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WATER QUALITY OF THE SOUTHERN GULF OF LAKE TANA USING INDICATOR BACTERIA AND PHYSICOCHEMICAL PARAMETERS

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MSc. Thesis

By

Belayneh Daniel

August 2018

Bahir Dar University, Ethiopia

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WATER QUALITY OF THE SOUTHERN GULF OF LAKE TANA USING INDICATOR BACTERIA AND PHYSICOCHEMICAL PARAMETERS

A thesis Submitted to the College of Science, School of graduate Studies

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In Partial Fulfillment of the Requirements for the degree of

MASTER OF SCIENEC IN BIOLOGY (APPLIED MICROBIOLOGY)

By

Belayneh Daniel

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Bahir Dar University, Ethiopia

THESIS APPROVAL SHEET

As a thesis research advisor, I certify that I have read and evaluated this thesis prepared, under my guidance by Mr Belayneh Daniel Tebore entitled "Assessment on Water Quality of the Southern Gulf of Lake Tana using Indicator Microorganisms and other Physicochemical Parameters West Gojjam, Ethiopia" and I recommended the paper to be submitted as fulfilling the requirement for the Degree of Master in Biology in the field of Applied Microbiology

………………………….	…………………	………………….
Name of advisor	Signature	Date

As members of the board examiners for the MSc thesis open defense examination. We certify that we have read and evaluate the thesis prepared by Mr Belayneh Daniel Tebore and examined the candidate. We recommend the thesis to be accepted as fulfilling requirement for the degree of MSc in Biology in the field of applied Microbiology.

1.	……………………………	……………….	………………….
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DECLARATION

I the undersigned; declare that the project comprises my own work. In compliance with initially accepted practices, I have duly acknowledged and referenced all materials all materials used in this work. I understand the non-adherence to the principle of academic honesty and integrity.

Misrepresentation /fabrication of any data/ date/ fact/ source will constitute sufficient ground for disciplinary action by the university and can also evoke penal action from the source which have not been cited or acknowledge.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variances
APHA	American Public Health Association
ASTM	A Standard Test Method
BOD	Biological Oxygen Demand
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
EC	Electrical Conductivity
EEPA	Ethiopian Environmental Protection Authority
FAO	Food and Agricultural Organization
FC	Fecal Coliform
FS	Fecal Stereptococci
ISO	International Organization for Standardization
MPN	Most Probable Number
MPCA	Minnesota Pollution Control Agency
NHMRC	National Health and Medical Research Council
NRMMC	National Resource Management Ministerial Council
TC	Total Coliform
TDS	Total Dissolved Solids
UNEP	United Nation Environmental Program
UNFPA	United Nations Population Fund
UNICEF	United Nations Children Emergency Fund
USEPA	United States Environmental Protection Authority
WHO	World Health Organization

ABSTRACT

Lake Tana water resource is of crucial importance serving multiple purposes and having largest surface area with fresh water body in Ethiopia. However, Lake Tana is facing water quality problem due to pollution caused by anthropogenic influences. This study was undertaken to assess water quality of the Southern gulf of Lake Tana using indicator microorganisms and some physicochemical parameters. A total of 48 water samples were collected from water of Southern gulf of Lake Tana. In this study, sites were selected purposely and sampling was taken seasonally dividing into wet and dry seasons. Indicator microorganisms (total and fecal coliforms) and some physicochemical parameters such as pH, Temperature, EC, TDS, Turbidity, NO_3^-, PO^-_4, NH_4, DO and BOD5 were determined to estimate pollution status in different sites. In the present study, total coliforms and fecal coliforms were enumerated using a multiple tube fermentation technique with MacConkey broth as the presumptive medium, eosine methylene blue (EMB) agar as the confirmatory medium. In this study counts of fecal coliforms were 1 MPN/100ml to 1600 MPN/100ml with lowest and highest mean value of 1MPN/100 ml at S8 to 1076.5±3.1 MPN/100ml at S4 with significant $p<0.05$ and total coliforms counts were also ranges 1 MPN/100ml to 1600 MPN/100ml with mean value of 4.8±1.81 MPN/100ml at SR6 to 1600 MPN/100ml at S4 and SR8 with significant $p<0.05$. Most of high count of total and fecal coliforms in this study was recorded during wet season. Physicochemical parameters of this study showed that some of parameters were under the group that made the lake was not polluted, but some parameters where in the group that informs the lake was deteriorated. Although there was significant variation in most of the physicochemical parameters on season and sites, some of the physicochemical parameters were insignificant to sites and revealed some contamination both dry and wet seasons. Generally, southern gulf of Lake Tana water also showed that some of the parameters were within the limits of USEPA and EEPA some were exceeded the limits which depict occurrence of pollution. Therefore, undertaking constructive management action and giving attention is needed for this anthropogenic interference which causing Southern gulf of Lake Tana water was polluted.

Key word: Bacteria, Lake Tana, pollution, physicochemical,

1. INTRODUCTION

1.1 Background of the study

Lake Tana which is largest lake in the country, its quality is liable to impairment likewise other lakes because of human induced activities. Agriculture inputs like pesticides, fertilizers and organic manure drain, wastewater from different institution, industries, residents, recreation centers and street runoff loaded directly into the lake (Dagew *et al*., 2013).

Bahir Dar city has a flat plateau earth structure which is located at11°36"North latitudes and 37°23"East longitudes. The naming of the city as Bahir Dar is connection with its 396 proximity to the two water bodies of Lake Tana and River Abay (Nile). Hence, literally Bahir Dar means a city situated on or very close to the shore of Lake Tana and Blue Nile. Today, it is one of the fast growing and largest cities in the country. In line with its growth, different service sectors such as education, health and transport and communication have grown. The city has expanded rapidly throughout the 20th century and today sewage discharge into Lake Tana has become a serious and highly visible problem (Matthew, 2011). At the same time, as the city modernizes, it is converting more and more land into streets, parking lots, hotels, etc., increasing the amount of surfaces that cannot absorb the seasonal rains in the area. This storm runoff overflows sewage systems and creates an influx of contaminated water entering Lake Tana (Aylew Wondie, 2009).

Nutrient enriched runoff from farmlands, pollutants from septic sewers and other human-related activities increase the flux of both inorganic and organic substances into water which cause an intense negative effect upon the quality of surface waters worldwide. Surface water bodies are most susceptible to pollution due to their accessibility for disposal of waste waters (Young *et al*., 1989; Etim and Obot, 2014).

It has been widely known that water contains a large numbers of chemical and physical parameters such as, ammonia, nitrate, phosphate, temperature of water, turbidity, transparency, total dissolved solids dissolved oxygen and biological oxygen demand as well as biological components which are known to influence aquatic ecosystem (Schowoerbel, 1972). Therefore, the study of physicochemical and microbiological characteristics could help in understanding the pollution in relation to its inhabitants. Lake is considered as the ecological barometers of the health of a region as they are playing an important role to regulate the micro-climate of any region, there by influencing the life of the people adjacent to it. The environmental conditions of any lake system depend upon the nature of that Lake and its exposure to various environmental factors. Hence, the surface water quality not only depends on natural phenomenon (precipitation inputs, erosion) but also on anthropogenic actions (urban, industrial and agricultural activities) (Papatheodorou *et al.*, 2006).

Pollution caused by toxic waste water, surface water runoffs from municipal, industrial and agricultural sources have increased pollution load and further limited healthy water resources and surface water quality management. Bearing this idea in mind it is inevitable to understand quality of surface water for various purposes such as use for drinking, industries, agriculture, recreation and related uses. Knowledge on point and non-point sources of pollution and pollutants in the region are also prerequisite for appropriate use of water (Oluduro and Aderiye, 2007).

Therefore, assessing the quality of lake water using indicator microorganisms and physicochemical parameters is of pivotal importance in combating the problems associated with pollution and deterioration of the Lake.

1.2. Statement of the problem

The deterioration of water quality has led to the destruction of ecosystem balance, contamination and pollution of ground and surface water resources. Quality of water can be regarded as a network of variables such as pH, oxygen concentration, temperature, etc. and any changes in these physical, chemical and microbial variables can affect aquatic biota in a variety of ways (Kolawole *et al*., 2011). Since the quality water is directly related to health and is important for determination of water utility, it is very essential and important to test the quality of the water before it is used for drinking, domestic, agricultural or industrial purposes. The utility of surface water like lake and river water for various purposes is governed by physicochemical and biological quality of the water. Not only this but also, quality of water is highly important component to understand the healthiness of a water body and it’s a critical factor affecting human health and welfare (Singh *et al*., 2013).

Seasonal variations in temperature, precipitation, surface runoff, ground water flow, and water interception and abstraction have significant effects on river discharge, and subsequently, on the concentration of pollutants in lake water (Marale *et al*., 2012). Other anthropogenic activities such as direct discharge of fecal materials into channels contaminate river and lake with pathogenic microorganisms (Sinha and Biswas, 2011). The resulting impacts of these factors add many nutrients, toxic substances and pathogens to water bodies. Subsequently, use of the contaminated water for domestic, agricultural, industrial or recreational purposes greatly affects public health (Susan, *et al*., 2017).

Ethiopia is one of the tropical countries, which is gifted with many forms of aquatic ecosystems, especially a number of lakes that are of great scientific interest and economic importance. Lake Tana water resource is of crucial importance serving multiple purposes and having largest surface area with fresh water body in Ethiopia. It has also been identified as growth corridor by the federal government. Even though it was a crucial resource, it receives urban surface runoffs, industrial and agricultural waste from the catchment and its quality has been affected by waste discharge from various activities around the region. Due to there is high population density and vast anthropogenic activities in the Southern gulf of Lake Tana that destruct quality of water, managing and ensuring the safety of lake from deterioration as well as pollution is needed with continuous research (Goraw *et al*., 2010).

Although some researches were done on the issue of impact of anthropogenic fecal pollution of Lake Tana by Goraw *et al*. (2010) and determination of surface water quality status and identifying potential pollution sources of Lake Tana by Dagnew *et al*. (2013), focusing on indicator microorganisms such as total coliform, fecal coliform and physicochemical parameters to assess quality of water on Southern Gulf of Lake in regular basis are much limited and investigations were not conducted in the sites we were specifically and purposely selected. Not only this, but also these researches were not enough as its water importance to community living around watershed and Lake Tana was still facing water quality problem due to pollutions.

Therefore this study was conducted to assess water quality status of the Southern gulf of Lake Tana using indicator microorganisms and other physicochemical parameters.

1.3 Significance of the Study

Findings of this study will provide valuable information that will serve as a platform for monitoring anthropogenic based faecal and organic pollution of Southern gulf of Lake Tana. The data obtained from this investigation may also assures current water quality of Lake Tana and serve as an important tool for the relevant authorities to enforce policies to ensure portability of Lake Tana water as well as control recurrence of Pollution.

1. 4 Objectives of study

1.4.1 General objective

The general objective of this study was to assess water quality of the Southern gulf of Lake Tana using indicator microorganisms and some physicochemical parameters.

1.4.2 Specific objectives

1. To examine indicator bacteria of the Southern gulf of Lake Tana using total coliforms and fecal coliforms

2. To determine physicochemical water quality of the Southern gulf of Lake Tana

3. To examine seasonal variation of indicator bacteria and physicochemical water quality parameters then to compare the study sites current status based on national and international standards for surface water quality

2. LITERATURE REVIEW

2.1. Water quality and its factors for deterioration

Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource; for example, high salinity is a frequent problem in arid and coastal areas (Stark *et al*., 2000).

Eutrophication results not only from point sources, such as wastewater discharges with high nutrient loads (principally nitrogen and phosphorus), but also from diffuse sources such as run-off from livestock feedlots or agricultural land fertilized with organic and inorganic fertilizers. Pollution from diffuse sources, such as agricultural runoff, or from numerous small inputs over a wide area, such as faecal pollution from unsewered settlements, is particularly difficult to control (Meyer *et al.*, 2005).

