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ANALYSIS OF WATER QUALITY OF LAKE TANA USING SOME BACTERIAL INDICATORS, NORTHWESTERN ETHIOPIA

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ABSTRACT:

Water quality degradation is a problem in Lake Tana. This study aimed to assess human impacts on the water quality of Lake Tana using some indicator bacteria. E.coli was highest at S8 (40 cfu/100 ml) and S7 (48 cfu/100 ml), while at S0, S4 and S5 (0 cfu/100 ml) in the wet season and it increased in the dry season in the range of 2 cfu/100 ml (S0 and S1) to 14 cfu/100 ml (S9). And also, F. coliform showed 0 cfu/100 ml at the reference site (S0) and the highest at the impacted site S7 (232 cfu/100 ml) in the wet season while in the dry season 0 cfu/100 ml was detected at S0 and 103 cfu/100 ml detected at S9. Analysis for total coliform (TC) ranges from 2 cfu/100 ml (S0) to 240 cfu/100 ml (S7) in the wet season and 13 cfu/100 ml (S2) to 136 cfu/100 ml (S9) in the dry season, with an average of 54.6364 cfu/100 ml which indicates the presence of contamination and the water was very poor for drinking.

KEYWORDS: *Bacteria; E.coli; Lake Tana; Water quality; Fecal contamination.*

INTRODUCTION:

Water availability in quantity and quality of freshwater is a problem on a global scale. Water scarcity is considered as one of the major challenges for livelihoods in sub-Saharan Africa. In Ethiopia, water availability is erratic due to the seasonal variation in rainfall and a lack of structures regulating the water flow of rivers. The water quality of

Ethiopian water bodies is changed. The water quality of Ethiopian lakes showed dramatic changes in the last few years (Mulugeta, 2013; Sisay, 2013). The problem is the result of the point source and nonpoint source pollution which causes a change in physicochemical parameters of Ethiopian lakes. These are indications of water quality degradation of lakes in the country (FDRE EPA, 2004). Water quality degradation is also a problem in Lake Tana.

There is a great deal of human activities that have negative impacts on Lake Tana that needs to be corrected. Some of the largest contributors to the pollution are domestic sewage, agricultural inputs and outputs, industrial inputs and outputs, silt from the agricultural activity, etc. In addition to the chemical pollution, bacterial pollution (Escherichia coli (E. coli), Salmonella, Hepatitis A virus, Cryptosporidium, and others) is documented. The pollution has endangered the wildlife (fish, birds and animals) found in the lake and threatens the clean water source. Additionally, recreational, fishing, boating and swimming activities are affected due to the pollution (Eshete, 2003).

This study on Water Quality of Lake Tana using some indicator bacterial analysis is fundamental for the understanding of the water quality of Lake Tana suitability for different functions. The study is showing to what extent Lake water quality is affected. This study aimed to assess human impacts on water quality of Lake Tana using some indicator bacteria (Escherichia coli, Fecal coliform and Total coliform).

MATERIALS AND METHODS:

The study area

Lake Tana is located between 37 ^{0} 00$^{'}$-37^{0} 20`East Longitude and 11$^{0}$ 37`-12^{0}00'North Latitude. It is situated in the north-western highlands of Ethiopia with an altitude of 1784.5m a.s.l. (Eshete, 2003; Misganaw and Getu, 2016). The lake is the largest freshwater Lake in Ethiopia with a surface area of about 3200 km^{2}, it covers 50% of the total inland water of the country (Misganaw and Getu, 2016; Eshete, 2003). It is a shallow lake with an average depth of 8 m and a maximum of 14 m (Berhan *et al.*, 2016).

The Lake is experiencing changes in the water quality due to human activities (Teshale *et al.*, 2001; Goraw *et al.*, 2010). The Lake is the main recipient of most urban wastes, agricultural and industrial pollutants. Consequently, the lake is expected to be degraded by anthropogenic activities. Algal blooming and decline in biodiversity are observed in some parts of the lake (Eshete, 2003).

