/l - 35.33±3.61mg/l) and phosphates (2.10±1.07 mg/l - 3.35± 1.63mg/l) were above the WHO recommended levels of drinking water. Both total coliforms and fecal coliforms were exceedingly higher and ranged from 2415±10.0 MPN/100ml to 184± 52.19 MPN/100ml and 2400± 10.0 MPN/100ml to 7.25± 5.06 MPN/100ml respectively. The land use results showed there was a reduction in the forest area and an increase in the built-up area. A decrease in the water areas also resulted to a decline in the cultivated area. The findings indicated that the water was not fit for human consumption. The county government of Kajiado together with other lead agencies such as National Environment Management Authority and the Ministry of Water, need to come up with measures of reducing the channeling of municipal waste into the river. It's also recommended that the public be informed on ways and importance of protecting the river as it's their immediate source of water.

CHAPTER 1: INTRODUCTION

1.1 Background to the study

Water is a vital resource for human life and other living creations in the aquatic ecosystems. However, these aquatic ecosystems are major sinks for pollutants and due to their sensitivity, they are the main indicators for environmental impacts caused by human activities (Fernández-luqueño *et al.,* 2013). Water pollution as a result of human activities has led to a large amount of available water either ground or surface water, being unsuitable for use and or consumption, thus leading to water scarcity globally.

Water pollution is the presence of elements, compounds or energy in water at levels which affect or change its functioning and or present risks to humans and other targets (Fernández-luqueño *et al.*, 2013). This can affect the physical, chemical and bacteriological parameters of the water. Water pollution can be from the agricultural and industrial sector, municipal and residential wastes. The physical parameters can include: temperature, pH, turbidity, total dissolved solids, among others. They are mostly tampered with when there are additions of other elements into the water. Chemical parameters in this study, are those that require oxygen for their breakdown, that is, chemical oxygen demand and biological oxygen demand. Bacteriological contamination is a major factor of pollution which is majorly brought about by poor hygiene and sanitation. In this study, bacteriological contamination was focussed on total coliforms and faecal coliforms. All these parameters result to a direct impact on human health linked to lack or poor access of safe drinking water, exposure to disease causing pathogens and chemical toxicants via the food chain (Schwarzenbach *et al.,* 2010).

Due to increasing population along the rivers and the rise in water demand, the Mbagathi river water is getting polluted by the day. Most of the house-hold waste water gets channelled into the river, due to lack of a sewer line. In addition, surface run-off from farms has contributed to the pollution of the water, through the introduction of other solutes. With the increasing demand of the water, the water levels have greatly reduced. With a reduction of the water levels, the people who use the water downstream, receive water that is highly polluted, because there is less dilution of the waste waters. The study of Mbagathi River water quality is therefore important, to monitor the physico-chemical and bacteriological contamination, so as to determine whether it’s safe for human consumption.

A similar study done on Kalundu stream in Kitui, established that the stream is highly polluted downstream as a result of channelling of waste water into the stream, and dumping of solid waste into the river (Kioko and Matata, 2021). Another study done on Athi River, in Machakos County, on the impact of anthropogenic activities on water quality, found that, the closer the human activities are to the river, the higher the pollution rate, due to the direct channelling of waste into the river (Ratemo, 2018).

1.2 Statement of Problem

Over the years, human population along Mbagathi River has been rising, with informal settlement along the river. Anthropogenic activities along this particular river and its environs has led to destruction of forest cover, increased built environment and cultivated land. These human activities have negative implications on the water quality in this river that is relied by many people along its stretch. The increase in human population has led to high water demand for domestic use, irrigation and drinking (Engel *et al.*, 2011). Despite the population increase and urbanization, there is no existing sewer line and waste water treatment plant within the area. The situation leads to municipal, agricultural and residential waste being channelled to the rivers within the area. However, there is inadequate data on the extent of water pollution within Mbagathi River. Therefore, the need to monitor the physico-chemical, nutrients and bacteriological contamination in the river caused by human activities and to strategize on how to reduce water pollution in the river.

1.3 Broad Objective

The broad objective of the study, was to determine the physico-chemical, nutrients and bacteriological water quality of Mbagathi River.

1.3.1 Specific Objectives

1. To determine the levels of selected physico-chemical parameters (temperature, pH, turbidity, TDS, BOD, COD, nitrates and phosphates) of water in Mbagathi river.
2. To determine the level of bacteriological loads (total coliforms and faecal coliforms) in Mbagathi river.
3. To determine the land use and land cover impacts on water quality along Mbagathi River catchment.

1.4 Hypothesis

Null hypothesis was used in this research:

1. The levels of physico-chemical parameters do not vary significantly among different sampling sites along Mbagathi River.

2. The levels of bacteriological loads in the river are not significantly different among the sampling sites along the Mbagathi River.
3. Land use changes along Mbagathi River and its environs have not significantly caused pollution in the river.

1.5 Significance of the study

The study findings will be beneficial to both the private and public sectors along the Mbagathi riverine ecosystem. The information can be used to help the business community, decision makers and other interested parties to make better decisions on economic activities such as agricultural practices. The information will be useful to companies which purify water as from the pollutants they are able to know which water treatment method can be used to produce the best quality water.

The Ministry of Agriculture and Water can use the information to advice the farmers and the community who live along the river, on the methods to use to treat water before it is used for irrigation and domestic purposes. The information gathered is a contribution to additional knowledge on the quality of river water. The information will form a source of literature to scholars doing similar studies. The information acquired through the study can be used by policy makers to formulate strategies to prevent water pollution.

1.6 Conceptual framework

Water pollution is mainly from the industrial, municipal and agricultural sector. The wastes from these sectors thereby fall under the independent variables. The independent variables are inputs that are expected to influence the water quality. In this regard, the water quality is affected daily in regards to its physico-chemical and bacteriological levels. The physical and bacteriological levels change in seasons and also due to inputs into the rivers (Joshua *et al*., 2018). The changes in the water quality therefore fall under the dependent variables. Dependent variables in this case are parameters that are affected or changed due to some inputs in the water.

Intervening variables are strategies that can be used to reduce or prevent the impact on water quality from different types of wastes. The measures fall under the management level of different sectors, to protect the environment and the natural resources. With the efficiency of industrial and municipal waste management systems, the amount of wastes that is directed into rivers will be reduced or fully eliminated (Engel *et al*., 2011). Agricultural practices along the river banks can also be streamlined to ensure that the rivers water remain in good quality. For example, by ensuring there is no farming within the riparian zone, will reduce the amount of agrochemicals getting into the river. In addition, planting trees along the river banks will prevent soil erosion. These measures are therefore important to consider in order to develop solutions.

When any form of waste is channelled into the river, the parameters of the water are also altered. For example, when sewerage is channelled into the river, the bacteriological and physical parameters of the water will be changed, hence affecting the water quality. To stop the channelling of sewage into the river, developing a sewer line can be implemented so as to protect the water quality.

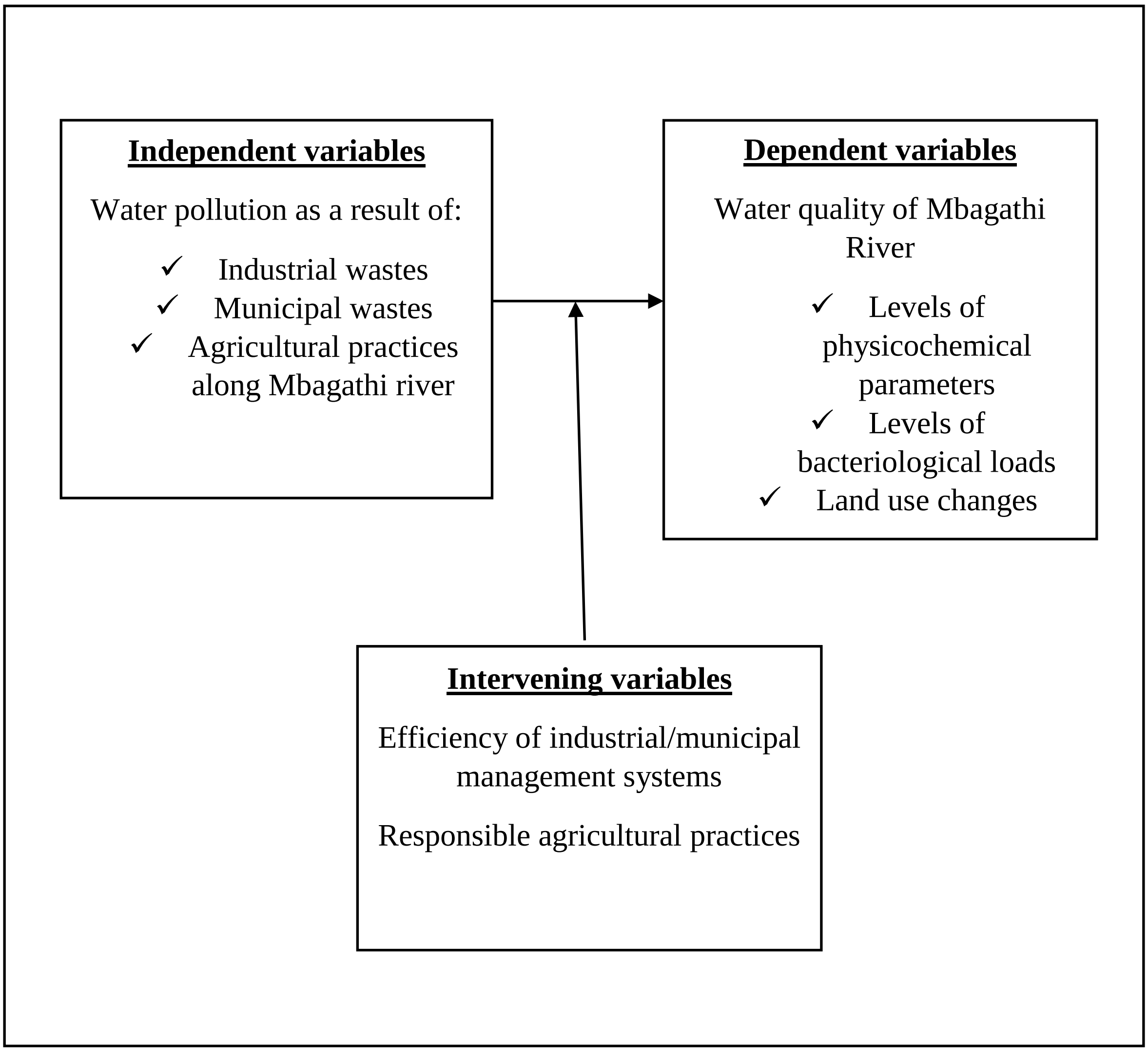

***Figure 1.1**: Conceptual framework indicating the independent, dependent and intervening variables for the study*

1.7 Scope, Assumptions and Limitations

The project focussed only on the selected physico-chemical and bacteriological parameters to determine the water quality. The land use changes were investigated at a radius of 5Km from the river bank. It was assumed that the parameters focussed on, would give a clear indication of the water quality, since the water is mostly used for drinking and residential use. Another assumption made was that the radius of 5Km would give clear information of the changes that have occurred within the years. The section studied was limited to the upstream part of Mbagathi River, starting from Athi Springs to Gataka.

1.8 Definition of terms

Analysis of Variance (ANOVA) test, is a formula to find out whether the results are significant to each other (Bjorklund, 2015).

Brilliant Green Lactose Bile (BLGB), is a chemical used for isolation and differentiating the density of coliform bacteria in water (Echapare *et al*., 2019).

Colony Forming Units (CFU), is a formula used for the enumeration of identified coliform bacteria (Tancini *et al*., 2012).

Ecosystem is a community of both living and non-living components interacting in their environment (Fernández-luqueño *et al.*, 2013).

Most Probable Number (MPN) refers to a statistical method for the estimation of viable numbers of bacteria in a sample (Echapare *et al*., 2019)

Nephelometric Turbidity Unit (NTU) is a measuring unit for turbidity (Chatanga *et al*., 2019)

Water pollution is the addittion of elements, compounds and energy into water at levels which change or affect its functioning (Fernández-luqueño *et al.*, 2013).

Variable is a quantity that may change in an experiment (Joshua *et al*., 2018)

CHAPTER 2: LITERATURE REVIEW

2.1 Water pollution

Water is vital for industrial and economic development of the globe and at the same time, creation of livelihoods. It is important for the sustainability of life. It is used for irrigation, energy production, mineral extraction and consumption among many others which are of direct or indirect benefits. Water pollution can be caused by population growth, and human activities. With population growth, there is environmental degradation through development, industrialization and urbanisation resulting to high quantities of wastes that end up in the water resources. According to Schwarzenbach *et al.,* (2010), "the source of micro pollutants in natural water are diverse." These include natural and synthetic compounds, from point and non-point sources.