2.2 Indicator microorganisms

Indicator microorganisms are a basic monitoring tool used to measure both changes in environmental water quality or conditions, and the potential presence of hard to detect pathogenic organisms. Sometimes they are called bio indicators. They are known to be either particularly tolerant or particularly sensitive to pollution (Ronald *et al*., 1983). An indicator microorganism provides evidence of the presence or absence of a pathogenic microorganism that survives under similar physical, chemical, and nutrient conditions. Indicator microorganisms are used to assess the microbiological quality of water (Hijnen *et al*., 2000).

2.2.1 Coliform bacteria

Coliform bacteria are Gram-negative, rod-shaped, non-spore-forming, aerobic and facultative anaerobic bacteria that are able to grow in the presence of bile salts. They are diverse groups of bacteria include *Escherichia coli*, *Enterobacter, Klebsiella* and *Citrobacter a*nd belong to the family Enterobacteriaceae. They are always present in both polluted and non-polluted waters, soils and plants, as well as from the feces of warm blooded animals (Bitton, 2005). Total coliforms (TC) are coliforms which are common in the environment (soil or vegetables). They are generally harmless. They are able to ferment lactose to acid and gas within 24 h at 35±2^{o}C. TC cannot be used as an indicator for the sanitary quality of untreated raw water, for they are naturally abundant in the environment. On the other hand, fecal (thermotolerant) coliforms (FC) are subgroup of TC bacteria. They exist in the intestines and feces of people and animals. The organisms produce acid and gas from lactose at 44 - 45^{o}C. The presence of fecal coliform in water often indicates recent fecal contaminations (World Health Organization, 2011).

2.3. Physicochemical parameters and organic pollution of water

Organic pollution occurs when large quantities of organic compounds, which act as substrates for microorganisms, are released into water resources. During the decomposition process the dissolved oxygen in the receiving water may be used up at a greater rate than it can be replenished, causing oxygen depletion and having severe consequences for the stream biota (Laugeri and Hespanhol, 1990). Organic effluents also frequently contain large quantities of suspended solids which reduce the light available to photosynthetic organisms and, on settling out, alter the characteristics of the river and lake bed, rendering it an unsuitable habitat for many invertebrates. Toxic ammonia is often. Organic pollutants consist of proteins, carbohydrates, fats and nucleic acids in a multiplicity of combinations (Lennctech, 2017).

It is very essential and important to test the water for ecological and other purpose. Water must be tested with different physic-chemical parameters. Selection of parameters for testing of water is solely depends upon for what purpose we going to use that water and what extent we need its quality and purity (Singh *et al*., 2013). Water does content different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Some physical test should be performed for testing of its physical appearance such as temperature, color, odour, pH, turbidity, TDS etc, while chemical tests should be perform for its BOD, COD, dissolved oxygen, ammonia, nitrate, phosphate, alkalinity and other characteristics (Patil *et al*., 2012).

2.3.1 pH

Hydrogen ion concentration (pH) can determine the survival of microorganisms and the ionization of chemicals in the water (LeBlanc *et al*., 1997). This, in turns, affects the treatment efficiency of the water. In addition, the greater acidity of the water can be increasing corrosiveness of the pipelines and contaminate the water. Hence, the taste of the water can be changed and cause skin itching during swimming as well as bathing (Bitton, 2005).

2.3.2 Temperature

Microorganisms are able to survive in various temperature ranges from below freezing point temperature to boiling point (100^{o}C) of water temperature. The increasing of water temperature can enhance the growth of microorganisms, the disinfection demand, nitrification processes, and taste, odor, color and corrosion problems (World Health Organizations, 2008).

2.3.3 Electrical Conductivity

Electrical conductivity (EC) is the ability of a substance to conduct electricity. It is used to give an indication of the amount of inorganic materials in the water including, calcium, bicarbonate, nitrogen, phosphorus, iron, sulfur and others. The recommended EC value of drinking water is 1500 µȘ/cm (World Health Organizations, 1984).

2.3.4 Total dissolved solids

Total dissolved solids (TDS) also indicate the salinity behavior and the amount of other substances suspended and or dissolved in the water. These substances affect the sunlight reaching to submerged aquatic plant and consequently reduce photosynthesis and decrease the amount of dissolved oxygen released by aquatic plants. TDS and TSS also increase water temperature by absorbing heat from sunlight and thereby reduce dissolved oxygen further (Ho *et al*., 2003).

2.3.5 Turbidity

Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shone through the water sample (United State Environmental Protection Authority, 2012). Material that causes water to be turbid includes clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms (Crump *et al*., 2004). A standard for turbidity of surface water is not more than 5 Nephelometric Turbidity Units (NTU). Water with readings in this range will appear to be clear. To reach low levels of turbidity during water treatment, it is sometimes necessary to remove particles or suspended particulates by filtration, screening, or flocculation. Turbidity can provide food and shelter for pathogens (World Health Organizations, 2006)

2.3.6 Dissolved Oxygen

Dissolved oxygen (DO) refers to the amount of oxygen (O_2) dissolved in water. Because fish and other aquatic organisms cannot survive without oxygen, DO is one of the most important water quality parameters. DO is usually expressed as a concentration of oxygen in a volume of water (milligrams of oxygen per liter of water, or mg/L). In nature, oxygen from the atmosphere can be mixed into (diffused into) a body of water (World Health Organizations, 2011). The mixing is easiest where water is rough (for example, where water is tumbling over rocks or where there are waves). Oxygen is also introduced into water by green aquatic plants and algae during photosynthesis. Cold water holds more oxygen than warm water. For example, pure water at 4°C (40F) can hold about 13.2 mg/L DO at 100% saturation, while pure water at 25°C (77F) can hold only 8.4 mg/L at 100% saturation. Water with a high concentration of dissolved minerals cannot hold as much DO as pure water (Minnesota Pollution Control Agency, 2009).

2.3.7 Biological oxygen demand (BOD)

The biochemical oxygen demand of water or polluted water is the amount of oxygen required for the biological decomposition of dissolved organic matter to occur under standard condition at a standardized time and temperature (A Standard Test Method, 2012). Usually, the time is taken as 5 days and the temperature is 20°C. The test measures the molecular oxygen utilized during a specified incubation period for the biochemical degradation of organic material (carbonaceous demand) and the oxygen used to oxidize inorganic material such as sulfides and ferrous ion. It also may measure the amount of oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand). Efficiency of any treatment plant can be judged by considering influent BOD and the effluent BOD and so also the organic loading on the unit (Rasel *et al*., 2013).

2.3.8 Nitrate and Ammonia

Nitrate (NO3-) and ammonia (NH3+) are naturally occurring ions that are part of the nitrogen cycle. Nitrate can reach both surface and ground water as a consequence of agricultural activity, from wastewater treatment and from oxidation of nitrogenous waste product in human and animal excreta. This, in turns, it contaminates Lakes, rivers, streams and ground water. Nitrite can be formed either due to the oxidation of ammonium compounds or chemically in distribution pipes by *Nitrosomonas* bacteria during stagnation of nitrate-containing and oxygen-poor drinking water in galvanized steel pipes (World Health Organization, 2011).

Nitrate has generally no significant health hazard in small quantity. However, when the concentration of nitrate is above 50 mg/l can cause methemoglobinemia or 'blue-baby in infant and cancer in adult (World Health Organization, 1996). This condition occurs due to the conversion of the consumed nitrate into nitrite and the nitrite involve in the oxidation of normal hemoglobin to methemoglobin. It harms the infants by reducing the ability of blood to transport oxygen. Higher (> 1.5 mg/l) concentration of ammonia in drinking water can cause odor and taste problems. Moreover, a major concern with ammonia in drinking water is nitrification associated with the formation of nitrate and nitrites that can cause health problems at higher concentrations (World Health Organizations, 2011).

2.3.9 Phosphate

Introduction of high concentration of phosphate along with nitrate into surface water can stimulate the growth of aquatic plants and algae. This, in turns, results in depletion of dissolved oxygen and death of aquatic organisms. Phosphates are generally not toxic to people or animals unless they occur at a very high level. If the level of phosphate greater than 1.0 mg/l, it may interfere with coagulation in water treatment plant. Consequently, organic particles harboring microorganisms may not be completely removed before distributing the drinking water to the users (Murphy, 2007).

2.4. Microbial and physicochemical parameters pollution sources and effects on Lake Ecosystem

Lake pollution is one of the serious environmental problems in recent years with socio-economic development and pollutants discharge increase from industry, agriculture and domesticity. Increasing human populations and the expansion of industrial and agricultural activities have been important driving factors for the rapid deterioration of fresh water ecosystems. Water quality can be assessed by various physicochemical and microbial parameters such as, temperature, PH, TDS, turbidity, electrical conductivity, nitrate, phosphorus, potassium, dissolved oxygen, BOD5, fecal and total coliforms (Morse *et al.*, 2007). Microorganisms consist of approximately 60% of the Earth's biomass and are highly diverse in their morphology, biochemistry as well as functional aspects. Despite the acknowledged value of microorganisms, our understanding of their diversity and many of their key roles in sustaining life supporting systems is still very less (Sood *et al*., 2010).

The microbial contamination of water is often of fecal nature related to humans (water sewage treatment plants, combined sewage overflow (CSO), non-collective sewage systems), domesticated animals (manure spreading, pit stock overflow), or wildlife. The main origins of microbial contamination of natural aquatic resources are discharges of water treatment plants, decontamination stations, hospitals, industries considered as point sources, etc. Urban development is a factor that can affect bacterial counts of lakes because human and domestic animal waste, as potential sources of contamination, can increase with presence of urban development (McLellan and Jensen, 2003). Correlation between pathogens concentrations and urban activities is well documented. On the other hand, diffuse sources (slurry, manure, sludge application) may also be considered. The abundance and importance of pathogens in water depend on factors such as the contamination level, pathogens' persistence in water bodies, biological reservoirs (including aquatic plants and sediments) and the ability of pathogens to be transported. The land use management practices and the size of the watershed also influence the survival of microorganisms (Marsalek and Rochfort, 2004).

Fecal total coliforms contamination from human and animal waste not only contributes to the degradation of aquatic systems but also affects water quality, thereby posing a serious threat to human health from exposure to pathogenic bacteria, viruses, and protozoa and it can be determined by most probable number method (MPN/100ml) or membrane filtration method (Sinton *et a*l., 1998).

Therefore, it is very important to test the water before it is used for recreational, domestic, agricultural, industrial purpose. Water must be tested with different physicochemical parameters and microbial indicators. Selection of parameters for testing of water is solely depends upon for what purpose we going to use that water and what extent we need its quality and purity. Water does content different types of floating, dissolved, suspended and bacteriological impurities (Patil *et al*., 2012).

Most surface water or lake ecosystems are sensitive to changes in pH and therefore monitoring of pH has been incorporated into the environmental laws of most industrialized countries. The WHO (2006) standards recommend that lake water be in the pH range of 6.5-8.5. The pH of lake water body can be affected by different sources. First, it is affected by amount of plant growth and organic material within a body of water. When this material decomposes, carbon dioxide is released. The carbon dioxide combines with water to form carbonic acid (Nicolau *et al*., 2006).

Although this is a weak acid, large amounts of it will lower the pH. Secondly; many industrial processes require water of exact pH readings and thus add chemicals to change the pH to meet their needs. After use, this altered pH water is discharged as an effluent, either directly into a body of water or through the local sewage treatment plant. A third factor which determines the pH of a body of water is the dumping of chemicals into the water by individuals, industries, and communities. The excesses of dissolved metals in solution will negatively affect the health of the lake organisms as well as poison humans when such waters are used for domestic purposes (Agbozu *et al*., 2007).