Sampling sites

This study was conducted in five study areas. Two urban centers: Bahir Dar city and Gorgora town. Bahir Dar city has a high impact and Gorgora town minimal impact. The other category is two agricultural centers: Megech area that has high impact and Tana Kirkos area that has minimal impact. Ambobahir is a reference site with likely to have less impact and used for comparison of

impacted areas with less impacted sites selected based on the criteria indicated in 2.5. Each study area has sampling sites. Bahir Dar study area sampling sites are: Kuriftu (S_1), Tana Transport (S_2) and Tana Hotel (S_3) and Gorgora study area sampling sites are Gorgora hotel (S_{10}), Gorgora Transport (S_9) and Debresina (S_8). Tana Kirkos study area sampling sites are Tana kirkos (S_4) and Gumara (S_5) and Megech study area sampling sites are Megech Inlet (S_7) and Megech East (S_6). But Ambobahir study area is a reference site that has one sampling site named by Ambobahir (S_0). Sampling sites S_0 to S_{10} are in the region bounded by latitudes 11º35'49.8''N to 12º16'51.7''N and by longitudes 037º23'21.8''E to 037 º 24'49.5''E, and ranging in altitude from 1,784 to 1,791 mas. This was measured using the Global Positioning System (GPS) (Figure.1).

Sample collection

Water Samples from the lake were taken along the side of the lake in all sampling sites seasonally in wet and dry seasons for one year. Water samples for bacterial analysis were collected in plastic bottles from each site and analyzed following the protocols used for water sample analysis (APHA, 2005). Sampling sites were for human-influenced sites and reference sites, as well as samples, were collected for wet and dry seasons which were used for comparison.

Sample Analyses

Coliforms will be tested by the Most Probable Number Test (MPN) and Membrane Filtration tests (MF). The MPN technique, referred to as the Multiple Tube Fermentation Technique, is a technique based on serial dilution of the sample in test tubes containing a selective liquid media. At the end of the incubation, the analyst counts the number of positive test tubes to estimate the number of coliforms in the sample. The MF test refers to a technique where 100 ml of the sample is filtered onto a membrane. The membrane is placed on a growth selective media for coliforms. After incubation, colonies were counted (Rhonda *et al*, 2006).

Selection of Reference Area

There is a problem getting a reference site that fulfils all the above criteria; the reference of this study was identified based on the following criteria as indicated by Jennifer *et al.* (2003):

1) Same water body type, size and chemical characteristics as treated sites,

2) Within the same watershed as treated sites,

3) Minimal impacts within the last few years, and

4) Limited anthropogenic inputs.

Data Analysis

Basic statistical measurements were done. One-way ANOVA was used to study the difference among sites, where significant values ($P < 0.05$) were obtained and the least significant difference test was subsequently applied to detect the specific point of difference among variables was

conducted. Graphs were used to evaluate differences in bacterial parameters among the reference and impacted sites as well as the wet and dry seasons. All statistical analyses were performed using the SPSS statistical software (Version 23; SPSS Inc, 2016) and Excel spreadsheet, 2007.

RESULT AND DISCUSSION:

In this study, the average results for bacterial parameters that differentiate impacted from less impaired sites and wet and dry seasons were given in Table 1 and Annex I respectively. Bacterial variables that are modified by habitat disturbances show a short-term pollution effect with impaired sites. The environmental processes physical, chemical and biological interactions at ecosystem scale affect the Lake water quality including bacterial composition. Therefore, it is logical to examine the bacterial contaminants as potentially influencing the Lake Tana water quality.