Climate change which is playing an important role in water, affects freshwater in three ways: water quality, quantity and water timing. A change in one aspect, affects the rest, thereby having a dependent relationship (Engel *et al.*, 2011*)*. With the impact of climate change, urban areas are prone to increased risks of flooding and insufficient water and sanitation.

Water pollution accidents can be caused by heavy rainfall, floods or drought and in the event, result to the release of industrial wastewater or sewage from residential and commercial areas. In such cases, fresh waters become contaminated affecting the availability of safe drinking water (Beach, 2001). Limited facilities to treat sewage or drinking water are a major challenge in both rural and urban set-ups. In most cities and communities, they discharge sewage and untreated waste water into the surrounding water resources. There is an increased volume of human excreta, other toxins and solid wastes from the urban areas leading to deterioration of water resources. This is due to high population growth in urban areas (Beach, 2001).

Agriculture being another major source of water pollution is evident in urban areas as well. With the change in technology and advancement in agricultural practices, anybody can today carry out cultivation or animal rearing anywhere. The main causes of water pollution from agriculture (crop farming and livestock rearing), are due to use of chemical products. The pollutants get into the waters either through run-off or seepage into the ground water. Other sources of water pollutants may include soil debris from construction sites, oil and toxic substances from car maintenance and run-off from surfaces (Savin & Trzaskowski, 2014).

Pollution together with the high water demand by humans affects the biodiversity, ecosystem functioning and the natural services which the community depends on. According to (Edokpayi *et al*., 2014), the problem of water pollution does not require the construction of dams for it to be solved, but by the conservation of the natural water resources in existence.

With a change in the hydrological cycle, rivers experience a change in the surface water level. Fresh water ecosystems respond quickly to changes in the physical parameters like temperature and pH, and as a result, imminent change in the ecosystem. The physical and bacteriological composition of rivers varies in different seasons (Joshua *et al.,* 2018). For example, in the dry seasons, the water levels reduce due to evaporation, and as a result, the concentration of solutes is very high. In addition, oxygen solubility reduces during the dry periods. When water is contaminated, it affects the aquatic ecosystem, decreases agricultural output and causes diseases such as cholera, diarrhoea, and typhoid among many others. It is therefore important to monitor water quality indicators, to establish whether the water is appropriate for intended use (Araza *et al.,* 2019). An investment in drinking water supply and sanitation will result in an improvement in human health and economic productivity.

A high number of people in growing regions are not sufficiently supplied with portable water. As a result, they end up sourcing water from boreholes, wells and rivers which are under high possibilities of contamination. This leads to the risk of water borne diseases becoming a concern in many urban or upcoming centres. The main bacterial micro-organisms present in contaminated water include: *Salmonella sp., Shigella sp., Escherichia coli and Vibrio cholera. E. Coli,* is used to indicate the presence of coliforms in water (Abila *et al.,* 2012). In reference to the World Health Organization water quality standards, there should be no faecal coliform present in 100ml of drinking water.

Water quality problems is greatly being experienced in the urban areas. Among the urban dwellers, the urban poor suffer most from water quality problems. They mostly live in slums and informal settlement due to rapid urban growth and inadequate sanitation. The urban poor also pay more for water compared to the neighbouring rich people, because of the lack of access to water supply system. They mostly rely on private vendors. Main challenges concerning water, facing major cities in the world include: lack of house-hold water connection, rapid urbanization, leakage of water supply systems mainly due to poor conditions, maintenance and illegal connections, increasing water demand, totally exploited renewable water sources hence water scarcity, population growth resulting to high demand and poor urban planning – hence piped water connection becomes a challenge.

Management of water bodies and/or resources is one of the ways that can help in improving water quality. In many regions globally, it has not yet been effectively implemented, while in other regions it is affected by factors such as implementation cost and policies. Development of policies that govern water supply and usage have been drafted but the implementation becomes a major issue. There are many institutions that have been established to protect the water bodies, but there is still a gap in the implementation. Unplanned construction, limited resources, and local-political interference are among the many issues that need to be considered in-order to improve on the management of water (Engel *et al.,* 2011).

2.2 Physico-chemical parameters

2.2.1 Temperature

It affects the quality and quantity of water. During the dry season, the rate of evaporation is higher resulting to a reduction in the water quantity. At the same time, the quality of the waters will reduce. With high temperature, the amount of oxygen reduces in the water, and the amount of solutes present increases (Joshua *et al.,* 2018). Due to this, the waters can become un-inhabitable to some aquatic organisms. Pollutants also dissolve easily in warm waters compared to cool waters. The level of water pollution is therefore affected by temperature. Water temperatures can also be affected by human activities like: land-use intensification, release of industrial effluents, agriculture, urban development and climate change (Bjorklund, 2015). It affects all other water parameters differently, depending with the seasons and inputs in the water.

2.2.2 pH

pH is determining the acidic or basic levels of water. The pH of water determines the dilution of pollutants. It strongly relates with water temperature. Human activities have a vital role in affecting the pH levels of water. For example, acid rain which is produced by coal burning, can cause the waters to be acidic. Urbanization and industrial effluents also change the pH levels of water (Bjorklund, 2015). During the dry seasons, the pH is low and high or neutral during the wet seasons. When the waters are acidic, there is minimal biological activity that takes place (Echapare *et al.,* 2019). Aquatic animals may also fail to survive in such waters, thereby losing their habitation and at the end, they die resulting to a reduction in the aquatic life. The pH of water should be neutral or slightly alkaline to favour the use of the water and to support aquatic life.

2.2.3 Turbidity

Turbidity is how cloudy the water appears and it's caused by soil particles. The more the solids suspended in the water, the higher the turbidity. During the dry seasons, the water is more turbid since more solids are suspended due to the low water quantity. In the wet season, solids suspended are less because of dilution hence low turbidity. The turbidity of water can affect its uses in various ways. With high levels of turbidity, the biological productivity in an aquatic ecosystem will most likely reduce (Echapare *et al.*, 2019). Organisms such as fish can also be affected with turbidity, affecting their movement and habitation.

2.2.4 Total Dissolved Solids (TDS)

Total dissolved solids are impurities which can originate from natural sources like rocks and soils, or anthropogenic sources from activities like mining and quarrying (Ugbaja & Ephraim, 2019).

The dilution of solutes/solids in water depends on the amount of water available. During dry seasons, water quantity reduces and as a result solids do not fully dissolve. Siltation is also high during this season, and as a result, the undissolved solutes, settle at the bottom of the water bodies, together with the silt. During wet seasons, when the flow of water is higher, the amount of solids/solutes that are dissolved increases (Echapare *et al.*, 2019). Less silt settles at the bottom of the rivers, but also at the river banks.

TDS can be a mix of inorganic salts and organic matter that are dissolved in water. TDS in water can be from natural sources, sewage, urban run-off, industrial waste water and chemicals used in other industrial processes. Changes in TDS values indicate major water pollution in the rivers.

2.2.5 Nitrates and Phosphates

Nitrates and phosphates are majorly as a result of agricultural activities that takes place. Nitrate is a main source of nitrogen for plants. It's from a family with atoms of nitrogen and oxygen occurring naturally. Its needed for the production of amino acids, used for the manufacture of proteins in plants and animals (Mahmud & Said, 2013). Phosphates is a product of phosphorous and oxygen and it mainly occurs naturally in water bodies. It's essential for the growth of biological organisms for their metabolic and photosynthetic process. They are mainly found in sewage effluents containing detergents, fertilizers and pesticides. It can also be found from leachate of open dumpsites that flow into rivers (Echapare *et al.*, 2019).

Nitrates and phosphates are useful nutrients but in high concentrations they can cause problems to humans and deteriorate the water quality. Elevated nitrate levels in the water may cause methaemoglobinaemia also called blue baby syndrome in infants and a cancer of the stomach in adults. High nitrate concentrations can also cause eutrophication. Eutrophication is when there is too much nutrient in the water body causing excessive growth of algae, which affects water quality. The growth of algae destroys the aquatic ecosystem, by destroying conditions suitable for aquatic life. The domination of algal blooms in water bodies causes the level of oxygen to reduce, resulting to the loss of aquatic life (Mahmud &Said, 2013). The waters also become unsuitable for human consumption, and the treatment of the waters become expensive. Waters with high levels of nitrates and phosphates are characterised with unpleasant odour and taste. This will thereby affect the economic level of the people, in search of cleaner and safer water for consumption. Their levels are mostly high during the wet seasons when agricultural activities are at the peak (Mahmud & Said, 2013).

2.2.6 Biological Oxygen Demand and Chemical Oxygen Demand

BOD is oxygen needed for the decomposing of organic matter under aerobic conditions (Kane *et al.*, 2016). BOD test is the best for determination of organic pollution in water bodies. High levels of BOD indicate the presence of organic matter (sewerage) in the water. Organic pollution is commonly from agricultural fields (livestock rearing), residential and commercial buildings which produce and release organic matter (Gebre, 2017).

The presence of dissolved oxygen is important for aquatic life. Organic matter in waste water is the source of food for aerobic bacteria. The more the organic matter in the waters, the higher the dissolved oxygen requirement for its breakdown. Oxygen in the streams is from the atmosphere and plants during the photosynthesis process.

COD is the total oxygen needed to oxidize organic matter into carbon dioxide and water (Kane *et al.,* 2016). It involves both organic and inorganic matter oxidation levels. Industrial waste which is common for inorganic waste is thereby included in this category.
The test for BOD takes longer than that of COD, but one result can give an idea of the other. For example, by testing COD, one can get an idea of whether or not BOD concentrations will be higher or lower.

2.3 Bacteriological Contamination

Many people depend on water from boreholes and wells which are easily contaminated with microbiological pollutants. As a result, water borne diseases become a major risk to the public. Developing countries, are at major risk of these diseases, due to poor sanitation and shallow wells and boreholes. Access to piped water within the developed countries is also a challenge adding up to the reliance of open untreated water from water bodies. The main water-borne diseases include cholera caused by *Vibrio cholerae*, legionellosis caused by *Legionella pneumophila* and typhoid fever caused by *Salmonella typhi and S. paratyphi*. The presence of *E.Coli* in water indicates present water-borne pathogens (Abila *et al.*, 2012).

Total coliforms includes bacteria in the soils and water that have been influenced by surface run-off and animal waste. It is a group of Gram-negative, rod-shaped bacteria with shared characteristics. It includes thermos-tolerant coliforms, bacteria of faecal origin and bacteria that is not from environmental sources. It may or may not indicate the presence of faecal coliforms. Total coliforms can be caused by soils and organic matter getting into water or conditions that are favourable for the development of other types of coliforms. In the laboratory, they can be grown at temperatures of 35-37˚C in a lactose medium. The identification is through acid and gas production from the lactose fermentation (Tancini *et al.,* 2012).

There are two main techniques used to determine coliforms in water: multiple fermentation tube and most probable number. Through the multiple fermentation tube, measured water samples are put in test-tubes with a culture medium, then incubated at specific temperatures form a certain period. Through the most probable number method, the water sample is filtered for the retention of the bacteria in the filter. The filter is then placed in a culture medium and incubated under certain temperatures for a specific period of time. During the culturing phase, a lactose (lauryl tryptose) broth is used for isolation of the bacteria and then brilliant green lactose bile (BGLB) broth is used for the confirmation of total coliforms (Tancini *et al.,* 2012).

Feacal coliforms are from human and animal by-products. It is mostly produced from house-holds sewage and industrial effluents (Echapare *et al.*, 2019). Further tests of faecal contamination are done to specifically identify *E.Coli*. An *E.coli* medium helps confirm the presence of faecal coliforms in the water (Tancini *et al.*, 2012).

2.4 Land-use changes

Land use is referred to as the anthropogenic activities taking place on land, while land cover is the vegetation, rocks, forests or buildings that cover the land (Hossain, 2017). Natural and human activities along the river banks, can lead to land use changes. With changes in land-use, water quality is also affected. Land use changes can include cultivated land, forest land, grassland, water area or built-up area (Huang, *et al.,* 2013).

Agriculture, deforestation, industrialization and urbanization are the common human activities that act as drivers for land use changes (Tahiru, *et al.,* 2020). By determining the relationship between water quality and land use changes, it will be helpful in establishing threats to water quality and developing sustainable water quality management methods.

Surface water management is greatly affected by environmental degradation. In the Sub-Sahara Africa, majority of the people depend on natural resources for their livelihood. But due to environmental degradation, the resources are either depleted or polluted. Over 60% of the people in the sub-Sahara depend on agriculture, which is mostly done within or around river basins (Tahiru *et al.,* 2020).