The sources of impaired temperature is due to seasonal variations and can also be affected by weather, removal of shading stream bank vegetation, building dams around lake, discharging cooling water, discharging storm water, and groundwater influx. The optimal health of aquatic organisms from microbes to fish depends on temperature (Spellman and Drinan, 2012). If temperatures are outside the optimal range for a prolonged period, organisms are stressed and can die. For fish, the reproductive stage (including spawning and embryo development) is the most temperature-sensitive period. Macro invertebrates (for example, insects, crayfish, worms, clams, and snails) will move about in the stream bed to find their optimal temperature (Wade *et al*., 2002). The temperature of the water also affects the volume of dissolved oxygen (DO) it can hold (water's ability to contain dissolved oxygen decreases as water temperature rises), the form of ammonia (harmful or harmless to aquatic life), and the rate of photosynthesis by aquatic plants, metabolic rates of aquatic organisms, and the sensitivity of organisms to pollution (Melillo *et al.*, 2014).

Conductivity shows significant correlation with parameters such as temperature, pH value alkalinity, total hardness, calcium, total solids, total dissolved solids and chemical oxygen demand chloride and iron concentration of water. Storm water runoff, sewage effluents, catchment geology and agricultural effluents running into streams are sources and have a significant influence on the conductivity of water. A failing sewage system also would raise the conductivity because of the presence of chloride, phosphate and nitrate; an oil spill would lower the conductivity (Gupta and Paul, 2010).

The sources of increased TDS in the Lake can also result from runoff from roads that have been salted in the winter. Organic matter from wastewater treatment plants may contribute higher levels of nitrate or phosphate ions. If TDS levels are high, especially due to dissolved salts, many forms of life are affected. The salts act to dehydrate the skin of lake animals. Not only this but also, as levels of TSS increase, a water body begins to lose its ability to support a diversity of Lake life (Chapman *et al*., 2000). Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Some cold water species, such as trout and stoneflies, are especially sensitive to changes in dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in dissolved oxygen levels TSS can also destroy fish habitat because suspended solids settle to the bottom and can eventually blanket the river bed. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae (Scannell and Jacob, 2001).

Suspended solids can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in a diminished food sources, and increased difficulties in finding food. Natural movements and migrations of aquatic populations may be disrupted. TDS values in Lakes and streams are typically found to be in the range of 50 to 250 mg/L. In areas of especially hard water or high salinity, TDS values may be as high as 500 mg/L. It has great importance in water and wastewater treatment. It normally represents the amount of organics solids in water. It is helpful in assessing the amount biologically inert organic matter, such as lignin in case of wood pulping waste liquids (American Public Health Association, 2005).

Study done by Fitsum *et al*. (2015) also indicates the sources of surface water turbidity are due to improper disposal of sewage, surface runoff and wastewater from different domestic activities. Other study also done by Yirga Kebede (2016) revealed that the source of high turbidity of Lake Tana is due to catchment runoff, soil erosion, waste discharge from urban areas (Bahir Dar and Gonder), recession agriculture and poor farming practices around large quantities of top soil ending up in the rivers and Lake Tana after heavy rains.

Furthermore, sediment often tops the list of substances or pollutants causing turbidity. However, any watershed has multiple sources of the pollutants or physical features that can affect water clarity. These can be divided into natural or background, and human induced sources. Natural sources can include erosion from upland, riparian, stream bank, and stream channel areas however, this is difficult to measure due to agriculture and development activity (Korostynska *et al*., 2012). Human activities can accelerate erosion. Tannic acids often associated with peat and bog areas cause water to be colored resulting in turbidity. Algae that grow with nourishment from nutrients entering the stream through leaf decomposition or other naturally occurring decomposition processes can also be a source of turbidity. Stream channel movement can also release sediment (Minnesota Pollution Control Agency, 2008).

BOD directly affects the amount of dissolved oxygen in lake and streams. The greater the BOD, the more rapidly oxygen is depleted in the lakes. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen aquatic organisms which become stressed, suffocate and die (Penn *et al*., 2003). Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots and food-processing plants; failing septic systems; and urban storm water runoff. The discharge of wastes with high levels of BOD can cause water quality problems such as severe dissolved oxygen depletion and fish kills in the receiving water bodies (Sanchez *et al*., 2007).

Moreover, low dissolved oxygen (DO) primarily results from excessive algae growth caused by phosphorus. Nitrogen is another nutrient that can contribute to algae growth. As the algae die and decompose, the process consumes dissolved oxygen. This can result in insufficient amounts of dissolved oxygen available for fish and other aquatic life. Die-off and decomposition of submerged plants also contributes to low dissolved oxygen. The process of decomposition is called Carbonaceous Biochemical Oxygen Demand (World Health Organizations, 2011).

Sources of phosphorus include discharges from municipal and private wastewater treatment, cropland and urban storm water runoff, and natural decay of vegetation. Direct discharge of pollutants from point source and nonpoint sources into Lake and river segment add to its CBOD loadings, creating an oxygen demand that may depress DO below acceptable concentrations. Nutrient levels in surface water occasionally create sufficient eutrophication to generate CBOD loads from decaying algae (Minnesota Pollution Control Agency, 2009).

Surface water eutrophication is caused by some nutrients mainly phosphorus, nitrogen and ammonia. Phosphorus (P) and nitrogen (N) are the primary nutrients that in excessive amounts pollute our lakes, streams, and wetlands. Nitrogen is essential to the production of plant and animal tissue. It is used primarily by plants and animals to synthesize protein. Nitrogen enters the Lake ecosystem in several chemical forms and also occurs in other dissolved or particulate forms, such as tissues of living and dead organisms (World Health Organizations, 1996). A compound nitrate which containing nitrogen, can exist in the atmosphere or as a dissolved gas in water, and at elevated levels can have harmful effects on humans and animals. Nitrates and ammonia in surface water can cause severe illness in infants and domestic animals. Common sources of excess nitrate reaching lakes and streams include septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, sanitary landfills, and garbage dumps (Minnesota Pollution Control Agency, 2008).

Furthermore, these excessive nutrients come from both point pollution such as wastewater from industry and municipal sewage, and non-point pollution like irrigation water, surface run water containing fertilizers from farmland, etc. Increased nutrient load to water body is now recognized as a major threat to the structure and functions of near shore coastal lake ecosystems, and severe eutrophication problems associated with harmful algal bloom form a major manifestation (Yang *et al*., 2008).

According to different study done by researchers quality of Lake Tana water is facing different Challenges due to deterioration. Consequently, Lake Tana which known by socioeconomic and center of tourism as well as biodiversity is turbid and functioning only low biological and other productivity. Factors like urbanization and population growth, sedimentation and soil erosion, proliferation and decomposition of invasive weeds, risk of eutrophication, inappropriate solid and liquid disposal, fecal and microbiological pollution, irrigation and pattern of weather condition are some common challenges for quality of Lake Tana water (Goraw Goshu and Shimelis Aynalem, 2017).

3. MATERIALS AND METHODS

3.1. Description of the study area

The study was conducted in the Southern gulf of Lake Tana close to Bahir Dar city. Lake Tana region is a region in the northwestern highlands of Ethiopia experiencing changes in the environmental balance forced partly by climate change and mostly by the persistence of unsustainable production and consumption systems (Teshale *et al*. 2001). Lake Tana, which is source of Blue Nile, is largest lake by surface area of (3156km^2) in Ethiopia, comprising about 50 percent of total fresh water resources of Ethiopia. It is a shallow lake with mean depth of 8m and maximum depth of 14m. It is situated at 1800 m above sea level on a basaltic plateau. Seven large, permanent rivers and about 40 small seasonal rivers feed the lake (Nagelkerke, 1997).

Lake Tana area has warm temperature climate and mean annual temperature of 13.5-27.7^{o}C , the mean annual rainfall is about 1500mm of which 54 percent fall in the month of July and August, when the rainfall can reach 250-300mm per month. The seasonal rainfall cause the lake fluctuates regularly with an average of difference between the minimum, in May-June, and Maximum in September- October of about 1.5m. Lake Tana and its adjacent wetlands provide directly and indirectly a livelihood for more than 500,000 people (Gordon *et al*., 2007) and about three million people live in the catchment. The population density is high in the areas to the northeast and south of Lake Tana, with the highest in the north and south of Lake Tana (Teshale *et al*., 2001).

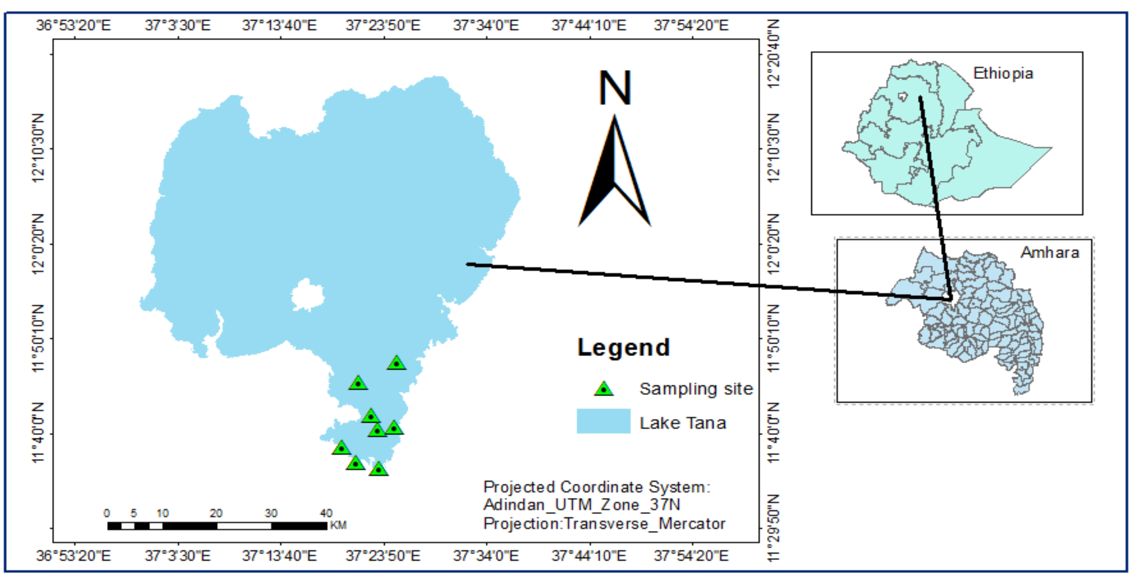

Figure 1: Map showing sampling sites (Designed for sampling sites of this study in 2018)

3.2. Study design and periods

The study was experimental type aiming to assess water quality of the Southern gulf of Lake Tana from water samples in two season's variations from January to March 2018 for dry seasons and June to July 2018 for wet season.

3.3. Selection criteria of sampling sites

According to United Nation Environmental Program, water quality monitoring is a practical guide to the design and implementation of freshwater quality. Surface water sample size determination for larger lakes is mainly depends on surface area of the lake (George, 2007). The sample stations would be proportional to the area of the lake in logarithm of 10 km^2. A lake having an area of 10 km^2, one sampling site is adequate for regular monitoring activity (Nelson *et al*., 2009). Based on this assumption, Lake Tana having an area of 3156km^2 requires a minimum of four sampling sites.

Number of sampling sites = $\log_{10}$ total surface area of the lake in km^2= $\log_{10}3156$ = 4 sample sites. Yet, this estimate will not include sampling sites selected for specific water quality assessment. In this study, Southern gulf of Lake Tana water quality a section of Lake Tana was specifically investigated. Based on this fact a total of eight sites were selected.. From these sites four study sites were from the shores line area expected to be more polluted and the rest of four were from pelagic area where pollution is expected to be minimal as the result of dilution.

Table 1: Sampling sites and areas

Sites	Coordinates		Areas of Sampling
	North	East	
S1	11400	365320	Near Taitu recreational center
S2	115010	371340	Close to Kuriftu and Grand Hotels
S3	121020	374410	Between Tana and Shum Abo Hotels
S4	112950	375420	Close to St. Michael Monastery
SR5	122040	37330	Pelagic area
SR6	122140	37340	Pelagic area
SR7	12350	382210	Pelagic area
SR8	13020	382030	Pelagic area

3.4. Sampling techniques and sample collection

The samples for some physicochemical and microbial parameters were collected at the same day from the surface of the lake to achieve consistency in sampling. Hence a total of 48 samples were collected from the surface (from about 30 cm depths). Water samples for some physicochemical parameters analyses were collected using clean, sterile glass bottles. Before collection of sample, the container was thoroughly rinsed with water and sterilized. The samples were labeled properly before it was transported to the laboratory using a permanent marker on the container (American Water Works Association, 1982).