E. coli is the most reliable indicator of fecal bacterial contamination of surface waters in the U.S. according to the water quality standards of USEPA. For partial-body contact, *E. coli* levels cannot exceed 575 colony forming units (cfu) per 100 ml of water (US EPA, 2009). For full-body contact, *E. coli* levels cannot exceed 235 cfu per 100 ml of water (US EPA, 2009; Channah and Berenise, 2014). The USEPA recommended conversion factor between fecal coliform and *E. coli* is 126/200 that results in an *E. coli*/Fecal Coliform (EC/FC) ratio of 0.63 (USEPA and Environment Canada, 2002). About 18 percent of Total coliforms are found to be fecal coliforms (US EPA, 2009).

E. Coli (Cell/ml)

There were no significant differences in *E. Coli* values ($p<0.05$) between the reference site and impacted sites. But there was a significant difference between dry and wet season (Figure 2).

The amount of *E.coli* was highest at S_8 (40 cfu/100 ml) and S_7 (48 cfu/100 ml), while at S_0, S_4 and S_5 (0 cfu/100 ml) in the wet season and it increased in the dry season in the range of 2 cfu/100 ml (S_0 and S_1) to 14 cfu/100 ml (S_9) (Appendix 1). In the wet season sewage from urban areas, animal fecal materials and agricultural wastes enter through runoff and the increased *E.coli* level might be due to the wastes drain into the lake (Table 1 and Appendix 1).

E. coli is considered to be the species of coliform bacteria and the best indicator of fecal pollution shows the possible presence of pathogens (US EPA, 2009). The presence of *E. coli* may be indicative of contamination with other bacteria, viruses or protozoa that can cause sickness (Channah and Berenise, 2014). The presence of *E. coli* in water is a strong indication of sewage or animal waste contamination. Sewage may contain different types of disease-causing organisms. *E.coli* in water may originate from the waste of both humans and other warm-blooded animals, such as dogs, cats, livestock and wildlife (US EPA, 2009).

Naturally, *E. coli* bacterium lives and grows in the gastrointestinal tract of humans and animals but if it gets in the kidneys or blood, it can cause illness. According to Ingerson and Reid (2011), the infection may spread within the body (to blood, liver and nervous system). In addition to gastrointestinal illness, eye infections, skin irritations, ear, nose, throat infections and respiratory illness are also *E. coli* related problems. These serious health effects are higher in swimmers than non-swimmers (Channah and Berenise, 2014).

According to the United States, Environmental Protection Agency (US EPA) criteria for *E. coli* density is (<33 cfu/ 100 ml for freshwater) (US EPA, 2009; Igbinosa *et al*., 2012). Concentration of *E.coli* in stream water is 10 cfu/100 ml (US EPA, 2002).

A number of environmental factors will affect bacteria survival in water bodies. *E.coli* counts are often higher during the wet season compared to the dry season. In the study area, the highest count is found in the wet season where there is water runoff from different wastewater sources (Appendix 1). Higher *E. coli* counts may be found in warmer waters because *E.coli* survives longer at its optimal growth temperatures (*E. coli* are adapted to living in the warm environment of the intestines of warm-blooded animals). However, ultraviolet light from the sun can kill bacteria in clear streams, rivers or lakes (US EPA, 2002). The *E.coli* concentration of Lake Tana water is above the recommended limit for drinking water as is indicated in Table 2. According to Rhonda *et al*., (2006) *E.coli* dependent water quality rating of Lake Tana water in the dry season is in the category of fair (2) but in the wet season sites, S_7, S_8 and S_9 were in the rating of poor water quality as referred in Table 3. Hence, the water quality of Lake Tana is affected by waste discharges.

F. Coliform

There were no significant differences in F. coliform values ($p<0.05$) between the reference site and impacted sites. But there was a significant difference between the wet and dry season. It showed 0 cfu/100 ml at the reference site (S_0) and the highest at the impacted site S_7 (232 cfu/100 ml) in the wet season while in the dry season 0 cfu/100 ml was detected at S_0 and S_3 and 103 cfu/100 ml detected at S_9 (Figure 3 and Appendix 1). This indicates that the number of F. Coliform in Lake Tana was higher in the wet season than the dry season in many of the impacted sites (from S_1 to S_{10}).