As a result of changes in land use, the river basins are negatively impacted. Soil erosion along the river basins leading to sedimentation, nutrient discharge through surface run-off as a result of agro-chemicals and bush burning are some agriculture activities that deteriorate water quality. Soil erosion is mostly experienced in cultivated land or bare land compared to forested and built land. The type of crops cultivated, determine the agro-chemicals to be used and as a result, the absorption of the chemicals and their run-off, determine the nutrient concentration in water bodies (Hossain, 2017).

Several previous research has indicated that different types of land use have a different effect on water quality. For example, water from agricultural land that gets into streams has high nutrient concentration compared to water from forested land (Hossain, 2017).

2.5 Sources of pollutants

Pollution from land use comes from either point or non-point sources. Point source is from a specific place that can be identified, while non-point source is from a general or multiple sources which cannot be easily traced (Camara *et al.,* 2019). Point sources can include, waste water from the municipal and industrial facilities and sewer discharge. Non-point sources can be related to land management, geological and hydrological factors (surface run-off) of an area for example, run-off from agricultural fields.

Water pollutants can be identified as either organic or inorganic. Organic pollutants can include chemicals such as insecticides and pesticides, bacteria from human and animal waste, food processing wastes among many others. Inorganic pollutants may arise from heavy metals, chemical wastes and radioactive wastes.

2.6 Gaps in literature

Despite the knowledge of water pollution globally, there still remains a gap in implementation measures to deal with the issue. In every country today, water has been highlighted as a human footprint. Population growth is being experienced annually, and water pollution is rising. Policies have been made, Water Ministries and Departments have been established, the public-private partnership have been incorporated, strategies of reducing water pollution have been developed, but implementation remains an issue of concern. In different regions, implementation is approached differently and it experiences different challenges. High cost of operation, unlicensed water vendors, unlicensed abstraction of water, and poor planning are among the many challenges that affect implementation. There is need for more information through research and practical bit on implementation measures. There is also a gap in the interraction between land use changes and water quality, at different seasons. When the area being studied is large, the monitoring becomes difficult to cover. There is the need to identify the relationship in large catchment scales. A study in 2014, in the University of Nairobi on effects of land use changes on stream flow, only focussed on land use changes but did not take into consideration the pollution levels. It therefore left a gap in stating the land use changes effects on water quality (Kwamboka, 2014). Another study done on Athi River, on the impact of anthropogenic activities on water quality, did not cover land use changes. It only focussed on the lower section of Athi River (Ratemo, 2018). In both examples, the interraction between land use changes and water pollution has not been addressed. This study is therefore important because it will address the gap between the relationship of land use changes and water pollution levels.

CHAPTER 3: METHODOLOGY

3.1 Name of study Area

The study was done in Kajiado North Sub-County, Kajiado County specifically in Mbagathi River, from its source at Athi springs (1º18´21.7´´S, 36º39´45.3´´E) to Gataka (1º22´13.3´´S, 36º43´23.3´´E). The river is a tributary of River Athi. It is located at the South-west direction from Nairobi city, an approximately 21.1km from the Nairobi Central Business Centre.

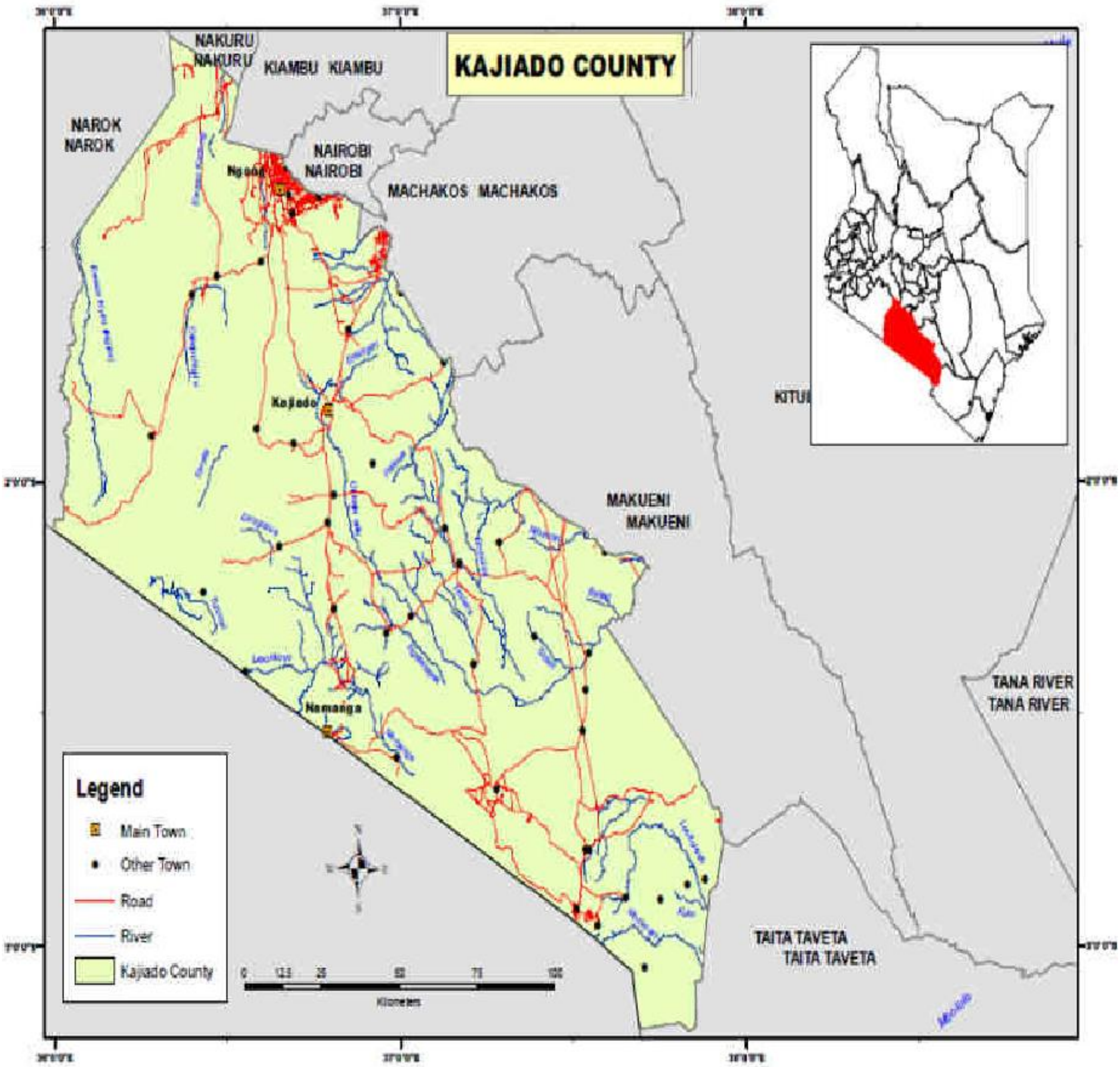

Figure 3.1*: Map showing Kajiado County* (Kajiado, 2018)

3.1.1 Climate

The area is characterised by wet and dry seasons. The long rainy period is from March to May, and short rainy season from October to December. The rainfall pattern is mostly influenced by altitude. Due to the Ngong Hills, there are heavy rains that occur in the area, receiving an average rainfall as high as 1250mm per annum. Temperatures range between 16-35 ˚C (Bobadoye *et al*., 2014).

3.1.2 Geology

The area is slightly sloppy at the catchment area which is inside the Ngong/Thogoto forest, and flat terrain as it moves towards the Nairobi national park. The soils are fertile within Kajiado North. It is mostly dominated by clay soils. The drainage of the region is suspected to be sourced from the Ngong hills through the underground recharge of boreholes(Bobadoye *et al*., 2014). Mbagathi River has two major tributaries which are Enkongu springs and Athi springs.

3.1.3 Economic activity

The main economic activity is agriculture and trade. Agricultural activities include crop farming and livestock rearing. It is mostly practised through irrigation and/or along the river. Trading has grown within the region over the years due to population growth(CIDP Kajiado, 2013). The population of Kajiado County is estimated to approximately 1,117,840, while in Kajiado north, it's estimated to 129,253 males and 130,700 females (CIDP Kajiado, 2018).

3.2 Research Design

The research design which was used was correlational research design. Laboratory analysis in accordance to scientific guidelines were carried out to accept or reject the hypothesis. It was scientific observation because samples were collected and analysed in the laboratory. Correlational research design was used to carry out analysis from the different points of the river. It also explained the relationship between two variables: dependent and independent variables. Land use and land cover changes was also observed from previous satellite images and analysed through Arc GIS. A percentage change analysis was done for the different land uses.

3.3 Selection of sampling sites

The criteria used was cluster sampling. The clusters were according to locations within the study area. From each location, there was one sampling point, resulting to a selection of 3 sampling sections of the river. The first point was at Athi spring (1º18´21.7´´S, 36º39´45.3´´E) which is in Kererapon location, then at Embulbul (1º20´58.6´´S, 36º41´23.4´´E) and Embulbul location and lastly at Gataka (1º22´13.3´´S, 36º43´23.3´´E) at Nkaimurunya location. The sampling sites were about 5km away from each other.

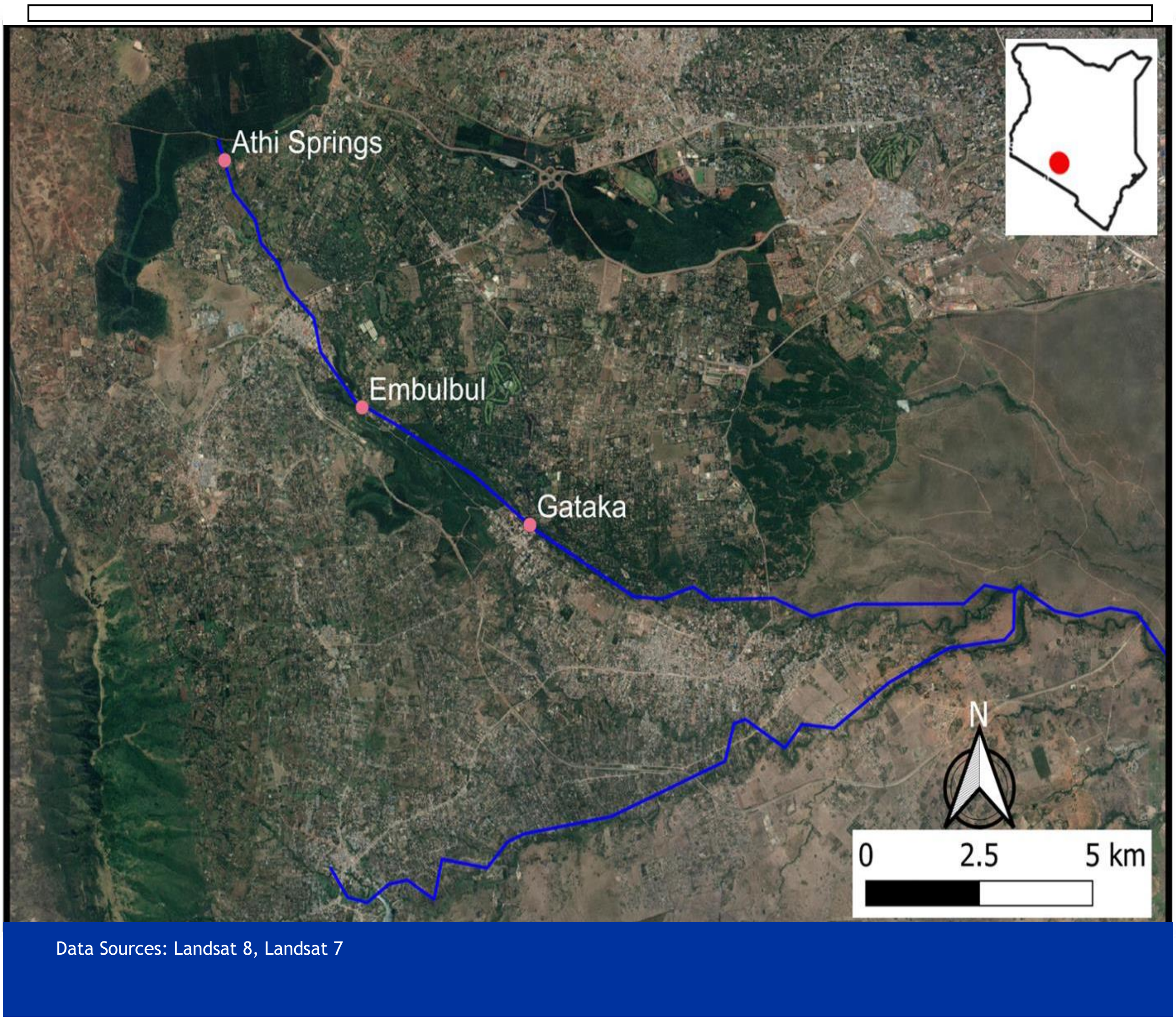

Figure 3.2: Map showing Mbagathi River and the sampling points (Arc GIS, version10.4)

The selection was done in a way to predict the changes in concentration of pollutants depending on intensity of human activities. At the Athi Springs, the point had minimal human activities and therefore a good point to determine the least amount of pollutants available. At Embulbul, the point experiences some human effects, such as municipal waste being channelled into the river. There is some development of residential and commercial homes starting to emerge 5km from the Athi springs, and Embulbul was a good point of establishing some of the pollutants getting into the river. Gataka, which is the downstream point was an access point to the river where there is also an influx of population. Between Embulbul and

Gataka, there is the oloolua forest in which the river passes by. Due to encroachment of the forest for commercial purposes, Gataka was an ideal point of establishing whether there is any purification of the water taking place within the forest. It was also a good point of relating it to Athi Springs which had minimal human intervention, and analyse the relationship and/or difference of water at the points.