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For bacteriological examination, the water samples were collected using a pre sterilized 200ml glass bottle. The sample collection procedures follow standard procedures (APHA, 1998). The samples were transported to the laboratory using an ice filled Ice box, and were taken to the laboratory, and analyzed less than 24 hours from the time of collection for fecal and total coliforms. Sampling time was arranged to include all time and condition of the day at a regular interval.

3.5. Indicator microorganisms and physicochemical parameters Test Methods

3.5.1. Tests for indicator microorganisms

The total coliform and fecal coliform count was done by standard MPN (Most Probable Number) test method. The double and single strength broth preparations were inoculated with loop full samples for both indicator microorganisms were analyzed by culturing them in MacConkey broth and incubating 24 hours at temperature of $35 \pm 0.5^{o}C$ or $37 \pm 0.5^{o}C$ for total coliform and 48 hours at $44 \pm 0.25^{o}C$ or $44.5 \pm 0.25^{o}C$ for fecal coliform (thermo tolerant) coliform and EMB (Eosin Methylene Blue agar) were confirmed *E. coli*. The results of analysis were read against standards such that for positive test results, gas production inside Durham tubes or turbidity and purple color change of MacConkey broth to yellow due to lactose fermentation was used as a positive indicator of total and fecal coliform presence. Negative test result was indicated by absence or both gas and persistence in color of the broth to purple. Finally number of positive tubes was expressed using MPN table according to ISO (2000).

3.5.2. Tests for physicochemical parameters

Electrical conductivity, TDS and pH were measured at the time of sample collection on site using portable PH/Conductivity/TDS meter (Bante901P, China) as well as Temperature was measured by Thermometer during sampling. NO^{-}_{3}, PO^{-}_{4}, and NH_4 were measured using Spectrophotometer (Jenway 6305, Germany) using standard methods and BOD5 also determined following standard methods (APHA, 1998).

3.5.2.1. Determination of nitrate

Nitrate was determined by photometer using Palintest Nitratest method. Nitratest Tube was filled with sample to the 20 ml mark. Spoonful Nitratest powder and one Nitratest tablet was added. The tube was allowed to stand for about one minute and then gently inverted three or four times to aid flocculation and kept for two minutes or longer to ensure complete settlement. Screw cap was removed and wiped around the top of the tube with a clean tissue and then the clear solution carefully decanted into test tube, filling to the 10 ml mark. Nitricol tablet was crushed and mixed to dissolve and then kept for 10 minutes to allow full colour development. Finally Phot 63 on Spectrophotometer was selected for result as mg/l $NO_{3.}$

3.5.2.2. Determination of ammonium

Ammonium test or determination was carried out using Palintest based on an indophenol method. Test tube was filled with sample to the 10 ml mark. One ammonium number one tablet and ammonium number two tablet added, crushed and mixed to dissolve and kept for ten minutes to allow colour development. Finally Phot 62 on spectrophotometer was selected to measure ammonium mg/$NH_{4.}$

3.5.2.3. Determination of phosphate

Determination of phosphate was tested using Palintest Phosphate LR (low level or low reading) method. In this method, phosphate reacts under acid condition with ammonium molybdate acid to form phosphor-molybdic acid. Test tube was filled with sample to the 10 ml mark and phosphate number one LR tablet was added, crushed and mixed to dissolve. Phosphate number two LR number two tablet was added, mixed and crushed to dissolve and kept for 10 minutes to allow full colour development. Finally Phot 28 in spectrophotometer was selected for result as mg/l $PO_{4.}$

3.5.2.4. Determination of BOD5

Biological oxygen demand was determined by using BOD OxiTop meter as described by Yuan *et al*. (2001). A 100 ml volume of test sample was put into dark BOD bottles with magnetic stirrer. Two pellets of sodium hydroxide were placed in the bottles and tightly corked. They were then put into BOD meter and incubated at 20°C for 5 days. After which the BOD5 results were obtained directly from the meter reading.

3.5.2.5 Determination of DO and turbidity

On site turbidity was analyzed using turbidimeter (Nephelometer, AL250T-IR, Aqualytic)). Before analysis, prepared standards were used to calibrate the turbidimeter in the desired range for accuracy as indicated in the manufacturer's operating instruction. After calibration, control for the experiment (deionized water) was run in cuvettes by the analyte and standardized readings were taken in Nephelometricturbidity units (NTU). Dissolved oxygen was determined using DO meter probe (Bante820, China). During analysis, pre-rinsed probe was immersed into approximately 1.25 inch into samples and stabilized readings taken.

For each of microbial and physicochemical parameters prescribed level of different international and national standards like FAO (1985); USEPA (1989) and EEPA (2003) were used to compare water quality status of Southern gulf of Lake Tana.

3.6. Statistical data analysis

Statistical analyses were performed using IBM SPSS software version 21 (SPSS Inc, Chicago, USA). Results of physicochemical analysis and mean microbial load of the investigated water samples were compared with the set standards (WHO and EPA guide lines for surface water). Mean and Standard deviation comparison between the sampling sites were done by ANOVA and Paired Sample t-test was used to analyze variations between the seasonality (dry and wet) and sites. The parameters were correlated against each other to determine their relationship using Pearson’s correlation. Significance level of $p < 0.05$ was applied at all statistical tests.

4. RESULT AND DISCUSSION

4.1. Fecal and total coliform counts

Mean and standard deviation of quality of indicator bacteria (from MPN table index) of water samples collected from southern gulf of Lake Tana. From total of 48 samples indicator bacteria such as total and fecal coliforms were analyzed.

Table 2: Mean and Standard deviation of (where, N=3) indicator microorganisms status of Southern gulf of Lake Tana

Sites	Season	F.C(MPN/100ml) where, N=3	T.C(MPN/100ml) where, N=3
S1	Dry	15.7±4.4	1122±315.1
	Wet	1069±1.1	1522.2±134.7
S2	Dry	69.3±38.2	1522±134.6
	Wet	991.8±137	1444.5±134.7
S3	Dry	35.5±41.5	1277.8±77
	Wet	999.4±135	1400±185.6
S4	Dry	16.9±15.1	1522.2±134.7
	Wet	1076.5±3.1	1600
SR5	Dry	2±1.5	36.3±28.5
	Wet	468.1±134	1100±537.7
SR6	Dry	1.9±0.8	4.8±1.81
	Wet	807.9±74.2	1422.7±307.2
SR7	Dry	1.8±1.3	465.2±546.7
	Wet	597.7±56.1	1422.4±307.5
SR8	Dry	1	46.6±51.5
	Wet	952.8±126.3	1600

The result of this study indicated that all water samples collected from Lake Tana during study were positive of fecal and total coliforms. According to the result given in table 2, the counts of fecal coliforms were 1 MPN/100ml to 1600 MPN/100ml with lowest and highest mean MPN value of 1 MPN/100 ml at SR8 and 1076.5±3.1 MPN/100 ml at with close to St. Michael monastery significant $p<0.05$. The total coliforms were also ranges 1 MPN/100ml to 1600 MPN/100ml with mean value of 4.8±1.81 MPN/100ml (SR6) to 1600 MPN/100ml close to St. Michael monastery and SR8 with significant $p<0.05$ variation. This study was in line with earlier study done by Dagnew Aweke *et al*. (2013) on determination of surface water quality status and identifying potential pollution sources of Lake Tana but the proportion of fecal and total coliform of this study were higher when compared total coliforms count >180 MPN/100ml and Goraw Goshu *et al*. (2010) on anthropogenic fecal pollution impact in Bahir Dar Gulf of Lake Tana were total coliforms and fecal coliforms were detected in 100, 86% of all sampling sites analyzed throughout the sampling period.

This study also was similar with a research done by Sana *et al*. (2013) Manasbal Lake of Kashmir were all the samples obtained from the lake were positive with respect to the coliform counts, though the count was variable ranging between 4 and 460 MPN/100 ml and other study done by Bishnu (2017) Chimdi Lake of Sunsari District in Nepal were the presence of fecal coliform recorded in the water samples were 170 MPN/l00 ml, 220 MPN/l00 ml and 380 MPN/100 with average value was 256.66 MPN/l00 ml which was essentially polluted. Thus, the data evidently points that the bacterial pollution in lake water is mainly caused by domestic sewage and human excreta (Usharani *et al*., 2010).

The high fecal and total coliforms counts in present study might be attributed to organic deposits predominantly from human and animal sewerage as well as faecal contamination. Activities at the shoreline including washing clothes and bathing are other potential sources of faecal contamination (Madema *et al*., 2003). The high coliform load occurring during the wet season is a consequence of the high volume surface runoff deposits from sewage contaminated with human and animal wastes from land based sources.

Not only this, but also the count of this faecal coliforms is a good evidence for recent contamination of human faeces loaded into the lake through connection of sewer lines with surface drainage system and very close siltation of pit latrines into the Lake. Southern gulf of Lake Tana has surface drainage system which aids human and animal wastes loaded into the lake through connection of sewer lines.

Discharging human related wastes from restaurants, hospital, hotels, lodges, private homes and factories as well as leftover vegetables from food establishments assisted by urban runoff are may be sources for this high total and fecal coliforms (Dagnew *et al*. 2013).

4.2. Physicochemical parameters status

Mean and standard deviation quality of physicochemical parameters of water samples collected from southern gulf of Lake Tana. From total of 48 samples the following physicochemical parameters in the table was determined

Table 3: Mean and Standard deviation of physicochemical parameters status of Southern gulf of Lake Tana (N= 3).

Sites	Par. Sea.	pH	Temp (^{0}C)	Turb (NTU)	E.C (µS/cm)	TDS (Ppm)	NH_4 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	DO (mg/l)	BOD5 (mg/l)
S1	Dry	7.8±01	25±2	27.7±3	203±107	88±13.1	0.2±0.1	39.7±5.2	0.06±0.01	6.1±0.5	4.5±0.5
	Wet	7.9±0.05	22.7±1	11±0.4	285±1.5	148±4	0.5±0.2	36.3±3.1	0.38±0.05	4.7±0.2	11.7±3.1
S2	Dry	7.9±0.32	22.8±0	23±0.8	141±11	71±8.4	0.15±0.2	33.2±3.6	1.4±1.2	6.4±0.4	4±1.3
	Wet	8.7±0.	25.3±1.1	23.1±2	167±0.8	84±0.1	0.16±0.1	13.9±1.7	0.14±0.1	6.7±0.15	13
S3	Dry	8.2±0.6	24.9±0.7	22.9±6	174±22	81±6.1	0.1±0.07	26.7±3.7	1.6±0.5	6.2±0.4	4.7±1.5
	Wet	9.3±0.06	24±1.2	19.4±1	146±3.4	73±0.1	0.37±0.02	33±2.5	0.31±0.1	7.7±0.3	11±1.7
S4	Dry	8.4±0.4	25.6±0.5	24.8±4	193±16	86±13.1	0.16±0.07	57.2±8.6	0.58±0.95	6.5±0.5	5
	Wet	8.6±0.2	21.9±1.5	16±0.3	146±0.5	73±0.1	0.59±0.3	27±2.5	0.47±0.1	6.8±0.5	23±2.6
SR5	Dry	7.4±0.2	23.5±0.8	16.3±3	123±7.7	61±4.9	0.12±0.03	15±13	0.02±0.02	6.1±0.5	2.8±1.4
	Wet	9.3±0.06	21.3±0.6	18.7±1.5	131±0.1	66±0.4	0.2±0.27	8.1±6	0.04±0.04	7.6±0.5	5.7±1.5
SR6	Dry	7.4±0.1	23±0.7	14.9±2	122±9.9	71±14.6	0.08±0.07	4.5±3.9	0.02±0.02	6.7±0.5	2.3±0.6
	Wet	8.99±0.1	22	27±0.5	146.9±3	74±0.3	0.39±0.15	30±1.5	0.32±0.95	7.9±0.5	17±2.5
SR7	Dry	7±0.6	25±0.7	18.4±1.2	134±9.6	58±15.6	0.07±0.06	6.1±0.8	0.03±0.03	6.3±0.5	2.3±0.6
	Wet	8.9±0.2	21±1	24.9±0.2	139±1.9	71±0.1	0.32±0.11	17±1.5	0.12±0.05	7.5±0.5	22±2
SR8	Dry	7.3±0.9	24±1.3	11.8±1.7	116±6.9	62±6.7	0.03±0.03	4.5±3.9	0.02±0.02	6.9±0.6	4.±0.5
	Wet	8.9±0.02	20.7±0.6	26.8±0.6	157±47	70.6	0.56±0.01	34±1.5	0.28±0.04	6.7±0.9	20.5±3

Par. =Parameters; Sea. = Seasonality; Temp = temperature; EC = electrical conductivity; Turb = turbidity; TDS = total dissolved solids; DO=dissolved oxygen; BOD=biological oxygen demand; NO_3 = nitrates; PO_4 = phosphate; NH_4= ammonium

4.2.1 pH and temperature

According to the result given in table 3 , pH value ranges from 6.7 to 9.4 and mean±SD values of 7±0.2 recorded at SR7 and 9.32±0.06 at Tana and Shum Abo hotels without significant difference between the sites $p<0.05$. Among all sites Tana and Shum Abo hotels, and SR5 had highest values. The result of pH was higher than earlier work Eshetie Dejen (2003) on Lake Tana biodiversity potential and threats and Ayalew Wondie *et al*. (2007) on Seasonal variation in primary production of a large high altitude tropical lake (Lake Tana, Ethiopia).