The presence of fecal coliforms is an indicator of fecal contamination. However, the absence of fecal coliforms does not mean the absence of fecal contamination. The source of the fecal contamination could be animal excreta, wastewater, sludge, septage, or biosolids. Each of these wastes is derived from the feces and urine of warm-blooded animals. Since pathogens and fecal coliforms are excreted by warm-blooded animals, the detection of fecal coliforms indicates the

potential presence of pathogens. During rainfalls, fecal bacteria may be washed into rivers, streams, lakes, or groundwater (Channah and Berenise, 2014).

Water pollution caused by fecal contamination is a serious health problem due to the potential for contracting diseases from pathogens (Rhonda *et al*., 2006). The presence of pathogens is determined by testing of "indicator" organisms such as coliforms. Coliforms are sourced from the same sources as pathogenic organisms. Coliforms are relatively easy to identify than pathogens. They are usually present in larger numbers than more dangerous pathogens (USEPA, 2009).

USEPA and Environment Canada Fecal Coliform standard is (200 col/100 ml) (USEPA and Environment Canada, 2002). According to Igbinosa *et al*. (2012), the maximum limit for no risk (domestic and recreational use) for Fecal Coliform is 0 cfu/100 ml. The reasonable margin of safety, the recommended bathing water criteria based on a Fecal Coliform concentration of 200 cfu/100 ml (USEPA, 2002) infectious dose of F. coliform organisms in water is 106-1010 cfu/100 ml.

An extremely large range of sample values exists for S_1, S_2, S_7 and S_9 locations; however, the geometric mean standard of 200 cfu/100 ml for Fecal Coliform was exceeded only at S_7 location in the wet season (USEPA and Environment Canada, 2002) that was above the desired limit but below the permissible limit as indicated in Table 4. Therefore, variation in F. Coliform colony among study areas, sampling sites and sampling seasons is the result of fecal contamination.

T. Coliform

There were no significant differences in T.coliform values ($p<0.05$) between the reference site and impacted sites. But there was a significant difference between the wet and the dry season. The results of the analysis for total coliform (TC) bacteria ranges from 2 cfu/100 ml (S_0) to 240 cfu/100 ml (S_7) in the wet season and 13 cfu/100 ml (S_2) to 136 cfu/100 ml (S_9) in the dry season, with an average of 54.6364 cfu/100 ml which indicates the presence of contamination (Figure 4, Table 1 and Appendix 1).

For recreational waters, Total coliforms are no longer recommended as an indicator. For drinking water, Total coliforms are still the standard test because their presence indicates contamination of water by an outside source (Rhonda *et al*., 2006).

In all sampling sites the value is beyond the recommended maximum permissible limits of WHO (2006), and Adimasu (2015), zero/100 ml for the drinking uses. Therefore, the lake water was contaminated by T.coliform and it does not fit for drinking purposes as rated in Table 5.

According to Igbinosa *et al*. (2012), the maximum limit for no risk (domestic and recreational use) for total coliform is 10 cfu/100 ml. Concentration of T. Coliform in stream water is 400 cfu/100 ml (USEP, 2002). Many of the water samples analysed were contaminated (Appendix 1). The Lake

Tana water is rated as good according to Rhonda *et al*., (2006) water quality rating on the basis of Total Coliform colony (Table 5).

The current study has revealed that there was an undesirable impact on the microbial characteristics of Lake Tana. The major was discharge of untreated waste entering into the watershed from municipalities and domestic activities. This poses a health risk to several rural communities that rely on the water body for domestic and recreational purposes. The bacterial analysis of Lake Tana water indicated that it is polluted. The analysis showed that seasonal variations in water quality were experienced.

The result values of Lake Tana also indicated that Lake Tana affected by waste discharges and the water was very poor for drinking, therefore the water requires proper water treatment before use.