3.4 Sampling procedures

The samples were collected using sterilized plastic sampling bottles. The water was sampled some distance (0.5m) from the banks on both sides. Samples were collected between 9 am and 12 noon, and at 10 cm deep from the surface. The sampling bottles were cleaned 3 times with the river water, before sample collection. The samples were collected in triplicates at each point. Sampling was done once a month for a period of 4 months (October-January). After each sample was collected, the bottle was labelled, indicating the sampling site, time and date of collection. The sample bottles were then stored in a cool box and immediately taken to the Water Resource Authority laboratory, which is located in Industrial Area, Nairobi, for analysis.

3.5 Sample preparation and Laboratory analysis

3.5.1 Physical parameters

The parameters measured included: temperature, pH, turbidity, totally dissolved solids (TDS)

3.5.1.1 Temperature

It was measured on site, by a temperature meter (Model: Hanna H1 99300). The meter was turned on, dipped into the river at 10 cm and left to stabilize. After stabilizing, the readings were recorded in ˚C. The temperature measurements were done in triplicates at each sampling site.

3.5.1.2 pH

PH was measured on site, using a portable pH meter (Model: Ktech 943777), with a temperature compensation of 25 ^{o} C. The meter was turned on, dipped into the river at 10cm deep and left to stabilize. After it had stabilized, the readings were recorded in triplicates.

3.5.1.3 Turbidity

Turbidity is the cloudy nature of water caused by particles invisible to the eye. It was measured on site, using a turbidity meter (Model: Hach 2100P). A sample of water was placed into the tube used in the meter. The tube was then inserted into the meter, and the readings from the meter were recorded in NTUs. The measurements were done in triplicates.

3.5.1.4 Total Dissolved Solids

It's the amount of dissolved solids in water. The measurement was done in the field using a multi-meter with a TDS meter (Model: Hanna H1 99300). The meter was calibrated before going to the field. The meter was turned on, dipped into the river at 10cm deep and left to stabilize. After it had stabilized, the readings were recorded in mg/L.

3.5.2 Physico-chemical parameters

The physico-chemical parameters measured were: BOD, COD, Nitrates, and phosphates. They analysis was done according to their standard testing procedures(Length, 2016). The analyses for these parameters was done in the Water Resources Authority (WRA) laboratory in Industrial area, Nairobi.

3.5.2.1 Phosphates

The concentration of phosphates was determined using the spectrophotometer. The test was done by pippeting $50cm^3$ of the sample water into a $500cm^3$ volumetric flask. Ammonium molybdate solution and ascorbic acid were added in small portions, while gently shaking the mixture. The mixture was then diluted with deionised water and left to stand for 30 minutes, to ensure there is maximum colour development. The absorbance was then read at 660nm including the blank and recorded.

3.5.2.2 Nitrates

The concentration of nitrates was determined using the spectrophotometer. The test was done by placing $10cm^3$ of the water sample in a volumetric flask, and adding $10cm^3$ of sulphuric acid into it. The flask was then placed in a cold water bath for it to attain a thermal equilibrium. Brocine sulfanilic acid was then added and diluted with deionised water. The solution was placed in a hot water bath for maximum colour development for a period of 25 minutes. The solution was then cooled at room temperature, and the absorbance was read at 410nm including the blank and recorded.

3.5.3 Bacteriological tests

The test was done in the Water Resource Authority laboratory, Nairobi, using a coliform (MPN) count which was achieved through the membrane filtration method. A sample water of 10ml was diluted with 90 ml of sterile water and the mixture passed through a membrane filtration. The membrane was then placed in a petri dish with a nutrient broth agar. The plate was then put in an incubator under 35˚C, for 24 hours, for the estimation of faecal coliform (Echapare *et al.,* 2019). To confirm total coliform presence, the membrane was immersed in a Brilliant Green Lactose Bile, and incubated under 35˚C for 24 hours. In relation to cultural and the biochemical tests, colonies were identified. The number of colonies formed on the membrane were then observed of their colour and calculated to determine the number of bacteria present. Total coliform was calculated using the formula below, and enumerated as Colony Forming Units (CFU/ml):

$N \times D \times V = CFU/ml$ (Tancini *et al.*, 2012)

Where;

N= Number of colonies

D= Dilution factor

V= volume factor

3.5.4 Land use changes

Land along the river was classified into: cultivated land, forest land, water area and built-up area. A distance of 5 km from the river bank was used to identify the land uses. Satellite images (Landsat 7), of the last 17 years (2000-2017) were downloaded, and analysed using the GIS software (Arc GIS 10.4), to determine the land use changes over the years in percentages.

3.6 Data Analysis

Data collected was analysed using one-way Analysis of Variance (ANOVA) to test significant differences at $p \leq 0.05$ between parameters of the different sampling points. Where significant differences were found to exist, Post-Hoc Tukey’s test was used to separate the means(Bjorklund, 2015). Also Pearson correlation was employed to determine the relationship between the water parameters at the different sampling sites (Abdelmalik, 2018). The Pearson correlation was also used to find the relationship between the land use changes and the tested water quality parameters.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Levels of Physico-Chemical parameters in water

The study measured levels of physical and chemical parameters; temperature (in ^{0}C), pH, turbidity, totally dissolved solids (TDS), nitrates, phosphates, biological oxygen demand (BOD), and Chemical Oxygen Demand (COD) of Mbagathi River.

4.1.1 Physical Parameters

The results on physical parameters (temperature, pH, TDS, and turbidity) are shown in Table 4.1.

Table 4.1: Mean± Standard deviations of the physical parameters measured on site

Site/ Parameter	Athi Springs	Embulbul	Gataka	Average	WHO drinking water limit	P-value
Temperature (˚C)	20.30±1.25	20.0 ± 2.94	20.50±3.11	20.27±2.43	25.0	0.04
pH	7.27± 0.11	7.53 ± 0.05	7.50 ± 0.82	7.43±0.33	6.5 – 8.5	0.49
Turbidity (NTUs)	2.72 ± 1.09	23.53±9.49	105.33±4.68	43.86±5.09	0.3	0.00
TDS (mg/L)	423.00±8.16	469.75±10.1	487.0 ± 8.29	459.92±8.85	600	0.97

4.1.1.1 Temperature

The mean temperatures ranged from 20.0 ± 2.94˚C in Embulbul to 20.5 ± 3.11˚C in Gataka (Table 4.1). The mean temperature of 20.27˚C, recorded in the sites was within the recommended guideline set by WHO (25^{0}C). One-way ANOVA showed a significant difference in temperature among the sampling points ($p=0.04$, $\alpha=0.957$), and this could be attributed to the extent of the rivers exposure to direct sunlight and the quantity of waste channeled into the river.

River temperature is affected by weather conditions, such as solar penetration, solar angle in the river, precipitation and presence of vegetation alongside the river (Gerber *et al.,* 2015). In addition, anthropogenic activities such as direct waste channeling into the river can cause thermal pollution (Kebede *et al., 2020*).

Athi Springs and Embulbul recorded low temperatures of 20.30 ±1.25 and 20.0 ± 2.94 respectively (Table 4.1), which was as a result of lack of exposure to direct sunlight as the area is still covered with remnant forest. The low temperatures recorded at Athi spring could be attributed to the fact the part of the river is near the source and is shaded by the plants found along the river. In addition, the anthropogenic activities along these points are minimal, since it's protected. Due to this, sunlight does not penetrate easily to the waters, hence creating a cooling effect, while the high temperature recorded in Gataka, with a mean of 20.50 ± 2.94˚C (Table 4.1), could be attributed to direct sunlight exposure since all trees have been cleared and the water is exposed. Also, the sewage from the surrounding area is directed to the river leading to increasing temperatures.

Mbagathi water temperatures with a range from 20.50 ± 2.94˚C to 20.5 ± 3.11˚C (Table 4.1) were low than that of Iini and Ikiwe streams in Kenya, whose temperatures ranged between 21.6˚C to 23.5˚C (Tomno *et al.,* 2020) and Kalundu Stream in Kenya whose temperature ranges from 25.08 ± 0.57˚C to 25.39 ± 1.02˚C (Nzeve and Matata, 2021). The temperature of Mbagathi river were within the mean of 20.30 ± 2.76˚C recorded in Awash river in Ethiopia (Kebede *et al., 2020*).

4.1.1.2 pH

The study showed that the pH of the water varied along the river. It ranged from 7.27 ± 0.11 to 7.50 ± 0.82 (Table 4.1). Athi springs recorded the least pH of 7.27 ± 0.11, while Gataka had the highest of 7.50 ± 0.82. The pH levels were within the recommended WHO drinking water standards (6.5-8.0). There was no significant difference among the different sampling points, ($p=0.49$).

The changes in the pH values are attributed to the human activities around the river. The time of water sampling and the number of dissolved solids could be attributed to the high dissolved solids in municipal water which is discharged into the river, and also the temperature of the water when the water was sampled.

The low pH in Athi springs could be attributed to low human activities compared to Gataka which experiences a lot of anthropogenic activities such as development of commercial and residential houses. At Gataka the area is built up and has cultivation along the river and this could be responsible for the high pH of the water.

The pH range of 7.27 ± 0.11 to 7.53 ± 0.05 (Table 4.1) recorded in Mbagathi river is within the pH range of 6.40 ± 0.09 to 7.80 ± 0.16 of Kauthuluni Rivers (Nzung, 2019), and River Dzindi in South Africa with a pH of between 7.47 and 7.53 (Edokpayi *et al.,* 2014), but is lower than the pH recorded in Ikpoba River in Benin whose pH varied between 6.75 ± 0.01 to 6.78 ± 0.05 (Length, 2016).

4.1.1.3 Total Dissolved Solids

The mean values of Total Dissolved Solids (TDS) ranged from 487.0 ± 8.29 (mg/L) in Gataka to 423.00 ± 8.16(mg/L) (Table 4.1) in Athi Springs. The TDS was highest in Gataka. The one-way analysis of variance indicated there was no significant difference among the sampling points (p= 0.97). The values did comply with recommended WHO drinking water limits of 600mg/L.

TDS in a river is influenced by the natural and anthropogenic activities along the river. Anthropogenic activities can lead to sedimentation and soil erosion and result to high quantity of solids in surface water (Chatanga *et al.,* 2019). In addition, the amount of water in the river during different seasons can affect the level of TDS. When the waters are shallow, the TDS becomes higher since the dissolution rate is minimal compared to when the waters are deep (Ugbaja & Ephraim, 2019).

The high levels of dissolved solids in Gataka (Table 4.1), could be linked to the high amount of municipal waste channelled into the river, together with run-off from farming activities in the area (Table 4.1). Between Embulbul and Gataka, there is an influx of human activities, which lead to an increased amount of municipal waste. Small scale farming activities along the river and in the upper sections, also lead to siltation in the river. A lot of soil is washed into the river since the river is in a valley and development is taking place on the upper reaches.

Compared with other studies the total dissolved solids in Mbagathi river is higher than that in River Ikpoba in Benin of 47.69 ± 2.4 to 154.7 ± 3.4 mg/L (Length, 2016) and River Asu, Nigeria of 27.00 ± 7.93 to 53.50 ± 7.04 mg/L (Joshua *et al.,* 2018).

4.1.1.4 Turbidity

The study showed that the mean turbidity varied during the study period. It ranged from 2.72 ± 1.09 NTUs at Athi springs to 105.33 ± 4.68 NTUs (Table 4.1) at Gataka. The one-way analysis of variance indicated there was a significant difference among the sampling points ($p=0.00$, $\alpha=1.000$). The difference in each point could be as a result of the anthropogenic activities taking place in each point. The values exceeded the WHO limits of 5 NTUs, except Athi springs (Table 4.1).

The turbidity of a river is determined by the presence of suspended particles on the surface of water and also the turbulence of the water as it flows downstream and this is because of the resuspension of sediments as the water flows. (Araza *et al.*, 2019).