The pH values of this study also were found to be higher from earlier work done by Yirga Kebede (2016) on Lake Tana. The pH values in this study remained the water was alkaline. This might be due to presence organic matter and discharge of effluents from catchments to lake and might be due to the use of detergents by neighboring population for washing of cloths vehicles and utensils around the lake. High levels of pH might be also concentration of nutrients in water.

In the present investigation temperature of the lake was ranged from 20^0C to 26.6^0C with average mean values of 20.7^0C±0.6 at SR8 to 25.6±0.5^0C at S4. The data of water showed that southern gulf Lake Tana water temperature was not much impaired. But, it is higher than study done Ayalew Wondie *et al*. (2007) on Seasonal variation in primary production of a large high altitude tropical lake (Lake Tana, Ethiopia). Water temperature obtained during the sampling period for all sites showed significant variations. This might be due to depth of water, season, time of the day, cloudiness of the sky and the air temperature.

4.2.2 Turbidity

In present study turbidity was ranged from 10.4 to 30.21 NTU with average mean±SD value of 11±0.4 NTU to 27.7±2.99 NTU with significance difference with sites. Near Taitu recreational center and St. George Church was more turbid than other sites with mean±SD value of 27.7±2.99 NTU. When compared with turbidity values of earlier work done by Yirga Kebede (2016) on Tana Lake turbidity ranges between 5.1 to 989 NTU with the overall mean value of 199 NTU the turbidity value of southern gulf of lake Tana was found much lower. But, it was higher than work done by Eshetie Dejen (2003) on Lake Tana biodiversity potential and. This might be due to improper disposal of sewage, surface runoff and wastewater from different domestic activities of the Bahir Dar city and from inhabitants living around the lake.

Factors that cause high levels of turbidity include clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms (Ho *et al.*, 2003). Study done by Fitsum Geberyohannes *et al*. (2015) also indicates the sources of surface water turbidity are due to improper disposal of sewage, surface runoff and wastewater from different domestic activities. Other study also done by Yirga Kebede (2016) revealed that the source of high turbidity of Lake Tana is due to catchment runoff, soil erosion, waste discharge from urban areas (Bahir Dar and Gonder), recession agriculture and poor farming practices around large quantities of top soil ending up in the rivers and Lake Tana after heavy rains.

4.2.3 Electrical conductivity and Total dissolved solids

In this study the Electrical conductivity were ranges 108.9 to 326 μS/cm with highest average value of 285±1.5 μS/cm at Near Taitu recreational center and St. George Church within significantly $p<0.05$ different in season and sites. Compared to investigations done by Dagnew Aweke *et al*. (2013) on determination of surface water quality status and identifying potential pollution sources of Lake Tana and Goraw Goshu *et al*. (2010) on anthropogenic fecal pollution impact in Bahir Dar gulf of Lake Tana, the mean values of current investigation were lower. Despite fact that data recorded in this study revealed Electrical conductivity was found range that groups under pure water bodies, the variation at different sites may be an indication for the mixing of wastewater into Lake.

In this investigation TDS were in range of 40.3 to 151.7 ppm with highest averages of 148±4 ppm at S1. Although the TDS values in this study were in the category of pure water body, the variation still indicated the reach of organic matter from polluted area to non- polluted area. The total dissolved solids in water comprise mainly of inorganic salts and small amount of organic matter such as carbonate, bicarbonate, chloride, sulphate, sodium, potassium, calcium and magnesium.

4.2.4 Ammonium and nitrate

The concentrations of NH_4 in the sampling sites of the lake was recorded from 0.00 mg/l to 0.59 mg/l. Highest and lowest average values of ammonium was 0.03±0.03mg/l at SR8 to 0.59±0.01 mg/l at close to St. Michael monastery and Referral Hospital with significant $p< 0.05$. The result of this study also showed that nitrate range 5.03 mg/l to 64.5 mg/l with average values of 4.5±3.9

mg/l at SR6/SR8 to 57.2±8.6 mg/l at close to St. Michael monastery and Referral Hospital with $p<0.05$.

The mean value of nitrate obtained in this study was not agreed with the work of Yirga Kebede (2016) with low mean value of nitrate concentration ranged from 0.003 mg/l to 4.7 mg/l to the lake system which is much lower than nitrate values of southern gulf of Lake Tana.

This highest ammonium and nitrate values in this site might be fishing activity, discharging different garbage from hospital, waste from food establishments, dumping of leftover vegetables in the lake and mouth of the lake caused by high human influences. The highest record of nitrate in this study was during dry season. This might be low volume of lake water during dry time exposed to dumping of organic materials into the lake. Common sources of excess nitrate reaching lakes and streams include septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, sanitary landfills, and garbage dumps (Minnesota Pollution Control Agency, 2008).

Furthermore, these excessive nutrients come from both point pollution such as wastewater from industry and municipal sewage, and non-point pollution like irrigation water, surface run water containing fertilizers from farmland, etc. Increased nutrient load to water body is now recognized as a major threat to the structure and functions of near shore coastal lake ecosystems, and severe eutrophication problems associated with harmful algal bloom form a major manifestation (Yang *et al*., 2008).

4.2.5 Phosphorus

In this study phosphorus recorded in the ranges from 0.00 mg/l at to 2.12 mg/l at with average ranges of 0.02±0.02 mg/l at S8 to 1.6±0.5 mg/l at Tana and Shum Abo hotels. Compared with the phosphate values of Lake Tana with average phosphate varied between 0.07 to 3.50 mg/l done by Yirga Kebede (2016), Southern gulf of Lake Tana has lower phosphorus concentrations. One fascinating thing in this study was among all parameters phosphorus, nitrate and turbidity were recorded with high values during dry season. This might be due to effect of sewage; domestic wastes enriched with organic nutrients reached the lake in poor managements during dry season and might be also dumping of organic nutrients into lake when the water volume was reduced.

4.2.6 Dissolved oxygen and biological oxygen demand

Dissolved oxygen has the most significant role in natural waters among all the chemical substances. The amount of dissolved oxygen was southern gulf Tana Lake was ranges from 4.5 mg/l at Near Taitu recreational center and St. George Church to 8 mg/l with average values of 4.7±0.2 mg/l at Near Taitu recreational center and St. George Church during and 7.9±0.5 mg/l at SR6. All of the sites in this study did not have dissolved oxygen impairment except Near Taitu recreational center and St. George Church. The record of BOD which was sensitive for organic pollution in this study range from 2 mg/l to 25 mg/l with lowest and highest average values of 2.3±0.6 mg/l at SR6/SR7 to 23±2.6 mg/l at close to St. Michael monastery. The highest value of BOD in this site may be organic waste sink from the mouth of the lake caused by stressed anthropogenic activity.

Compared to earlier study done by Dagnew Aweke *et al*. (2013) which BOD test was in the range of 3.2 mg/l in less impacted area of the sampling stations and 23.7 mg/l in highly stressed areas of sampling locations it was higher than this study and lower than this study with DO having mean range of 6.62 ± 1.75 mg/l. The low level of Near Taitu recreational center and St. George Church might be decomposition of organic matter and dumping of waste from catchment activity such as fish farm, wastewater discharge and organic waste dumped from abattoir, indiscriminate dumping of wastes from catchment area to the lake.

The low DO at Near Taitu recreational center and St. George Church and high BOD at close to St. Michael monastery was a further testament of the some pollution levels of pollution in the waters of Southern gulf of Lake Tana which is similar study done by Akan *et al*. (2008) that pollution affecting the two parameters is more likely attributed to human sewerage, nutrients eutrophication, decomposition of organic wastes and fish processing and soap industries.

Fecal coliforms were positively correlated with pH, temperature, Ammonium and BOD5 (correlation coefficient, r = 0.60**, 0.4**, 0.64** and 0.67**) whereas total coliforms were positively correlated with pH, temperature, Turbidity, Electrical conductivity TDS, Ammonium, Nitrate, Phosphate and BOD (correlation coefficient, r = 0.73**, 0.32*, 0.44**, 0.39**, 0.3*, 0.6**, 0.63**, 0.34* and 0.55**) as well as total coliforms were also positively correlated with fecal coliforms. From these results it might be concluded that positively correlated parameters were an important determinant factors for the high counts of fecal and total coliforms. In present study fecal coliforms also positively correlated with total coliforms. Temperature also positively correlated with both fecal and total coliforms. It was one indication of temperature determine for high count of fecal and total coliforms which agrees with study done by Bushati and Neziri (2017) on microbial and physicochemical data on Shkodra Lake, Albania.

4.3. Current water quality status of southern gulf of Lake Tana based on seasonal variations and national and international standards

In this study, paired t-test was performed to determine if wet or dry periods affected indicator bacteria counts. There was a significant difference between mean total coliform counts in wet versus dry seasons. According present result in the table 2, the counts of fecal coliforms were 1 MPN/100ml during wet season to 1600 MPN/100ml during wet season with lowest and highest mean MPN value of 1 MPN/100 ml during dry season at SR8 and 1076.5±3.1 MPN/100 ml during wet season at wit Close to St. Michael Monastery h significant $p<0.05$. The recorded mean values of this study during wet season at Near Taitu recreational center and St. George Church and close to St. Michael monastery showed fecal coliforms were exceeded surface water permissive level which indicated the presence of pollution in the lake.

The high count of fecal coliforms at site one and at site four most probably arise from untreated wastewater of human and animal discharge assisted by surface runoff deposits into the lake through connection of sewer lines from Bahir Dar city and different anthropogenic activity in the gulf. The total coliforms were 1 MPN/100ml recorded during dry season to 1600 MPN/100ml which recorded during wet season with mean value of 4.8±1.81 MPN/100ml at SR6 during dry season to 1600 MPN/100ml at and close to St. Michael monastery SR8 during wet season with significant $p<0.05$ variation. Each recorded values of total coliforms counts during dry and wet season with mean values were not exceeded surface water permissive level. This May be due to high volume of Lake Tana water.

However, most of the data recorded during wet season was much higher than from data recorded during dry season. In this study S8 which was taken as reference site had high fecal coliforms and total coliforms during wet season succeeding SR6. This may be due to mixing of the water between reference and more influenced sites of anthropogenic activity in Southern gulf of Lake Tana. The high counts of total and fecal coliforms during wet season also agree with study done by Kora *et al.* (2017) on physicochemical and bacteriological screening of Hussain Sagar Lake in India.