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Table 1. Bacterial parameters value (Mean± SE, n= 23) of the eleven study sites

Parameter	Season		Mean ± SE
	Wet Mean ± SE	Dry Mean ± SE	
E. Coli (Cell/ml)	13.3636 ± 5.12440	6.5455 ± 1.11489	E. Coli (Cell/ml)
F. Coliform (Cell/ml)	82.5455 ± 23.70438	26.7273 ± 8.58338	F. Coliform (Cell/ml)
T. Coliform (Cell/ml)	113.0000 ± 25.00764	47.7273 ± 11.40183	T. Coliform (Cell/ml)

Table 2: Level of *E. coli* permitted for different types of water (USEPA, 2009)

Purpose	Level of *E. coli*
Drinking-Water	Zero
Freshwater (Recreation Water) Ambient Water Quality Criteria	126 cfu/100 ml
Surface Water Full-Body Contact (swimming)	235 cfu/100 ml
Surface Water Partial-Body Contact (Fishing, boating, etc…)	575 cfu/100 ml
Wastewater	< 2.2 cfu/100 ml
Irrigation or discharge	< 1.0 cfu/100 mL

Table 3: *Water quality rating based on* E. coli *colony* (Rhonda *et al*., 2006)

4 – Best	3 – Good	2 – Fair	1 – Poor
None detected. (For drinking water, this is the only acceptable level).	*E. coli* detected, but less than 2 colony forming units per plate. (Safe for contact recreation, such as swimming).	*E. coli* between 2 and 20 colony forming units per plate. (Not safe for contact recreation, but acceptable for noncontact recreation, such as boating).	*E. coli* greater than 20 colony forming units per plate. (Not considered safe for non contact recreation).

Table 4: F. coliform limits (Annie et al, 2002)

Water use	Desired level (cfu/100 ml)	Permissible level (cfu/100 ml)
Drinking	0	0
Swimming	<200	<1,000
boating or fishing	<1,000	<5,000

Table 5: Water quality rating on the basis of Total coliform colony (Rhonda *et al*., 2006)

4 – Best	3 – Good	2 – Fair	1 – Poor
None detected. (For drinking water, this is the only acceptable level).	Less than 20 colonies per plate.	20 to 200 colonies per plate.	More than 200 colonies or too many to count.