The high turbidity at Gataka (105.33 ± 4.68) (Table 4.1) could be attributed to the high number of suspended solids in the waste water which is attributed to the municipal and the run-off from the farms where pesticides and fertilizers are used by the farmers. The low turbidity at Athi spring is attributed to the low human activities and since it is a protected area, there is no soil erosion.

The turbidity of Mbagathi water is higher and within the range of Athi and Kauthuluni Rivers, Kenya which ranged between 0.60 to 1235.60 NTUs (Nzung, 2019), and lower than that of Mohokare River, Lesotho whose turbidity ranged between 36 to 174 NTUs (Chatanga *et al.*, 2019), and that of Nawuni catchment in Ghana which ranged between 83 to 308 NTUs (Tahiru *et al.*, 2020).

4.1.2 Chemical Parameters

The chemical parameters analyzed in the study were nitrates, phosphates, biological oxygen demand (BOD), and Chemical Oxygen Demand (COD) as shown in Table 4.2.

Table 4.2: Mean ± Standard deviations Chemical Parameters

Site/ Parameter	Athi Springs	Embulbul	Gataka	Average	WHO drinking water limit	P- value
BOD (mg/L)	3.88± 1.14	3.95 ± 1.22	10.45±3.47	6.09±1.94	5mg/l	0.22
COD (mg/L)	15.90±4.04	18.70±3.85	35.33±3.61	23.31±3.83	10mg/l	0.72
Nitrates (mg/L)	23.50±2.04	38.55± 4.38	62.70±5.06	41.58±3.82	50mg/l	0.32
Phosphates (mg/L)	2.10± 1.07	3.35± 1.63	3.34± 3.55	2.93±2.08	0.1mg/l	0.00

4.1.2.1 Biological Oxygen Demand

The study showed the mean values of BOD recorded during the study ranged from 3.88 ± 1.14mg/L in Athi springs to 10.45 ± 3.47mg/L in Gataka (Table 4.2). Using the One-way analysis of variance, there was no significant difference among the sampling points (p=0.22). The BOD levels were within the recommended WHO drinking water standards; 5mg/l, except for Gataka, which recorded higher values.

High levels of BOD in water indicate high contamination levels while low BOD levels indicate low contamination (Gebre, 2017).BOD is influenced by the amount of organic load deposited in the water bodies. The decomposition process of the organic matter determines the amount of oxygen which is absorbed from the water (Ugbaja & Ephraim, 2019).

The high BOD at Gataka could be attributed to the large amount of organic matter from the farms and the municipal sewage. The organic matter is broken down by aerobic bacteria which uses oxygen shows that a high BOD is equivalent to the high organic matter. Low BOD in Athi spring is attributed to little amount of organic matter as this is a protected area and therefore less organic matter to be broken down by aerobic bacteria.

The BOD recorded at Mbagathi river, of a range of 3.88 ± 1.14mg/L to 10.45 ± 3.47mg/L (Table 4.2) is higher than that recorded in Orem streams in Nigeria of 3.60 mg/l (Ugbaja & Ephraim, 2019), and lower than that recorded in River Ciliwung in India, of 20 mg/l (Kane *et al.*, 2016).

4.1.2.2 Chemical Oxygen Demand

The mean concentration ranged between 35.33 ± 3.61mg/L in Gataka to 15.90 ± 4.04mg/L in Athi springs (Table 4.2). The WHO drinking water standards demand COD value to be < 10 mg/l, and therefore all the points had higher values than the recommended COD value. COD analysis involves measurement of the oxygen-depletion capacity in a water body. It’s an important test to determine the pollution strength of industrial waste and sewage (Gebre, 2017).

The amount of COD increased downstream, indicating an increase in the amount of organic matter channeled to the river. Some of the pollutants along Gataka, are from; car washing business and washing of clothes in the river. Other organic pollutants, are from the municipal waste which is not treated. The water is therefore not suitable for human consumption because of the high level of contamination. Gataka in specific, has very high amounts of both COD and BOD, making it unfit for human use.

The results were similar to a study in River Ciliwung in India which had maximum COD levels of 90 mg/l at areas with higher human activities (Kane *et al.*, 2016), Mitheu Stream in Kenya which had a range between 189.0 ± 196.4 mg/L to 1304 ± 604.4 mg/L (Linge *et al.*, 2020).

4.1.2.3 Nitrates

The study revealed that the concentration (mg/L) of nitrates varied along the river. The mean concentration ranged from 23.50 mg/L at Athi springs to 62.70 mg/L at Gataka (Table 4.2). One-way ANOVA showed there was no significant difference in nitrate concentration among the sampling points (p=0.318). The mean concentration of nitrates was below the WHO concentration of 50mg/L for drinking water.

The concentration of nitrates in a river is influenced by agricultural activities in the area especially where there is application of fertilizers (Mahmud & Said, 2013). The other sources of nitrates into the river are from sewage effluents and agricultural run-off together with leachate of open dumpsites that flow into the rivers (Araza *et al.*,2019). Surface run-off from, shallow and/or poorly managed pit latrines and poor solid waste management can also influence nitrate concentration into the river (Gebre, 2017).

The low nitrates levels (23.50 ± 2.04mg/l) (Table 4.2), at Athi spring point could be attributed to low agricultural activities around and no municipal disposal as this is a protected area (Table 4.2). The high nitrate level at Gataka of (62.70 ± 5.06) could be attributed to the increase in human population and farming activities which use fertilizers to increase productivity as well as land cover in the area is reduced hence no means of slowing soil erosion.

The nitrate levels recorded in Mbagathi river compares well and are higher than those recorded in Anko River, Ethiopia whose nitrate concentrations ranged between 1.6mg/l and 3mg/l (Gebre, 2017), and River Mohokare in Lesotho, with nitrate levels of a range of 0.44mg/l to 1.76mg/l (Chatanga *et al.,* 2019).

4.1.2.4 Phosphates

The phosphate concentration along the river in mg/L varied during the study period. The concentration of phosphates ranged from 2.10 ± 1.07 mg/L in Athi springs to 3.35 ± 1.65mg/L in Gataka (Table 4.2). There was a significant difference in the mean of phosphates between the water samples for the studied river (p=0.00, α =.738). The phosphate concentration was above the WHO limits of 0.1mg/L of drinking water.

Phosphates can leach through soils and affect the ground water supply, but surface run-off of soils is the highest concern of phosphate contamination in streams and rivers (Mahmud &Said, 2013). High phosphate levels can be attributed to agricultural practices that use fertilizers, and release of waste waters containing detergents into the rivers (Mahmud & Said, 2013). Phosphate concentrations may vary depending with the different land uses. For example, in agricultural and urban land uses, the levels are expected to be high, while in forested areas, it's expected to be low (Kebede *et al.*, 2020). Despite, being important nutrients in the aquatic environment, if the limits exceed, they can be harmful to both humans and plants. Phosphates and nitrates have a relationship in which both have to be in good levels. If one is in excess, it can affect the use of the waters (Gebre, 2017).

The high level of phosphate concentration at Embulbul of (3.35 ± 1.63 mg/l) (Table 4.2), could be attributed to increased land use at this point of the river. Farming activities and urban development are on the increase in the region. Farming takes place throughout the year whether it’s a raining or dry season, due to the permanent nature of the river. Through the agricultural activities, there is the use of organic fertilizers that is manure, and as a result, there is the high concentration of phosphates into the water.

Comparatively, the level of phosphate recorded in Mbagathi river is within the same range as that recorded in River Anko in Ethiopia, whose phosphate concentrations varied between 2.1mg/l to 6.3mg/l (Gebre, 2017), but lower than that of Mitheu Streams in Kenya, with a range of between 0.10± 0.13 mg/L to 1.74± 2.91 mg/L (Linge *et al.*, 2020) and River Mohokare in Lesotho, with a phosphate range of 0.34mg/l to 1.14mg/l (Chatanga *et al.*, 2019).

4.2 Bacteriological Contamination Analysis

Assessment of the microbiological abundance in water was done as enumerated coliforms as the most common indicator organisms used in water quality monitoring. These organisms are an indication of contamination by either sewage or fecal matter.

Table 4.3: Mean ± Standard deviations of Bacteriological Contamination

Site/ Parameter	Athi Springs	Embulbul	Gataka	WHO drinking water limit	P- value
Total Coliforms (MPN/100ml)	2415.0± 10.0	2400.0± 0.0	184.0± 52.19	0	0.04
Fecal Coliforms (MPN/100ml)	360.0± 33.91	2400.0± 0.0	7.25± 5.06	0	0.01

4.2.1 Total Coliforms

The mean concentrations ranged between 2415.0 ± 10.0 MPN/100ml in Athi springs to 184.0 ± 52.19 MPN/100ml (Table 4.3) in Gataka. According to one-way ANOVA, the significant difference was, p=0.04, α=1.000. The water along the river exceeded the WHO drinking water standards, and is therefore not recommended for human consumption or any domestic use. According to the WHO guidelines, drinking water should have a zero record of total coliforms (Das & Horton, 2018)

The concentration of coliforms can be accounted to the human activities and population growth in the surrounding (Chatanga *et al.,* 2019). Total coliforms are found in contaminated water with human and animal waste together with other bacterial groups. Pit latrines that intersect with shallow water tables and poor sanitation process are a source to the pollution (Wotany *et al.,* 2019).

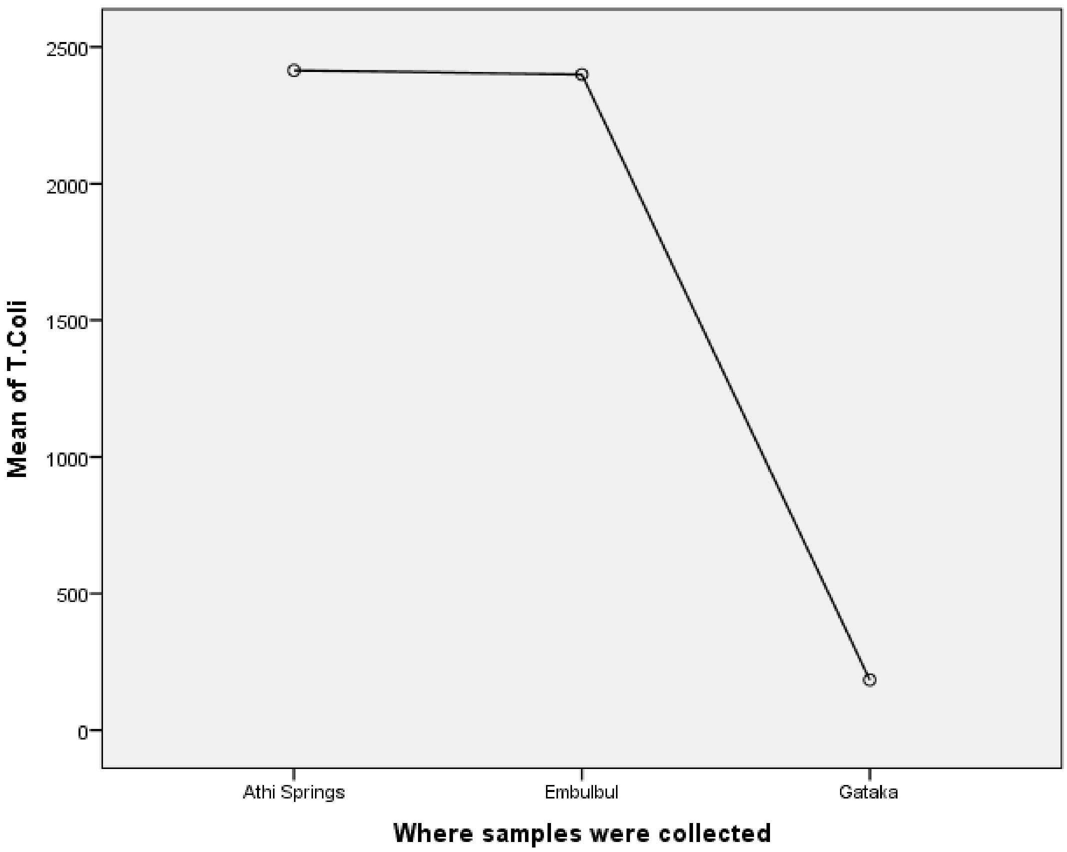

Figure 4.1: *Total Coliforms*

With an increase in built area and agricultural activities, the concentrations also increased. The river passes through a section of Oloolua forest where purification process takes place before the water gets into the river and the purification is responsible for the low total coliform count at Gataka (Table 4.3). The high number of coliform bacteria indicates pollution, from waste waters from households in the surrounding settlements.