In present study most the values of pH were higher during rainy or wet season than dry season. Between Tana and Shum Abo was highest having average pH value of 9.3±0.06 and succeeding SR5 which had average pH value of 9.3±0.06 recorded during in wet season exceeding surface water permissive without significant variation between sites $p>0.05$. Although temperature, electrical conductivity and total dissolved solids showed significant $p<0.05$ variations in the season and sites, result of this study revealed these parameters were within permissive level of surface water having highest average value of 25.6 ± 0.5^{0}C at close to St. Michael monastery 285±1.5 µS/cm at an Near Taitu recreational center and St. George Church d 148±4 ppm at Near Taitu recreational center and St. George Church recorded during wet season respectively.

Turbidity at Near Taitu recreational center and St. George Church nitrate at close to St. Michael monastery and phosphate at close to St. Michael monastery in this investigation were high during dry season exceeding surface water permissive level with significant $p<0.05$ variation between sites and season. This might be due to anthropogenic sources such as agriculture, sewage and urban effluents from catchment. This study pointed that southern gulf of Lake Tana was facing pollution in both and dry season caused by different anthropogenic activities. In this study highest value of ammonium recorded at close to St. Michael monastery during wet season with significant $p<0.05$ exceeding permissive level, but most of the values of ammonium was within permissive level of surface water. The highest record of ammonia during wet season also might be deposit of organic nutrient, septic systems, agricultural fertilizers, manure, industrial waste waters, sanitary landfills, and garbage dumps during rainy season caused erosion from the catchments.

Most of the DO values in this study were in the permissive level of surface water in both seasons with some significant $p<0.05$. In this Study highest value of BOD5 was recorded during wet season exceeding surface water permissive level without significant $p>0.05$ variation. This study revealed that even though most DO values were within permissive level of surface water, there were high values of BOD5. The addition of a variety of biodegradable pollutants into the lake from runoff and domestic sources stimulates the growth of microorganisms which consume the DO of the water and which inversely increasing the amount of BOD5. DO is a good indicator of water quality and its relation to the distribution and abundance of various algal species and some weeds along with the degree of pollution by organic matter and level of self-purification of water (Gupta *et al*., 2011).

Microbial and Physicochemical properties of the water gets varied season wise and in addition, anthropogenic activities such as agriculture, urbanization, domestic sewage, etc. in the catchment area result in the deterioration of water quality (Verma, 2012). Different properties like fecal coliforms, total coliforms, pH, EC, BOD5, NH_4 and TDS in this study showed maximum value during wet season, while minimum values were recorded dry season.

This study was similar with work of Yimenu Adane (2005) on characterization of domestic waste water disposal as point source pollution in the southern Gulf of Lake Tana and Selome Mekonnen (2006) on assessment of temporal hydrological variations due to land use changes using remote sensing in Lake Tana basin and as well as Ayalew Wondie *et al*. (2007) on Seasonal variation in primary production of a large high altitude tropical lake (Lake Tana, Ethiopia). The observed change might be attributed to the evaporation of lake water during dry season and subsequent dilution due to precipitation and run off from catchments rea during wet season.

From this investigation, it was possible to understand that area far from anthropogenic activity and human influences were somewhat lower pollution status than highly stressed area by human interventions. The way of interpretation was due to high fecal coliform counts exceeding permissive limits of surface water and fecal coliforms where best indicator microbes for pollution (Madema *et al*., 2003) rather than total coliforms.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The counts of fecal coliforms were 1 MPN/100ml to 1600 MPN/100ml with lowest and highest mean MPN value of 1 MPN/100 ml at SR8 and 1076.5±3.1 MPN/100 ml at with close to St. Michael monastery significant $p<0.05$. The total coliforms were also ranges 1 MPN/100ml to 1600 MPN/100ml with mean value of 4.8±1.81 MPN/100ml (SR6) to 1600 MPN/100ml close to St. Michael monastery and SR8 with significant $p<0.05$ variation. The result of physicochemical parameters also showed that some of the parameters were within surface water permissive level and some also beyond permissive level of surface water with and without significant variation in sites respectively. Although wet season was one factor for pollution load for southern gulf Lake Tana, there was contamination of the lake with some physicochemical parameters during dry and wet seasons. Hence, it can be conclude that Southern gulf of Lake Tana facing some pollution and needs some management actions to redeem it from deterioration.

5.2. Recommendations

Investigated work of this study pointed that Southern gulf of Lake Tana is facing challenges of some pollution. Depending on these findings it is recommended the following. It may be great to communicate all hotel and restaurant owners living and working southern gulf of Lake Tana in collaboration with boat workers for better results. The high count of fecal and total coliforms also may be indication of presence of disease causing microorganisms (pathogens). Team work and awareness must play a central role in waste management and in reducing overall volumes and harmful content of waste produced, so that solutions are sustainable. Hence, it is good to open other investigations on their presence and other resistant pathogens in broad manner to use the water for different purposes without any health related constraints. Issue of Lake Tana water is not just raised to fulfill requirements of some level, but it needs deep work and limnologists that install investigations for couple of years without accelerated time for living scientific conclusion and better lake restoration as well as control the lake from pollution.

6. LIMITATION OF THE STUDY

Conducting research on Lake Tana requires many sites with sufficient time (not with accelerated time) to reach precise scientific conclusions. This study conducted only in eight sites (four sites giving particular emphasis and rest of four sites as reference sites) and all physicochemical parameters, presence of pathogenic microorganisms and heavy metals were not tested due to time and financial issues.

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ANNEXES

Sites	Field and Lab triplications	F.C			MPN index/100ml	T.C			MPN index/100ml
		10ml	1ml	0.1ml		10ml	1ml	0.1ml	
Site 1	S1da	3	0	0	8	5	5	3	900
		3	0	0	8	5	5	2	500
		3	2	1	17	5	5	3	900
	S1db	4	4	0	34	5	5	5	1650
		0	0	0	1	5	5	5	1650
		3	2	0	14	5	5	2	500
	S1dc	3	0	1	11	5	5	3	900
		4	2	0	22	5	5	4	1600
		4	2	1	26	5	5	4	1600
Site 2	S2da	4	1	2	26	5	5	5	1650
		3	2	0	14	5	5	4	1600
		5	1	1	50	5	5	5	1650
	S2db	5	4	3	280	5	5	5	1650
		4	3	1	33	5	5	4	1600
		1	2	0	6	5	5	4	900
	S2dc	4	4	0	34	5	5	5	1650
		3	0	1	11	5	5	5	1650
		5	4	1	170	5	5	4	1600
Site 3	S3da	3	2	1	17	5	5	4	1600
		4	3	1	33	5	5	3	900
		3	2	1	17	5	5	4	1600
	S3db	5	3	1	110	5	5	4	1600
		4	2	1	26	5	5	4	1600
		5	3	1	110	5	5	2	500
	S3dc	2	0	0	4	5	5	5	1650

		1	0	0	2	5	5	5	1650
		0	0	0	1	5	5	2	500
Site 4	S4da	3	1	0	11	5	5	5	1650
		2	0	1	7	5	5	4	1600
		1	0	0	2	5	5	5	1650
	S4db	2	1	1	9	5	5	3	900
		3	1	1	14	5	5	5	1650
		5	3	0	80	5	5	5	1650
	S4dc	3	2	0	14	5	5	3	900
		4	0	0	13	5	5	5	1650
		2	1	1	9	5	5	4	1600

Table I: Dry season indicators microorganism's raw data of expected to be polluted sites

Table II: Dry season indicators microorganism's raw data of pelagic sites

Ref. Sites	Field and Lab triplications	F.C			MPN Index/100ml	T. C			MPN Index/100ml
		10ml	1ml	0.1ml		10ml	1ml	0.1ml	
SR5	SR5da	0	0	0	1	4	4	0	34
		0	0	0	1	4	2	1	26
		0	0	0	1	4	4	0	34
	SR5db	0	0	0	1	5	3	3	170
		0	0	0	1	3	2	1	17
		0	0	0	1	3	2	0	14
	SR5dc	1	1	0	4	2	0	1	7
		0	0	0	1	3	1	0	11
		1	2	0	6	3	1	1	14
SR6	SR6da	1	0	0	2	3	2	1	17
		0	0	0	1	1	0	0	2
		0	0	0	1	0	0	0	1
	SR6db	0	0	0	1	2	2	0	9
		0	0	0	1	1	0	1	4
		1	1	0	4	0	0	0	1
	SR6dc	0	0	0	1	0	0	0	1
		0	0	0	1	2	0	1	7
		0	0	0	1	0	0	0	1
SR7	SR7da	1	0	0	2	5	5	3	900
		0	1	0	2	4	3	1	33
		2	0	1	7	1	0	0	2
	SR7db	0	0	0	1	4	2	1	26
		0	0	0	1	2	0	1	7

		0	0	0	1	1	0	0	2
	SR7dc	0	0	0	1	5	5	5	1650
		0	0	0	1	5	5	5	1650
		0	0	0	1	4	1	0	17
SR8	SR8da	0	0	0	1	1	0	0	2
		0	0	0	1	3	1	1	14
		0	0	0	1	4	4	0	34
	SR8db	0	0	0	1	4	2	1	26
		0	0	0	1	4	0	1	17
		0	0	0	1	3	0	0	8
	SR8dc	0	0	0	1	5	5	1	300
		0	0	0	1	3	1	1	14
		0	0	0	1	2	0	0	4

Table III: Dry season physicochemical parameters raw data of expected to be polluted and pelagic sites

Sites	Field Triplic	pH	Temp (^{O}C)	Turbidity (NTU)	E.C (µS/cm)	TDS (ppm)	NH_4 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	D.O (mg/l)	BOD5 (mg/l)
Site 1	S1da	7.76	25.6	28.6	145.7	76.6	0.16	36.89	0.061	6.4(24.3^{o}c)	4.5
	S1db	7.94	26.6	30.21	326.5	102.5	0.14	34.6	0.072	6.3(25.6^{0}c	4
	S1dc	7.72	22.8	24.4	132.4	84.2	0.15	44.9	0.053	5.4(22.8^{o}c)	5
Site 2	S2da	7.8	22.8	23.8	134.2	67	0.13	28.9	0.023	6.6(24.5^{o}c)	5.5
	S2db	7.68	22.8	23.4	134.8	66	0.16	35.3	0.12	5.9(22.8^{o}c)	3.5
	S2dc	8.3	22.8	22.2	153.9	80.97	0.17	40.5	2.05	6.7(25.60c)	3
Site 3	S3da	7.87	25.1	16.4	184.1	80.6	0.133	27.6	2.12	6.6(23.5^{o}c)	3
	S3db	7.8	24.1	24.0	149.1	74.4	0.129	29.8	2.03	6.4(24.3^{o}c)	5
	S3dc	8.92	25.5	28.4	189.5	86.7	0.143	22.6	1.84	5.8(25.1^{o}c)	6
Site 4	S4da	8.53	25.1	20.65	178.6	80.12	0.15	59.5	1.94	5.9(23.5^{o}c)	5
	S4db	8.65	24.5	25.6	209.7	76.49	0.153	64.5	1.68	6.8(23.5^{o}c)	5
	S4dc	7.9	22.4	28.3	189.8	102	0.167	47.8	0.07	6.8 (23.5^{o}c)	5
Ref. Site 5	SR5da	7.4	24.3	14.6	132.03	65.3	0.125	22.7	0.06	5.9(23.5^{o}c)	4.5
	SR5db	7.6	23.5	15.3	120.3	55.7	0.13	24.7	0.04	5.5(22.7^{0}c)	2
	SR5dc	7.2	22.8	19.2	117.6	62.6	0.11	20.3	0.02	5.9(26.4^{0}c	2
Ref. Site 6	SR6da	7.3	22.9	12.5	111.3	78.4	0.13	8.4	0.03	6.6(25.6^{0}c	2.
	SR6db	7.42	22.8	16.3	122.5	80.3	0.11	6.02	0.02	6.7(22.8^{o}c)	2
	SR6dc	7.51	24.6	15.9	131.2	54.2	0.00	7.54	0.04	6.8(24.6^{o}c)	3
Ref. Site 7	SR7da	6.8	25.4	17.2	124.5	63.1	0.1	8.05	0.022	6.7(25.4^{o}c)	2
	SR7db	6.7	24.3	19.5	143.4	40.3	0.12	6.22	0.021	6.8(24.3^{o}c)	2
	SR7dc	6.9	24.6	18.4	134.8	70.1	0.00	5.03	0.01	6.8(24.6^{o}c)	2
Ref. Site 8	SR8da	6.92	25.1	19.6	108.9	50.2	0.08	5.34	0.08	6.7(25.1^{o}c)	3
	SR8db	7.2	22.8	18.2	122.8	66.4	0.073	6.84	0.00	6.6(22.8^{o}c)	4.5
	SR8dc	7.7	22.2	11.03	116.4	54.6	0.033	7.03	0.02	6.7(22.2^{o}c	4

Table IV: Wet season indicator microorganism's raw data of expected to be polluted sites.