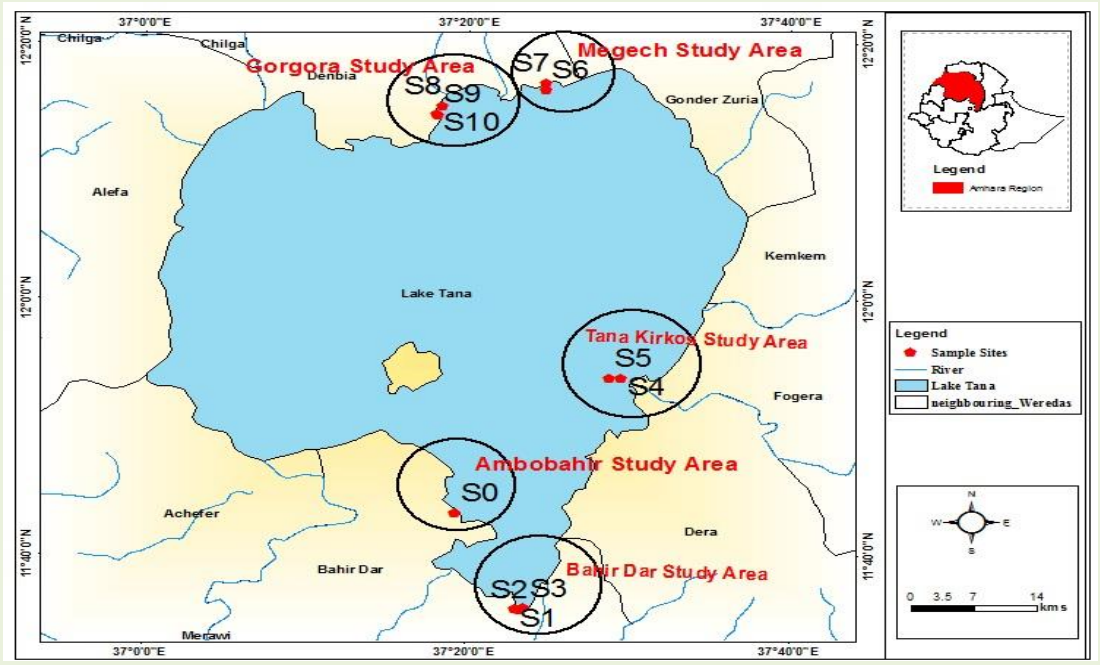

Figure 1. Map of Lake Tana showing study areas (Source: Coordinate Data)

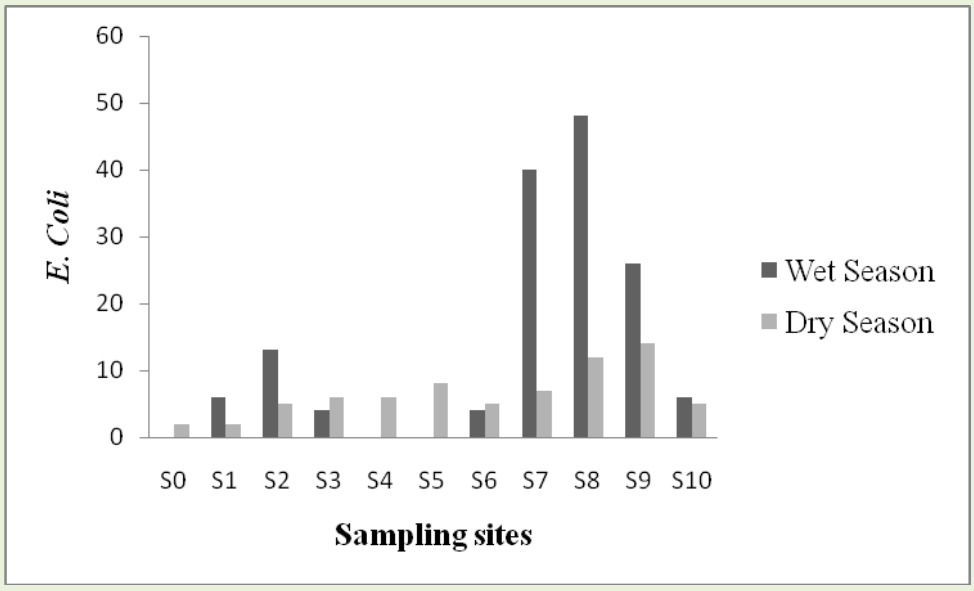

Figure 2: Escherichia coli, *E. coli* (cfu/100ml) in Lake Tana water.