The total coliform results in this study were similar to the study in River Bebedouro in Brazil whose concentrations were above 500 MPN/100ml (Bjorklund, 2015), Kalundu stream in Kenya whose concentrations ranged from 385 ± 188.9 to 337,133 ± 124,970 MPN/100ml (Nzeve and Matata, 2021) and River Lukemi in the Democratic Republic of Congo whose concentrations were above 1240 MPN/100ml (Nienie *et al.*, 2017).

4.2.2 Fecal Coliform

The mean concentrations ranged between 2400.0± 10.0 MPN/100ml at Athi springs to 7.25± 5.06 MPN/100ml (Table 4.3) at Gataka. According to the one-way analysis of variance, there was a significant, $p=0.01$, $\alpha=1.000$. The concentrations were above the recommended WHO limit, which states that drinking water should have a zero record of fecal coliforms (Das & Horton, 2018).

The high coliforms counts may be an indication of the presence of other types of enteric microorganism (Length, 2016). Fecal contamination in the river is an indication of human and animal waste in the water. It can be attributed to increased population and poor sanitation in the surroundings (Length, 2016).

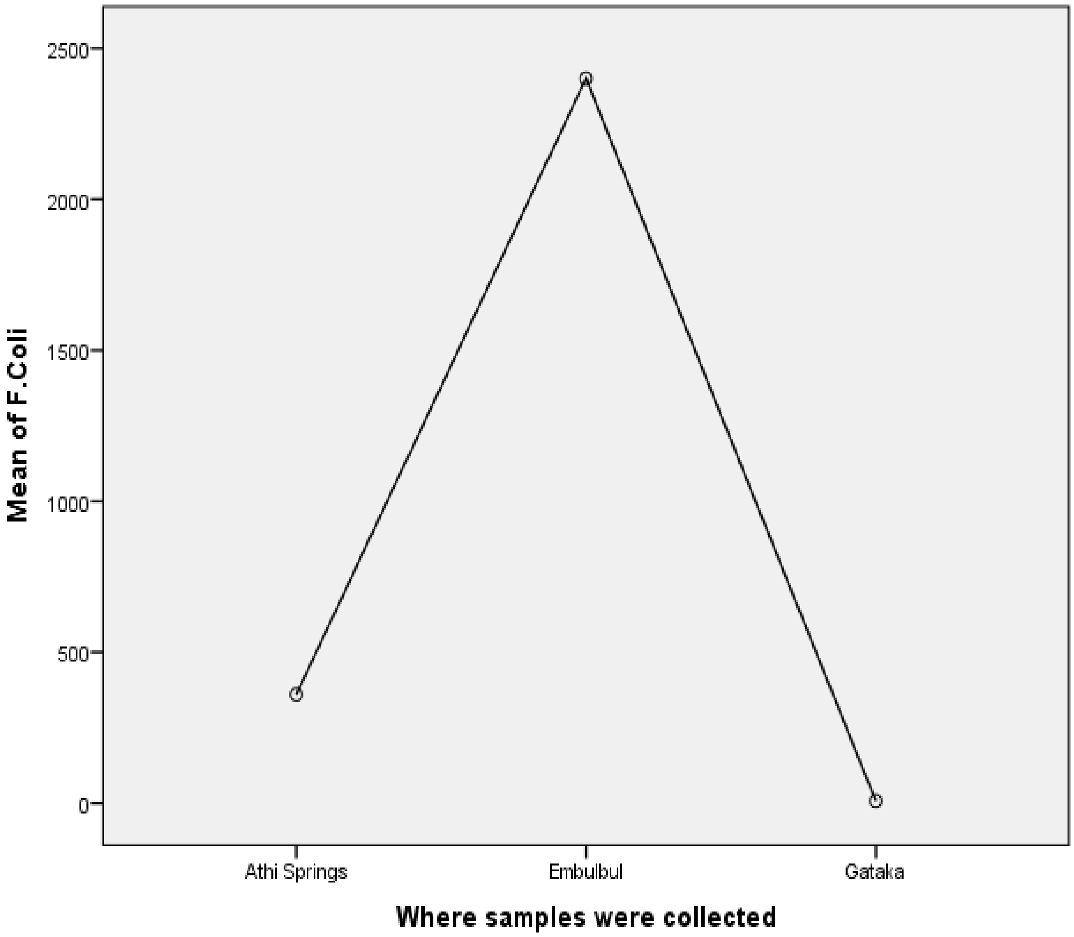

Figure 4.2: *Faecal Coliforms*

High fecal coliform counts in Embulbul could be attributed to the drainage of sewage into the river while at the Athi springs, it could also be attributed to the animal waste dropped as the animals drink water. The river passes through a section of Oloolua forest where purification process takes place, and the process is responsible for the low count at Gataka (Table 4.3).

These results are supported by previous studies done in River Awash Ethiopia, whose count was above 760MPN/100ml (Kebede *et al.,* 2020), River Frutal in Brazil which had above 500 MPN/100ml (Bjorklund, 2015) and Gondar town rivers and streams in Ethiopia, whose counts ranged between 42 MPN/100ml to 469MPN/100ml (Tessema *et al.,* 2019).

4.3 Land Use and Land Cover Analysis

To determine the land use and land cover changes over the years, satellite images of the land 5KM along the river were downloaded, and analyzed using the GIS software (Arc GIS version 10.4) in percentages. Land use and land cover maps were used to determine the spatial distance and grouping of land use and land cover classes in the area. The decrease in forest cover was linked to substantial increase in the area occupied by the agricultural fields and urban areas.

2005 LULC

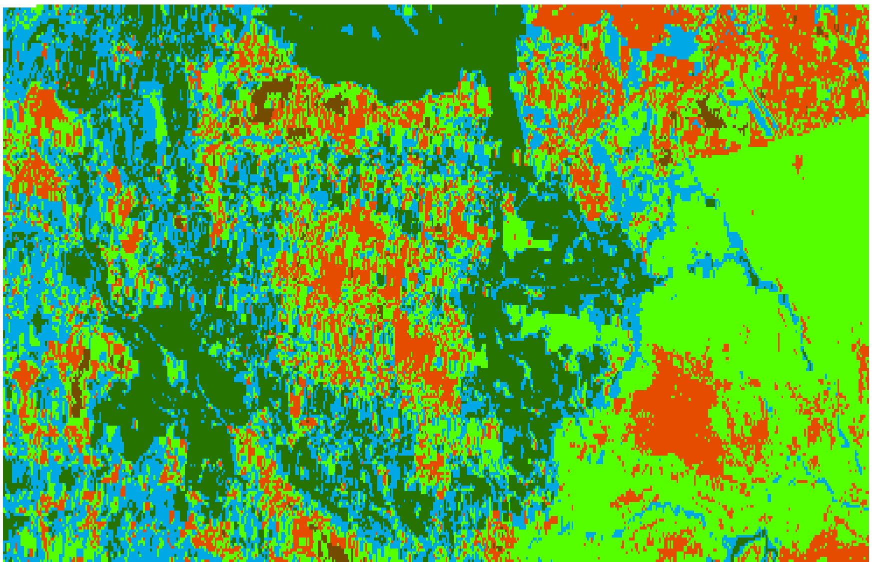

__Figure 4.3:__ Land Use and Land Cover in 2005 (Arc GIS, Version 10.4)

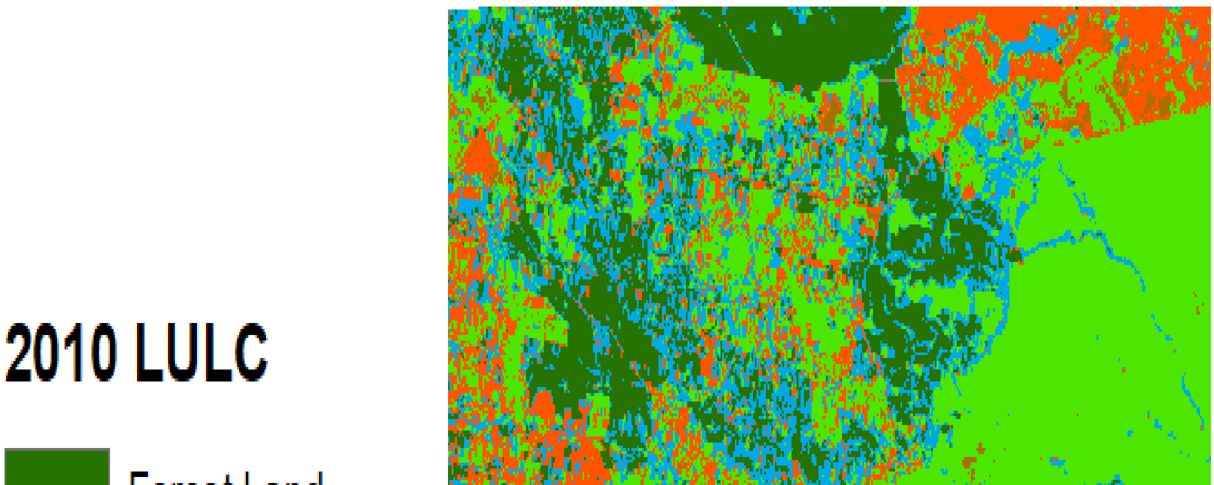

Figure 4.4: *Land Use and Land Cover in 2010 (Arc GIS, Version 10.4)*

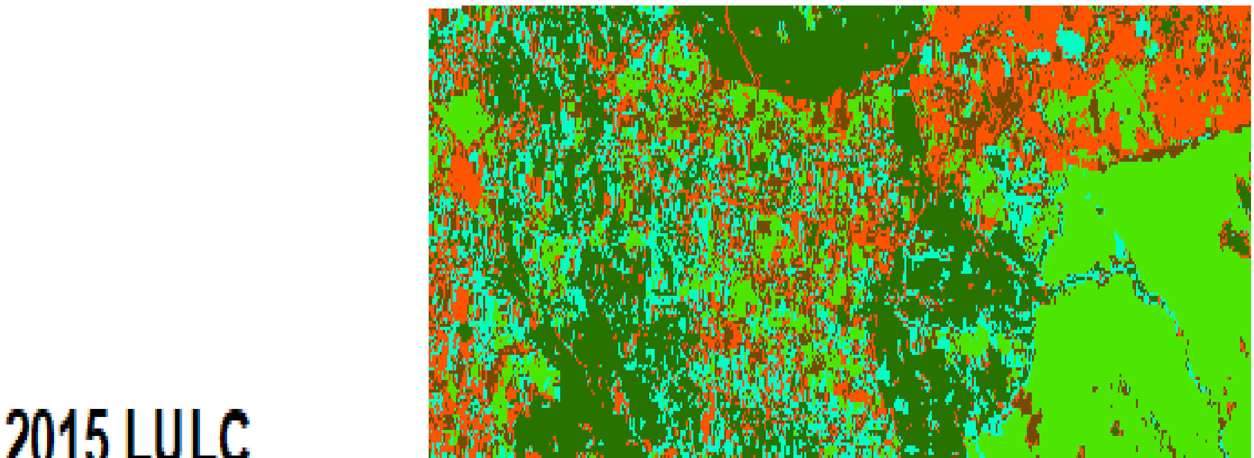

Figure 4.5: *Land Use and Land Cover in 2015 (Arc GIS, Version 10.4)*

2017 LULC

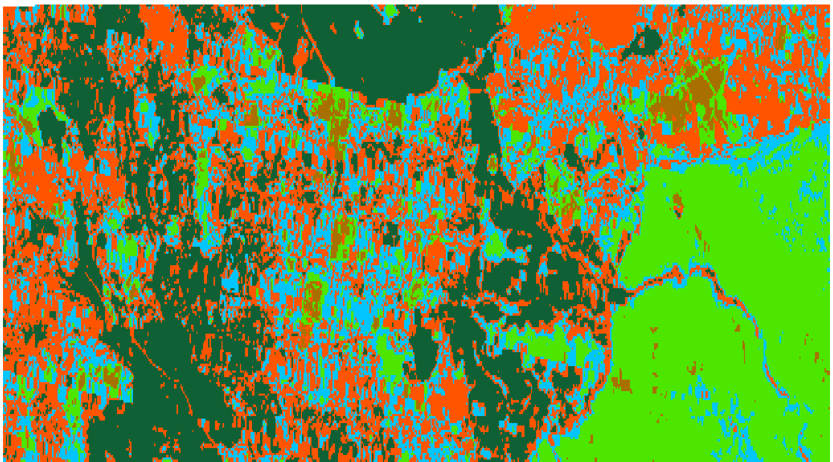

Figure 4.6: *Land Use and Land Cover in 2017 (Arc GIS, Version 10.4)*

Table 4.4: Total percentage (%) Change of Land Uses 2005-2010

	Area in 2005	**Area in 2010**	**Total Area**	**Change in 2005-2010**	**% Change**
Cultivated Land	116.28	158.95	275.23	42.67	15.50
Forest land	41	31.53	72.53	-9.47	-13.05
Water area	62.18	38.5	100.68	-23.68	-23.52
Built up area	50.78	65.81	116.59	15.03	12.89
Bare Land	44.07	19.52	63.59	-24.55	-38.61
TOTAL	314.31	314.31			