Sites	Field and Lab triplications	F.C			MPN index/100ml	T.C			MPN index/100ml
		10ml	1ml	0.1ml		10ml	1ml	0.1ml	
Site 1	S1wa	5	5	4	1600	5	5	4	1600
		5	5	5	>1600	5	5	5	>1600
		3	0	0	8	5	5	3	900
	S1wb	5	5	5	>1600	5	5	5	>1600
		2	1	0	7	5	5	5	>1600
		5	5	4	1600	5	5	4	1600
	S1wc	5	5	5	>1600	5	5	4	1600
		5	5	4	600	5	5	4	1600
		1	0	0	2	5	5	4	1600
Site 2	S2wa	5	5	5	>1600	5	5	5	>1600
		5	5	5	>1600	5	5	4	1600
		4	0	0	13	5	5	5	>1600
	S2wb	3	0	1	11	5	5	5	>1600
		5	5	5	>1600	5	5	4	1600
		5	5	4	1600	5	5	4	900
	S2wc	5	5	3	900	5	5	5	>1600
		5	5	5	>1600	5	5	5	>1600
		1	0	0	2	5	5	3	900
Site 3	S3wa	4	3	1	33	5	5	4	1600
		5	5	5	>1600	5	5	3	900
		5	5	3	900	5	5	4	1600
	S3wb	4	0	0	13	5	5	4	1600
		5	5	4	1600	5	5	4	1600
		5	5	5	>1600	5	5	2	500
	S3wc	5	1	1	50	5	5	5	>1600
		5	5	5	>1600	5	5	5	>1600
		5	5	5	>1600	5	5	4	1600
Site 4	S4wa	5	0	2	40	5	5	5	>1600
		5	5	4	1600	5	5	4	1600
		5	5	5	>1600	5	5	5	>1600
	S4wb	5	5	5	>1600	5	5	4	1600
		4	2	1	26	5	5	5	>1600
		5	5	5	>1600	5	5	5	>1600
	S4wc	5	5	4	1600	5	5	4	1600
		5	5	4	1600	5	5	5	>1600
		5	0	0	23	5	5	4	1600

Table V: Wet season indicator microorganism's raw data of pelagic sites

Ref. Sites	Field and Lab triplication	F.C			MPN Index/100ml	T. C			MPN Index/100ml
		10ml	1ml	0.1ml		10ml	1ml	0.1ml	
SR5	SR5wa	5	1	1	50	5	5	5	>1600
		4	0	1	17	5	5	5	>1600
		5	5	5	>1600	5	5	5	>1600
	SR5wb	5	5	5	>1600	5	5	5	>1600
		1	0	0	2	0	0	0	<2
		0	0	0	<2	5	5	5	>1600
	SR5wc	4	4	0	34	0	1	0	2
		3	0	0	8	5	5	5	>1600
		5	5	3	900	5	5	1	300
SR6	SR6wa	5	5	5	>1600	5	5	5	>1600
		4	1	0	17	5	5	5	>1600
		5	5	2	500	1	1	0	4
	SR6wb	5	5	5	>1600	5	5	5	>1600
		5	5	5	>1600	5	5	5	>1600
		5	5	5	>1600	5	5	5	>1600
	SR6wc	5	4	4	350	5	5	4	1600
		0	0	0	<2	5	5	5	>1600
		0	0	0	<2	5	5	5	>1600
SR7	SR7wa	4	1	1	21	5	5	5	>1600
		0	1	0	2	5	5	5	>1600
		0	0	0	<2	5	5	5	>1600
	SR7wb	5	5	5	>1600	5	5	5	>1600
		5	5	5	>1600	5	5	5	>1600
		5	4	1	170	0	0	0	<2
	SR7wc	4	4	0	34	5	5	5	>1600
		5	5	5	>1600	5	5	5	>1600
		5	4	4	350	5	5	5	>1600
SR8	SR8wa	5	5	5	>1600	5	5	5	>1600
		5	5	3	900	5	5	5	>1600
		5	5	3	900	5	5	5	>1600
	SR8wb	5	0	0	23	5	5	5	>1600
		5	5	4	1600	5	5	4	1600
		5	5	5	>1600	5	5	5	>1600
	SR8wc	5	5	5	>1600	5	5	5	>1600
		0	0	0	<2	5	5	5	>1600
		5	4	4	350	5	5	5	>1600

Table VI: Wet season physicochemical parameters raw data of expected to be polluted and pelagic sites

Sites	Field Triplic	pH	Temp (^{O}C)	Turbidity (NTU)	E.C (µS/cm)	TDS (ppm)	NH_4 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	D.O (mg/l)	BOD5 (mg/l)
Site 1	S1wa	7.87	22	10.4	284	144.2	0.45	33	0.38	4.5	9
	S1wb	7.96	22	11.1	285	147.1	0.47	37	0.39	4.6	11
	S1wc	7.96	24	10.7	287	151.7	0.43	39	0.39	4.9	15
Site 2	S2wa	8.65	26	20.5	168.2	83.6	0.13	12	0.13	6.9	13
	S2wb	8.69	26	25.3	166.6	83.7	0.15	15	0.14	6.6	13
	S2wc	8.71	24	23.7	167.1	83.9	0.2	14.8	0.15	6.7	13
Site 3	S3wa	9.3	25.4	18.5	143.4	72.8	0.34	33	0.32	7.3	10
	S3wb	9.28	23	20.5	150.1	72.7	0.37	35	0.33	7.9	10
	S3wc	9.4	23.5	19.1	146.2	72.9	0.39	30	0.3	7.8	13
Site 4	S4wa	8.36	21	15.9	146	73.4	0.59	25	0.49	6.6	25
	S4wb	8.78	21	16	145.8	73.2	0.58	30	0.47	6.5	20
	S4wc	8.54	21	16.4	146.8	73.4	0.59	27	0.47	7.4	24
Ref. Site 5	SR5wa	8.91	22	18.7	130.9	65.9	0.00	10	0.09	7.5	4
	SR5wb	9.01	21	18.6	131	66.3	0.03	13	0.01	7.6	6
	SR5wc	9.15	22	18.9	130.8	66.7	0.05	1.4	0.03	7.6	7
Ref. Site 6	SR6wa	9	22	27.3	143.9	74.4	0.51	30	0.32	7.9	15
	SR6wb	8.92	22	27.3	148.7	74.4	0.47	32	0.42	8	17
	SR6wc	9.1	22	28.2	148	73.9	0.48	29	0.23	8	20
Ref. Site 7	SR7wa	8.96	21	25.1	142	70.9	0.21	18	0.12	7.9	24
	SR7wb	8.92	20	24.7	141.7	70.8	0.27	16	0.13	7.9	20
	SR7wc	8.95	21	25	142	70.8	0.24	18	0.12	7.9	22
Ref. Site 8	SR8wa	8.96	21	26.7	137.2	70.6	0.45	34	0.32	8	20
	SR8wb	8.97	20	27	139.7	70.6	0.57	33	0.25	7	18
	SR8wc	9.01	20	26.8	140.9	70.6	0.55	36	0.27	8	23.5

Table VII: Paired sample t-test variation on season (Dry and Wet) and sampling sites of indicator microorganisms of Southern Gulf of Lake Tana

PST		Mean	SD	SEM	95% CID				
					Lower	Upper	T	df	Sig.
Pair 1	F.C - Sites	434.6796	497.1634	71.75935	290.3184	579.0408	6.057	47	0.00
Pair 2	F.C-Season	429.1796	496.8677	71.71668	284.9042	573.4549	5.984	47	0.00
Pair 3	T.C Sites	1084.85	616.2964	88.95473	905.8987	1263.806	12.196	47	0.00
Pair 4	T.C-Season	1079.35	615.3532	88.81858	900.6726	1258.032	12.152	47	0.00

PST= Paired Sample t Test, SD= Standard deviation, SEM= standard error of Mean, Sig. = Two tailed Significant differences, CID= 95% Confidence Interval of the Difference

Table VIII: Preason correlation matrices of indicator microorganisms and physicochemical of Suthern gulf of Lake Tana water

Correlation	pH	Temp	TUR	E.C	TDS	NH_4	NO_3	PO_4	DO	BOD5	F.C	T.C
pH	1											
Temp	0.4**	1										
TUR	0.49**	-0.13	1									
E.C	0.072	0.21	-0.01	1								
TDS	0.008	0.12	-0.23	0.78**	1							
NH_4	0.51**	0.5**	0.046	0.201	0.21	1						
NO_3	0.299*	0.05	0.316*	0.45**	0.37*	0.037**	1					
PO_4	0.066	0.08	0.063	0.119	0.1	0.021	0.343*	1				
DO	0.009	-0.19	-0.2	0.332*	0.37*	0.24	0.06	-0.01	1			
BOD5	0.69**	0.6**	0.319*	0.036	0.03	0.61**	0.117	-0.11	0.1	1		
F.C	0.60**	0.4**	0.025	0.215	0.22	0.64**	0.123	-0.1	0.2	0.67**	1	
T.C	0.73**	0.32*	0.44**	0.39**	0.3*	0.6**	0.63**	0.34*	0.1	0.55**	0.53**	1

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

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

Table IX: Paired sample t-test variation on season (Dry and Wet) and sampling sites of physicochemical parameters of southern gulf of Lake Tana