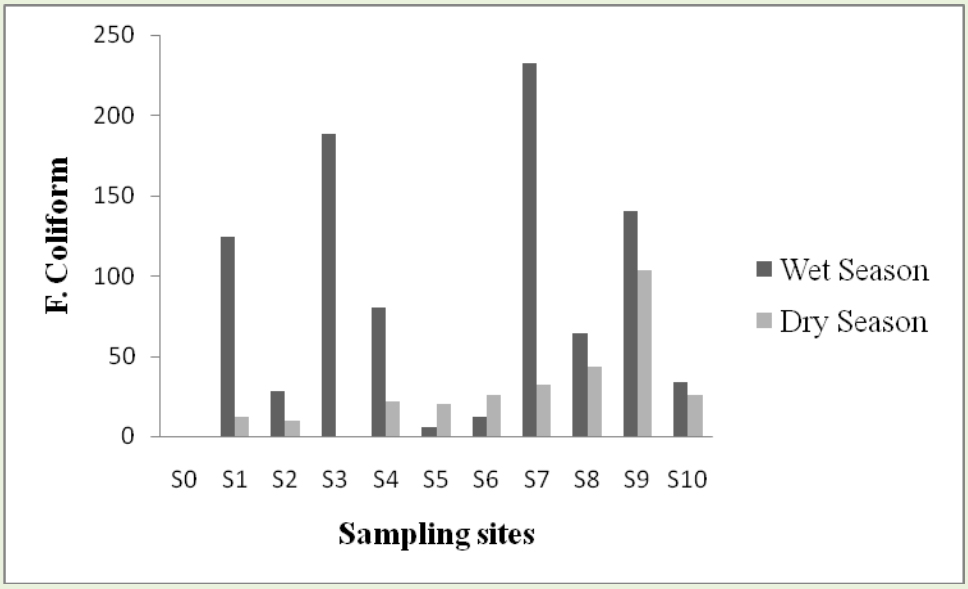

Figure 3: Fecal Bacteria, F. Coliform (Cell/ml) in Lake Tana water.

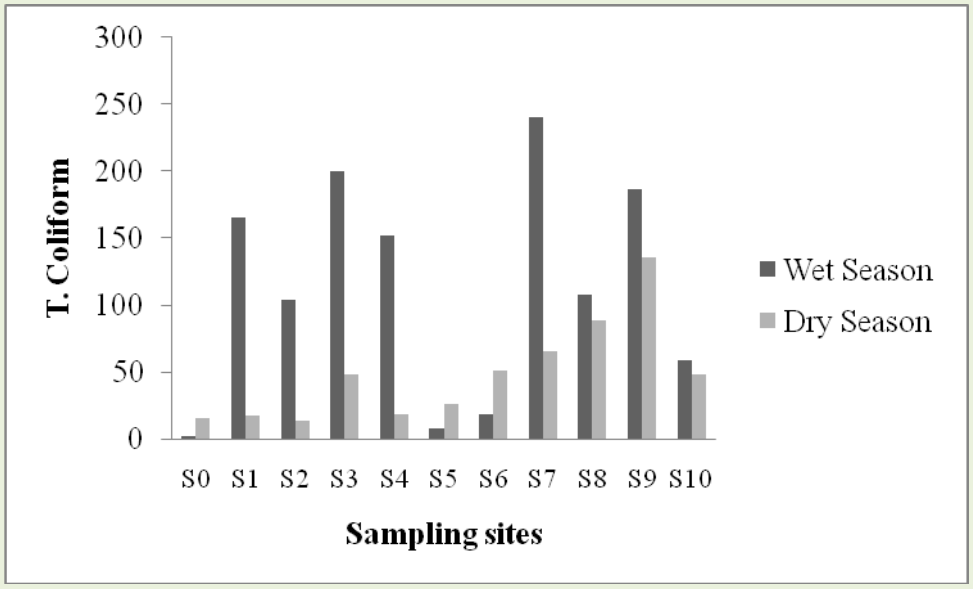

Figure 4: Total Coliform, T. Coliform (Cell/ml) in Lake Tana water.

Annex I : Bacterial parameters of 11 sites in wet and dry season of Lake Tana water

	Ambobahir		Bahir Dar Study area (S.A)						Tana Kirkos S.A				Megech S.A				Gorgora S. A					
Parameter	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
	S_0	S_0	S_1	S_1	S_2	S_2	S_3	S_3	S_4	S_4	S_5	S_5	S_6	S_6	S_7	S_7	S_8	S_8	S_9	S_9	S_{10}	S_{10}
E. Coli (Cell/ml)	0	2	6	2	13	5	4	6	0	6	0	8	4	5	40	7	48	12	26	14	6	5
F. Coliform (Cell/ml)	0	NTC	124	12	28	10	188	NTC	80	22	6	20	12	26	232	32	64	43	140	103	34	26
T. Coliform (Cell/ml)	2	15	165	17	104	13	200	48	152	18	8	26	18	51	240	65	108	88	187	136	59	48