Table 4.5: Total percentage (%) Change of Land Uses 2010-2015

	Area in 2010	Area in 2015	Total Area	Change in 2010-2015	% Change
Cultivated Land	158.95	109.77	268.72	-49.18	-18.30
Forest land	31.53	44.46	75.99	12.93	17.02
Water area	38.5	36.06	74.56	-2.44	-3.28
Built up area	65.81	60.03	125.84	-5.78	-4.59
Bare Land	19.52	64	83.52	44.48	53.26
TOTAL	314.31	314.31			

Table 4.6: Total percentage (%) Change of Land Uses 2015-2017

	Area in 2015	Area in 2017	Total Area	Change in 2015-2017	% Change
Cultivated Land	109.77	67.69	177.46	-42.08	-23.71
Forest land	44.46	41.11	85.57	-3.35	-3.91
Water area	36.06	59.13	95.19	23.07	24.24
Built up area	60.03	90.74	150.77	30.71	20.01
Bare Land	64	55.64	119.64	-8.36	-6.99
TOTAL	314.31	314.31			

Change = Area 1 – Area 2

% Change = (Change ⁄ Total Area) × 100

The results showed that during year 2005 and 2010, cultivated land increased by 15.50% (Table 4.4), while forest land decreased by 13.05% (Table 4.4). At the same time, water area decreased by 23.52% (Table 4.4), built up area increased by 12.89% (Table 4.4) and bare land decreased by 38.61% (Table 4.4). Between years 2010-2015, cultivated land decreased 18.30% (Table 4.5), forest land increased by 17.01% (Table 4.5), water area decreased by 2.27% (Table 4.5), built up areas decreased by 4.59% (Table 4.5) and bare land increased by 53.26% (Table 4.5). In the period between 2015 and 2017, cultivated land decreased by 23.71% (Table 4.6), forest land decreased by 3.91% (Table 4.6), water area increased by 24.24% (Table 4.6), built up area increased by 20.37% (Table 4.6) and bare land decreased by 6.99% (Table 4.6).

All the study periods were found to be characterized by decrease in cultivated land, water bodies, bare land and forests. However, there was an increase in built-up areas. The water bodies in the region have decreased over the years indicating a high demand of water. With more built up areas, the demand grows and the supply has reduced due to the reduced forested area. More forested land is cleared for cultivation and infrastructure development. Between 2005 and 2010, the cultivated land was still in use but with the decreased water, cultivation also reduced and built area started occupying the previously cultivated area. The forested area has also been encroached, due to search for more space.

The results are similar to a study done in the Nawuni catchment area in Ghana (Tahiru *et al.*, 2020) and Chaohu lake basin in China (Huang *et al.*, 2013)

4.4 Correlation Analysis

Water quality (physico-chemical and bacteriological) and its degree of pollution were assessed in relation to the standards defined and recommended by the World Health Organization.

Table 4.7: Correlation analysis of water parameters

	BOD	COD	$N0_3$	PO_3	T.C	F.C	Temp	pH	TDS	Turbidity
BOD	1	0.93*	0.87**	0.60*	-0.84	-0.51	0.45	0.45	0.62*	0.87**
COD	0.93*	1	0.95**	0.44	-0.92	-0.47	0.33	0.57	0.76*	0.96**

NO_3	0.86*	0.95*	1	0.39	-0.90	-0.26	0.18	0.66*	0.88*	0.97**
PO_3	0.60*	0.44	0.39	1	-0.12	-0.11	0.83**	0.51	0.37	0.26
T.C	-0.84*	-0.92*	-0.92**	-0.12	1	0.61*	-0.05	-0.36	-0.69*	-0.97**
F.C	-0.51	-0.47	-0.26	-0.11	0.61*	1	-0.99	0.39	0.12	-0.45
Temp	0.45	0.32	0.18	0.83**	-0.05	-0.09	1	0.26	0.19	0.15
pH	0.45	0.57	0.66*	0.51	-0.36	0.39	0.26	1	0.85*	0.52
TDS	0.62*	0.76*	0.88**	0.37	-0.69*	0.12	0.19	0.85*	1	0.82**
Turbidity	0.87*	0.96*	0.97*	0.26	-0.97**	-0.45	0.15	0.52	0.82*	1

Total coliforms had a negative correlation with all other parameters except fecal coliform, while fecal coliforms had a negative correlation with other parameters except pH and TDS (Table 4.7). From the above correlations, majority of the parameters had a significant correlation of either $p < 0.01$ or $p < 0.05$ (Table 4.7).

Table 4.8: Correlation analysis of selected water parameters and Land uses

	Cultivated area	**Forested area**	**Watered area**	**Built-up area**
BOD	.945	-.953	.518	.838
COD	.978	-.908	.408	.764
Phosphates	.757	-.215	-.480	-.051
Nitrates	.999*	-.771	.163	.575
Total Coliforms	-.944	.954	-.521	-.840

Fecal Coliforms	-.313	.819	-.994*	-.942
Cultivated area	1	-.801	.210	.614
Forested area	-.801	1	-.754	-.964
Watered area	.210	-.754	1	.901
Built up area	.614	-.964	.901	1

Biological oxygen demand and chemical oxygen demand had a negative correlation with forested area and a positive correlation with all other land uses (Table 4.8). This is attributed to the level of pollutants in forested areas. The forests carry-out the natural purification process from pollutants in water, hence less pollutants. As a result, the amount of oxygen needed to break down pollutants is minimal(Gülbaz, 2014). Phosphates had a negative correlation with all other land uses except the cultivated land, while nitrates had a negative correlation with forested area (Table 4.8). It could be attributed to the use of fertilizers in farming. The amount of nutrients increases with an increase in cultivation practices and a reduction in forested areas(Joshua *et al.*, 2018). Total coliforms and fecal coliforms had a negative correlation with all other land uses except the forested area (Table 4.8). This is as a result of the moisture content in the forests. Coliforms tend to exist better in soil moisture content that is high. As a result, due to the humid conditions experienced in forests, the coliforms will survive longer in such conditions. When the moisture content reduced, the coliform survival rate also reduce (Kebede *et al.,* 2020).

The parameters co-related in different points and also had a correlation with the land use changes. The increasing human activities alongside the river, have a huge impact on the water quality. Embulbul and Gataka which are experiencing an influx of people, has led to a change in the water quality. According to tables 4.1 and 4.2, the mean concentrations are increasing downstream. It is a clear indication of more channel engineered activities from the population. Other than table 4.3, which has a slight difference on the mean concentration, the concentrations are still above the WHO recommended limits.

The physico-chemical and bacteriological parameters have a significant relationship. With an increase in the physico-chemical and bacteriological parameters downstream, it was in relation with the kind of anthropogenic activities taking place on each point. The correlation between the physico-chemical and bacteriological parameters is similar to a study done in the streams of Gondor town, Ethiopia (Tessema *et al.*, 2019).

In relation to land use changes, there is a relationship between the water quality and the land use changes. Land use within watershed has been found to have huge impacts on water quality. The water quality may deteriorate due to alterations in the land cover patterns forced by human activities (Huang *et al.*, 2013). Over the years, the reduction of forest and water areas for built and cultivated area, has led to a reduction in the water quality. With more cutting down of trees, development of infrastructure and population growth, the water quality is deteriorating. With less vegetation, the soils are left loose and the probability of soil erosion rises. With high soil erosion rates, the TDS will rise and turbidity will be high. The deterioration is caused by the lack of enough trees to clean the river waters and channel engineering techniques. The water levels have also been affected because many people are drawing water from the river. In addition, with the encroachment of the forested areas, the water catchments are destroyed. This is evidenced by the increased built area over the years, and a reduction in the forest and water areas.

The study results are similar to Awash River study in Ethiopia (Kebede *et al.*, 2020), Nawuni water catchment area in Ghana (Tahiru *et al.*, 2020), Impacts of land changes, kajiado (Maina & Mundia, 2016)and Chaohu lake basin in China (Huang *et al.*, 2013).

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The study focused on three objectives on which summary, discussions, conclusions and recommendations are aligned to.

5.2 Summary

The results of the study indicated that the quality of the water of the study river did not meet expectations in terms of COD, phosphates and turbidity. These parameters had higher values greater than WHO recommended standards for drinking water. The results also revealed that the water was bacteriologically contaminated with both total coliforms and fecal coliforms which are enteric in nature. The presence of TCs in water indicates actual contamination with feaces (human and animal) and potential contamination by disease-causing pathogens of all kinds.

Land use and land cover (LULC) changes are a threat to water quality, and aquatic biodiversity in many watersheds across the globe. Forest, agricultural, and urban-settlement land uses were used to representatives of the human disturbance gradient on how these land use affect water quality and community structure. Conversion of land to farm land was one of the primary mode of human adjustment of the environment. It was evident that there has been a significant land-use and land cover change in the sub-catchment. There were clear differences in relationships between water quality characteristics and the land uses. From the correlational analysis results, there is a spatial relationship between land activities and water quality.

5.3 Conclusions

1) From the study area, it is clear that the levels COD, turbidity and phosphates were higher than the recommended WHO standards. However, temperature, pH, total dissolved solids (TDS) and nitrates were within the World Health Organization drinking water standards.
2) The results revealed that the river has microbiological contamination in-terms of fecal and total coliforms as it exceeded the WHO standards. The hotspot area is Embulbul which had the highest recording of bacterial contamination.
3) The decline in forest cover is almost equivalent to the increase in the built areas. A decline in water areas was in relation to the decline of forest cover. The cultivated land was in relation with the water areas. A reduction in the water areas, resulted to a reduction in the cultivated land but an increase in built up areas. The water quality parameters varied across forest land, agricultural, and urban-settlement land uses, therefore land use changes did not affect the water quality.

5.4 Recommendations

Following the findings of this research, various recommendations are suggested in order to curb the deterioration of water quality and to safeguard the health of the residents along Mbagathi River

Research Recommendations

1. Mandatory requirement of all households and industries to have a waste management mechanism and should also have good farming practices to reduce agricultural run-off.

2. Provision of adequate and suitable sanitation, and provision of clean and safe drinking water. This will safeguard the health of the residents living along Mbagathi River.
3. Monitoring of land cover cover changes in all watershed through techniques such as remote sensing to conserve and protect the riparian regions from degradation and destruction.

Policy Recommendations

1. Development of a waste disposal policy within the regions
2. Development of agricultural policies on farming along the river
3. Development of land use and land cover policies

5.5 Future Research

1) There is a need for further research on this area on seasonal variation of water quality in the larger Ngong Region.
2) There is also need for further research on the impact of contaminated groundwater on human health in the locations.
3) There is also the need to develop land-use scenarios to analyze the impact of land use change on the stream flow using hydrological models basing on the future scenarios.

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APPENDIX

FIELD DATA COLLECTION

SAMPLING SHEET RECORD

29th October 2020

PARAMETERS	ATHI SPRINGS	EMBULBUL	GATAKA
Temperature	20.2	17.3	17.6
pH	7.14	7.5	7.5
TDS	417	456	478
Turbidity	1.8	14.6	99.9

10th December 2020

PARAMETERS	ATHI SPRINGS	EMBULBUL	GATAKA
Temperature	19.9	18.6	19.1

pH	7.24	7.5	7.4
TDS	421	470	490
Turbidity	2.5	16.3	103.2

4th February 2021

PARAMETERS	ATHI SPRINGS	EMBULBUL	GATAKA
Temperature	22.3	23.1	24.2
pH	7.4	7.6	7.6
TDS	435	480	497
Turbidity	4.3	33.6	110.4

3rd March 2021

PARAMETERS	ATHI SPRINGS	EMBULBUL	GATAKA
Temperature	20.9	22.5	22.6
pH	7.3	7.5	7.5
TDS	419	473	483
Turbidity	2.3	29.6	107.8

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KEWI/LAB/FC/180-RESEARCH LAB

WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL604/2020**
Source: **Embulbul**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **04-02-2021**
Date Received: **04-02-2021**
Date Analysis Started: **04-02-2021**
Sample Submission Form: **604**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	5.0	Max 30	Max 500
COD	mg/l	22.9	Max 50	Max 1000
Nitrates	mg/l	**40.1**	Max 20	45
Phosphates	mg/l	4.5	Max 30	Max 30
Total Coli form	TC/100mls	**> 2400**	< 3	**<10**
Feacal Coli form	Tc/100mls	**> 2400**	Nil	Nil

ND:Not Detectable

COMMENTS/REMARKS: The sample performed as shown

This Report refers to a privately submitted sample, and all details in respect of the source and test results of similar products are not verified or confirmed.