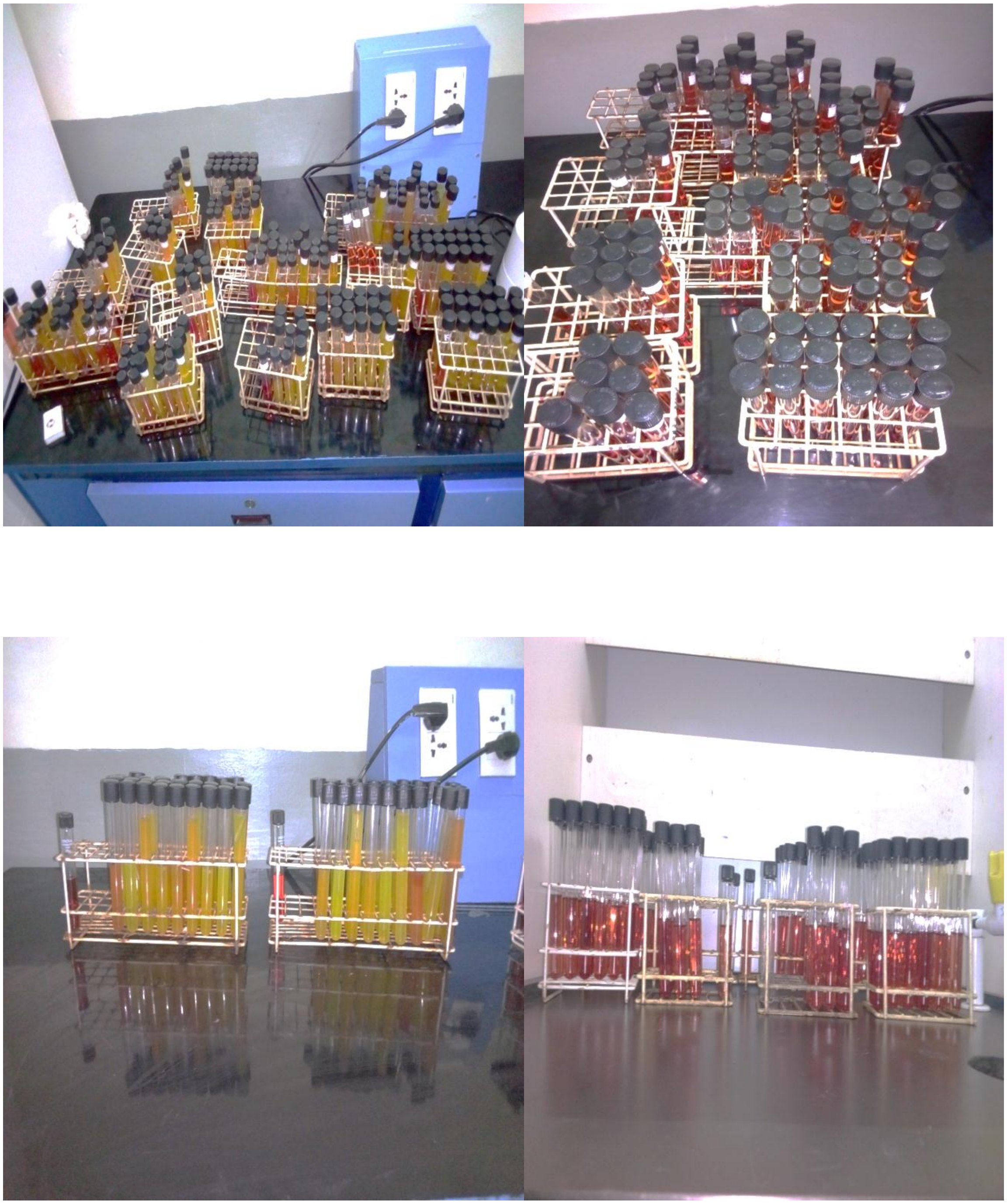
Paired Samples Test									
		Paired Differences							
		Mean	SD	SEM	95% CID				
					Lower	Upper	T	Df	Sig.
Pair 1	PH – Sites	-1.26146	5.08794	0.73438	-2.73884	0.21593	-1.718	47	0.092
Pair 2	PH –Season	-6.76146	4.50533	0.65029	-8.06967	-5.45325	10.398	47	0.00
Pair 3	Temp – Sites	13.79792	6.80389	0.98206	11.82227	15.77356	14.05	47	0.00
Pair 4	Tem-Season	8.29792	6.18211	0.89231	6.50282	10.09301	9.299	47	0.00
Pair 5	TUR – Sites	10.97479	7.72072	1.11439	8.73293	13.21665	9.848	47	0.00
Pair 6	TUR-Season	5.47479	7.28338	1.05127	3.35992	7.58966	5.208	47	0.00
Pair 7	E.C – Sites	147.3985	48.3473	6.97833	133.36	161.4371	21.122	47	0.00
Pair 8	E.C –Season	141.8985	46.92887	6.7736	128.2718	155.5253	20.949	47	0.00
Pair 9	TDS – Sites	67.8475	22.06905	3.18539	61.43931	74.25569	21.3	47	0.00
Pair 10	TDS –Season	62.3475	20.5884	2.97168	56.36925	68.32575	20.981	47	0.00
Pair 11	NH4 – Sites	-9.09209	5.37236	0.78364	-10.6695	-7.5147	-11.60	47	0.00
Pair 12	NH4- Season	-14.6666	4.93824	0.72032	-16.1165	-13.2166	-20.36	47	0.00
Pair 13	NO3 Sites	14.64833	16.88893	2.43771	9.7443	19.55237	6.009	47	0.00
Pair 14	NO3- Season	9.14833	15.73397	2.271	4.57966	13.717	4.028	47	0.00
Pair 15	PO4 – Sites	-9.13606	5.75654	0.83088	-10.8076	-7.46454	-10.99	47	0.00
Pair 16	PO4 – Season	-14.6361	5.1874	0.74874	-16.1423	-13.1298	-19.55	47	0.00
Pair 17	DO – Sites	-2.73958	5.09408	0.73527	-4.21875	-1.26042	-3.726	47	0.729
Pair 18	DO – Season	-8.23958	4.7739	0.68905	-9.62578	-6.85339	-11.96	47	0.00
Pair 19	BOD5 – Sites	0.11458	4.4748	0.64588	-1.18476	1.41393	0.177	47	0.86
Pair 20	BOD5 – Season	-5.38542	4.49969	0.64947	-6.69199	-4.07884	-8.292	47	0.00

SD= Std. Deviation, SE= Std. Error Mean, CID= 95% Confidence Interval of the Difference, Sig. = Two tailed significant difference.

Table X: Guidelines for the Microbiological and physicochemical parameters of surface water

Parameters	Permitted	Not permitted	References
F.C(MPN/100ml)	<1000 MPN/100ml	>1000 MPN/100ml	EPA (1989); EEPA (2003)
T.C (MPN/100ml)	<5000 MPN/100ml	>5000 MPN/100ml	EPA (1989); EEPA (2003)
pH	6.5-8.5	<6.5 and>8.5	EPA (1989); EEPA (2003)
Temp (0C)	25-30	>30	EPA (1989); EEPA (2003)
TUR (NTU)	<5	>5	EPA (1989); EEPA (2003)
E.C (µS/cm)	<1500	>1500	EPA (1989); EEPA (2003)
TDS (ppm)	<1000	>1000	EPA (1989); EEPA (2003)
NH_4 (mg/l)	<0.2	>0.2	EPA (1989); EEPA (2003)
NO_3 (mg/l)	<50	>50	EPA (1989); EEPA (2003)
PO_4 (mg/l)	<0.5	>0.5	EPA (1989); EEPA (2003)
DO (mg/l)	>5	<5	EPA (1989); EEPA (2003)
BOD5 (mg/l)	<5	>5	EPA (1989); EEPA (2003)

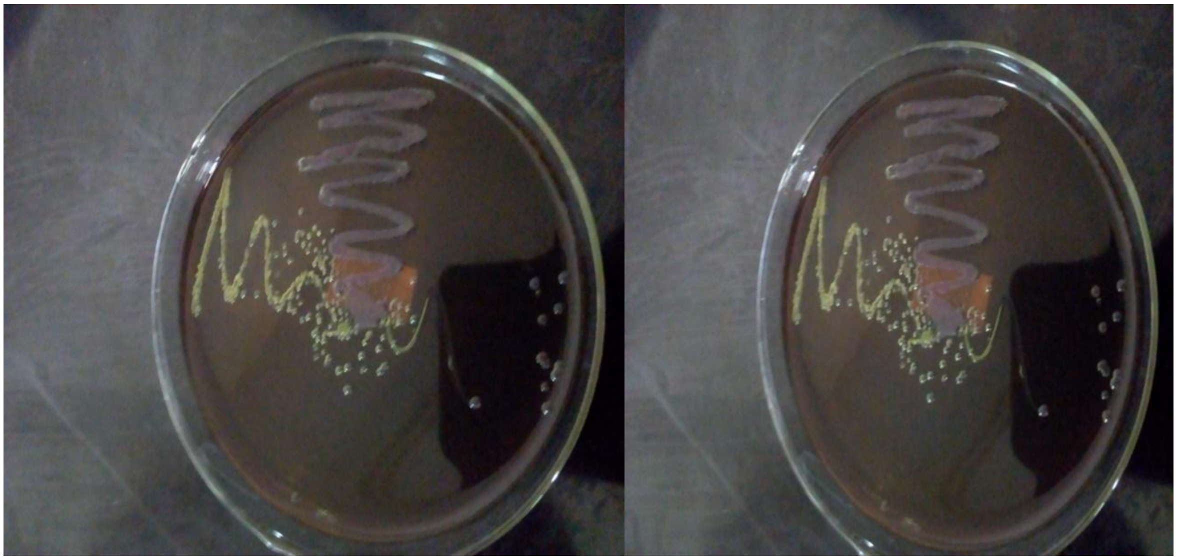
Figure II: Some on site analysis of physicochemical parameters and indicator microorganism laboratory experiment and their results



Media preparation and Presumptive Tests of indicator Microorganisms(fecal and total coliform)

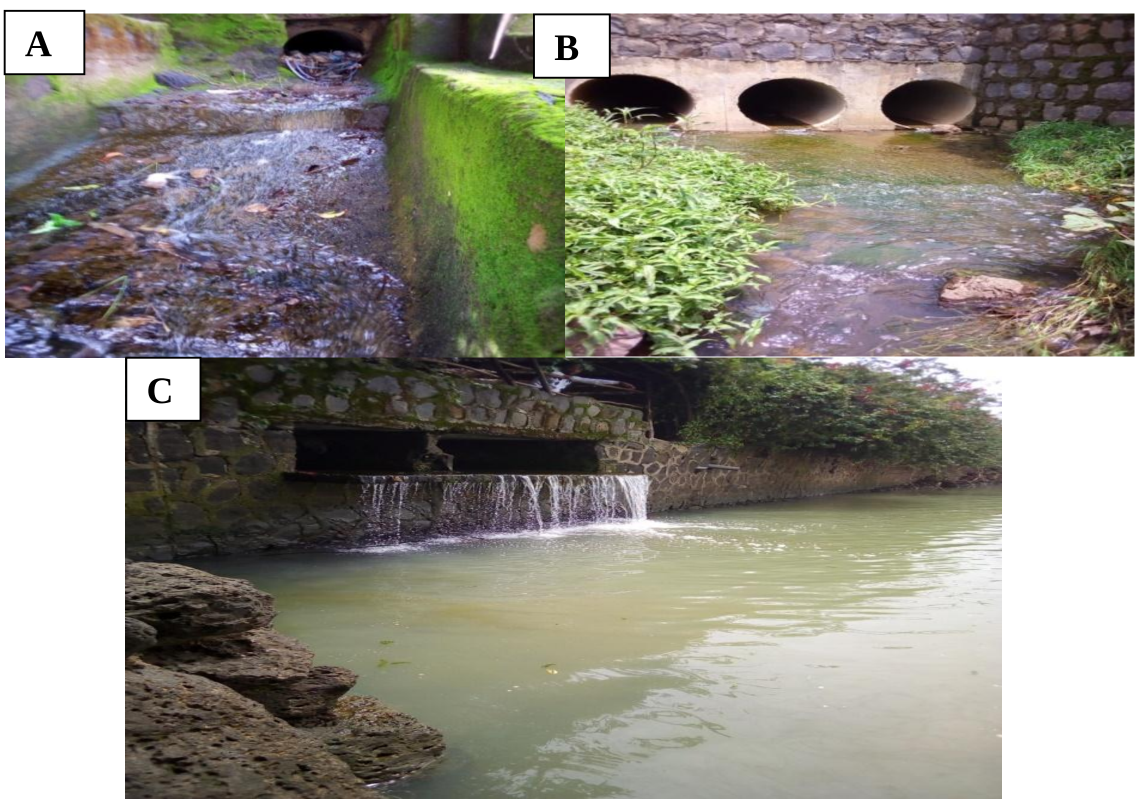
Some on site and Laboratory works

On site analysis of dissolved Oxygen and Turbidity



Confirmative tests of *E.coli*

Figure III: Some of the pictures were taken during sampling periods while surface runoff deposits into the lake through connection of sewer lines with surface drainage system and very close siltation of pit latrines into the Lake (A= around Taitu recreational center near St George Church; B=between Blue Nile Hotel and St Michael Monastery; C= Kuriftu Recreation and SPA).



Some of solid wastes and garbage near shore line of Lake Tana