For Director [signature] ....**Date** 25/02/2021

Kenya Water Institute
Water Quality Laboratory

KENYA WATER INSTITUTE

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P. O. Box 60013-00200, Nairobi

When replying please quote

KEWI/LAB/FC/180-RESEARCH LAB

WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL602/2020**
Source: **Gataka**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **04-02-2021**
Date Received: **04-02-2021**
Date Analysis Started: **04-02-2021**
Sample Submission Form: **602**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	11.5	Max 30	Max 500
COD	mg/l	38.3	Max 50	Max 1000
Nitrates	mg/l	**65.0**	Max 20	45
Phosphates	mg/l	6.0	Max 30	Max 30
Total Coli form	TC/100mls	200	<3	<10
Feacal Coli form	Tc/100mls	10	Nil	Nil

ND:Not Detectable

COMMENTS/REMARKS: The sample performed as shown

This Report refers to a privately submitted sample, and all details in respect of the source and test results of similar products are not verified or confirmed.

For Director .... Date 25/02/2024

Kenya Water Institute
Water Quality Laboratory

KENYA WATER INSTITUTE DIRECTOR KEWI P.O. Box 60013 NAIROBI

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KEWI/LAB/FC/180-RESEARCH LAB

WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL603/2021**
Source: **Gitwe (Athi Spring)**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **04-02-2021**
Date Received: **04-02-2021**
Date Analysis Started: **04-02-2021**
Sample Submission Form: **603**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	5.0	Max 30	Max 500
COD	mg/l	18.7	Max 50	Max 1000
Nitrates	mg/l	25.0	Max 20	45
Phosphates	mg/l	3.0	Max 30	Max 30
Total Coli form	TC/100mls	>2420	<3	<10
Feacal Coli form	Tc/100mls	380	Nil	Nil

ND:Not Detectable

COMMENTS/REMARKS: The sample performed as shown

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For Director .... Date 25/02/2021

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KEWI/LAB/FC/201 RESEARCH LAB

WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL720/2021**
Source: **Gataka**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **03-03-2021**
Date Received: **03-03-2021**
Date Analysis Started: **03-03-2021**
Sample Submission Form: **720**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	14.9	Max 30	Max 500
COD	mg/l	38.0	Max 50	Max 1000
Nitrates	mg/l	68.0	Max 20	45
Phosphates	mg/l	6.8	Max 30	Max 30
Total Coli form	TC/100mls	250	<3	<10
Feacal Coli form	Tc/100mls	13	Nil	Nil

ND: Not Detectable
COMMENTS/REMARKS: The sample performed as shown
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For Director ....Date 06/04/2021

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Water Quality Laboratory

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KEWI/LAB/FC/201-RESEARCH LAB

WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL722/2021**
Source: **Embulbul**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **03-03-2021**
Date Received: **03-03-2021**
Date Analysis Started: **03-03-2021**
Sample Submission Form: **722**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	5.0	Max 30	Max 500
COD	mg/l	21.0	Max 50	Max 1000
Nitrates	mg/l	**43.7**	Max 20	45
Phosphates	mg/l	5.0	Max 30	Max 30
Total Coli form	TC/100mls	**> 2400**	< 3	**<10**
Feacal Coli form	Tc/100mls	**> 2400**	Nil	Nil

ND:Not Detectable

COMMENTS/REMARKS: The sample performed as shown

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For Director .... **Date** 06/04/2021

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WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL721/2021**
Source: **Gitwe (Athi Spring)**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **03-03-2021**
Date Received: **03-03-2021**
Date Analysis Started: **03-03-2021**
Sample Submission Form: **721**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	4.7	Max 30	Max 500
COD	mg/l	20.0	Max 50	Max 1000
Nitrates	mg/l	25.5	Max 20	45
Phosphates	mg/l	3.0	Max 30	Max 30
Total Coli form	TC/100mls	> 2420	< 3	<10
Feacal Coli form	Tc/100mls	395	Nil	Nil

ND:Not Detectable

COMMENTS/REMARKS: The sample performed as shown

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For Director .... **Date** 06/04/2021

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KEWI/LAB/FC/139-RESEARCH LAB

WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL560/2020**
Source: **Gataka**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **10-12-2020**
Date Received: **10-12-2020**
Date Analysis Started: **10-12-2020**
Sample Submission Form: **560**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	7.4	Max 30	Max 500
COD	mg/l	30.6	Max 50	Max 1000
Nitrates	mg/l	**56.2**	Max 20	45
Phosphates	mg/l	0.24	Max 30	Max 30
Total Coli form	TC/100mls	**133**	<3	<10
Feacal Coli form	Tc/100mls	3	Nil	Nil

ND:Not Detectable

COMMENTS/REMARKS: The sample performed as shown

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For Director .... **Date** 04/01/2021

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KEWI/LAB/FC/139-RESEARCH LAB

WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL562/2020**
Source: **Embulbul**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **10-12-2020**
Date Received: **10-12-2020**
Date Analysis Started: **10-12-2020**
Sample Submission Form: **562**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	2.8	Max 30	Max 500
COD	mg/l	15.0	Max 50	Max 1000
Nitrates	mg/l	33.43	Max 20	45
Phosphates	mg/l	1.8	Max 30	Max 30
Total Coli form	TC/100mls	> 2400	< 3	<10
Feacal Coli form	Tc/100mls	> 2400	Nil	Nil

ND:Not Detectable

COMMENTS/REMARKS: The sample performed as shown

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For Director .... **Date** 04/01/2021

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KEWI/LAB/FC/139-RESEARCH LAB

WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL561/2020**
Source: **Gitwe (Athi Spring)**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **10-12-2020**
Date Received: **10-12-2020**
Date Analysis Started: **10-12-2020**
Sample Submission Form: **561**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULT	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2007)
BOD	mg/l	2.8	Max 30	Max 500
COD	mg/l	12.0	Max 50	Max 1000
Nitrates	mg/l	**21.5**	Max 20	45
Phosphates	mg/l	0.9	Max 30	Max 30
Total Coli form	TC/100mls	**> 2400**	<3	<10
Feacal Coli form	Tc/100mls	320	Nil	Nil

ND:Not Detectable
COMMENTS/REMARKS: The sample performed as shown
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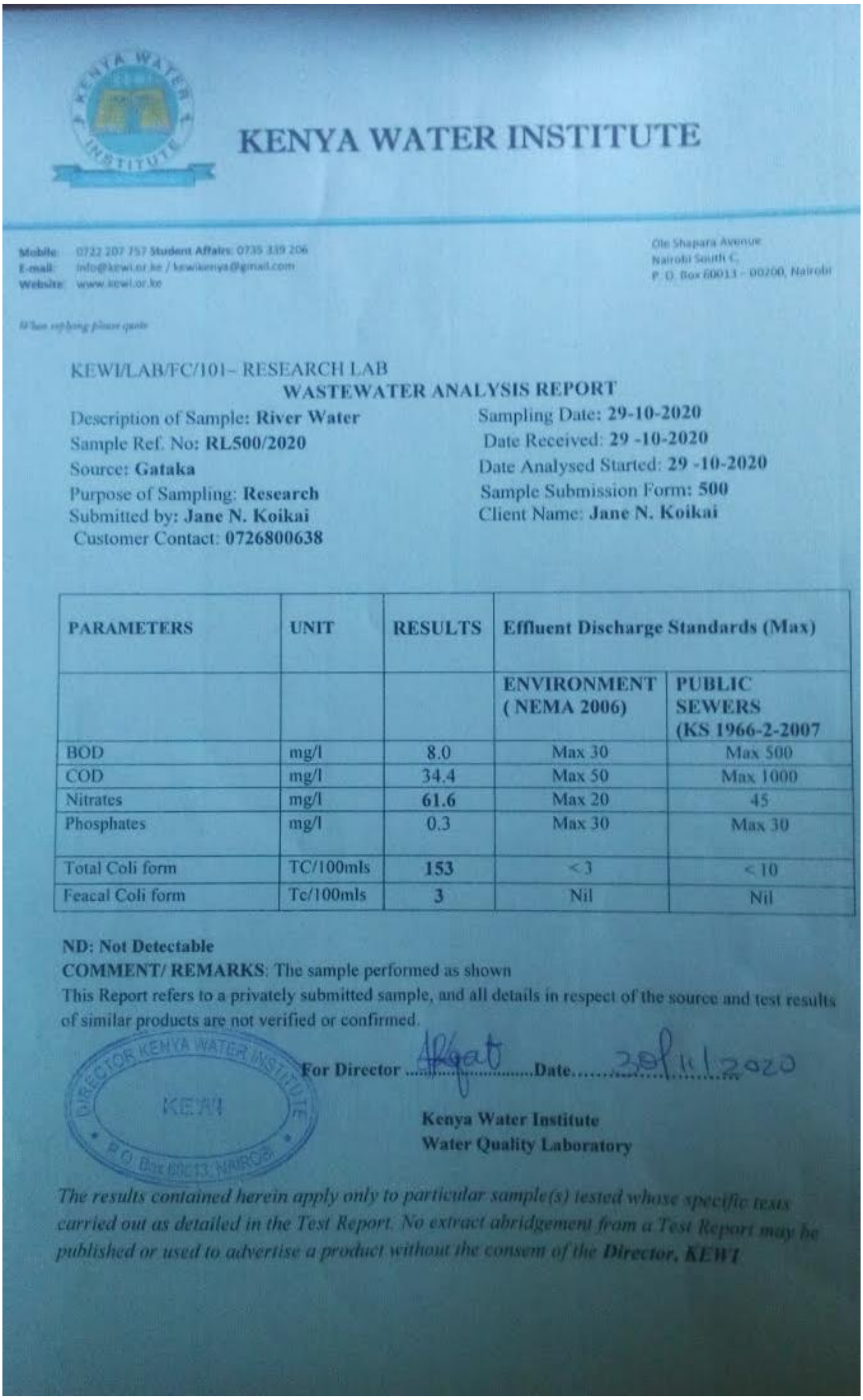

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WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL500/2020**
Source: **Gataka**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **29-10-2020**
Date Received: **29 -10-2020**
Date Analysed Started: **29 -10-2020**
Sample Submission Form: **500**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULTS	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2-2007
BOD	mg/l	8.0	Max 30	Max 500
COD	mg/l	34.4	Max 50	Max 1000
Nitrates	mg/l	**61.6**	Max 20	45
Phosphates	mg/l	0.3	Max 30	Max 30
Total Coli form	TC/100mls	**153**	<3	<10
Feacal Coli form	Tc/100mls	**3**	Nil	Nil

ND: Not Detectable

COMMENT/ REMARKS: The sample performed as shown

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For Director .... **Date** 30/11/2020

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WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL502/2020**
Source: **Embuibui**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **29-10-2020**
Date Received: **29 -10-2020**
Date Analysed Started: **29 -10-2020**
Sample Submission Form: **502**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULTS	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2-2007
BOD	mg/l	3.0	Max 30	Max 500
COD	mg/l	15.9	Max 50	Max 1000
Nitrates	mg/l	**36.96**	Max 20	45
Phosphates	mg/l	2.1	Max 30	Max 30
Total Coli form	TC/100mls	**> 2400**	< 3	< 10
Feacal Coli form	Tc/100mls	**> 2400**	Nil	Nil

ND: Not Detectable

COMMENT/ REMARKS: The sample performed as shown

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DIRECTOR KENYA WATER INSTITUTE
KEWI
P.O. Box 60013, NAIROBI

For Director ....[signature].......... **Date**.......30/11/2020.......

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WASTEWATER ANALYSIS REPORT

Description of Sample: **River Water**
Sample Ref. No: **RL501/2020**
Source: **Gitwe (Athi Spring)**
Purpose of Sampling: **Research**
Submitted by: **Jane N. Koikai**
Customer Contact: **0726800638**

Sampling Date: **29-10-2020**
Date Received: **29 -10-2020**
Date Analysed Started: **29 -10-2020**
Sample Submission Form: **501**
Client Name: **Jane N. Koikai**

PARAMETERS	UNIT	RESULTS	Effluent Discharge Standards (Max)	
			ENVIRONMENT (NEMA 2006)	PUBLIC SEWERS (KS 1966-2-2007
BOD	mg/l	3.0	Max 30	Max 500
COD	mg/l	12.9	Max 50	Max 1000
Nitrates	mg/l	**22.0**	Max 20	45
Phosphates	mg/l	1.5	Max 30	Max 30
Total Coli form	TC/100mls	**> 2420**	<3	< 10
Feacal Coli form	Tc/100mls	**345**	Nil	Nil

ND: Not Detectable

COMMENT/ REMARKS: The sample performed as shown

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