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Determination of Surface Water Quality Status and Identifying Potential Pollution Sources of Lake Tana: Particular Emphasis on the Lake Boundary of Bahirdar City, Amhara Region, North West Ethiopia, 2013

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Abstract
Background: The water quality of Lake Tana is influenced by environmental stress and anthropogenic activities. Point and non-point sources are the major factors which affect the quality of the lake.
Objectives: To determine surface water quality status of Lake Tana and to identify the potential pollution sources bound to Bahirdar City Administration, Ethiopia.
Methodology: Laboratory based cross – sectional study was conducted in order to assess the quality and to identify the potential pollution sources of the lake. Geo referenced water samples were collected at eight sampling stations. Repeated water samples were collected and analyzed.
Result: The common water quality monitoring parameter were analysed, very low dissolved oxygen (3.5 mg/l) and high biochemical oxygen demand (23.7mg/l) were investigated in severely stressed sites. In addition to these, enriched nutrient like phosphorus and nitrate were identified to a level that influences algal growth. According to microbial analysis, total coli forms >180mg/100ml and Escherichia coli type one were isolated.
Conclusions: The Canadian Water Quality Index result categorizes the lake as poor state to aquatic life, recreation and drinking.
Keywords: Water quality, Lake, surface water, Water pollution, Point source pollution, Water Quality Index

1. Introduction

Surface waters are most vulnerable to pollution due to natural processes and anthropogenic influences. 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 effects upon the quality of surface waters worldwide(1). Human - induced changes in the hydrologic system of lakes have direct and severe consequences on nutrient cycling and contaminant retention in adjacent floodplains (2). Contamination of surface water is a persistent threat to human health, aquatic life and economical loss (3).

Major lakes that had been recognized as an internationally important conservation sites due to their richness in biodiversity, the tropic status had changed as a result of anthropogenic activities (4). Eutrophication is the major problem resulted in many lakes, which degrades freshwater systems worldwide by reducing water quality and altering ecosystem structure and function (5).

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.

Monitoring the quality of the lake in sustainable way would play a key role in identifying the trend of the quality of the lake and to provide adequate information for decision makers. This study is aimed to contribute in determining the current status lake quality, and to identify potential source of pollution which needs serious attention.

2. Materials and Methods (Times New Roman, 12; Single-columned & Justified)

2.1. Study Design and Period

Laboratory based cross – sectional study was conducted to assess the quality status and the potential pollution sources of Lake Tana from March to July, 2013.

2.2. Study Area

Lake Tana is located at the North western part of Ethiopian highlands, just to the North of Bahirdar city, the capital of Amhara National Regional State located 565 Km from Addis Ababa and has a population of 277,566 (6). Bahirdar City is known as scenic tourism destination center because of Lake Tana Islands with historical and religious heritages. Lake Tana is geographically situated between latitude 10°58`12.47''N and longitude, 36°45`38.14'' E, at altitude of 1840 m.a.s.l. Lake Tana has a surface area of 3156 km², stretching approximately 84 km north - south and 66 km east-west. Its maximum depth is 14m and has a mean depth of 8.9m with decreasing trend due to siltation. The water volume of Lake Tana is estimated to be 49.3 billion m^3. Lake Tana water shade has a drainage area of over 16,500km² (7).

2.3. Sample Size Determination

According to United Nation Environmental Program (UNEP) Water Quality Monitoring, a practical guide to the design and implementation of freshwater quality studies and monitoring program (8), surface water sample size determination for larger lakes is mainly depend on surface area of the lake. 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. Based on this assumption, Lake Tana having an area of 3156km^2 requires a minimum of four sampling sites.

No. of sample sites = $\log_{10}$ surface area of lake in km^2 = $\log_{10} 3156$ = 4 sample sites

However, this estimate will not include sampling sites selected for specific water quality assessment monitoring program. Based on this fact the sample stations for the study were selected from twelve potential sites of the southern gulf of Lake Tana bounded to Bahirdar City Administration. These twelve sites were identified from the survey result of proximity, and access, anthropogenic activity, storm water loading, lakeshore recreation practice, marine harbor, habit of littering waste into the lake, open bathing and laundering activities were considered as critical point of attention for water quality assessment. These twelve sites were listed according to their geographical location from west to south in order to facilitate sampling procedure and to have a sampling frame. For this study six sites 50% from the total potential sites and two additional sites one from potential sites and one site which is far from reach of human activity as reference sites were selected. In total eight sites were selected for this study.

2.4. Sampling Technique

Systematic sampling technique was used to select the location sites. This technique was used in order to have better distribution of stations across the southern gulf of the lake. The first site was randomly selected by lottery method and the first location was row six, known as Ghihon Hotel and the rest sites were selected successively downward from the top listed sites according to sampling interval. Based on this procedure Ghiwon Hotele, St. George, Shum Abo Menafesha, West Gojjam Prison, Felege Hiwot Hospital and Avanti Hotel were selected. In addition to these sites one sampling site as reference site known as Kibran area which if far from the reach of human activity and another additional site from potential sites called Tana Hotel was included in this study for comparison.

2.5. Data Collection Procedure

2.5.1 Collection of Water Sample

The water sample was collected from June 7 – July 19/2013. Data was collected with prepared checklist. The data include water test result record and sanitary survey reports. Each site was assessed for the possible potential source of pollution. In the process of sample collection and analysis essential material and equipment were ready before transporting to the stations. The required type sample bottles, labels and marking pens, recording sheet, sample storage, transit containers, on site analysis testing apparatus, necessary protection equipments like life saving vest were ready.

Samples were collected on weekly base by clustering the stations into two batches. Samples for physical and chemical analysis were collected with pre-cleaned rinsed one liter capacity polyethylene containers while for bacteriological analysis sterilized standard 500ml glass bottles were used. Samples for DO and BOD were collected with 300ml BOD bottles. Sample was collected at 20 - 30cm depth from the surface of the lake with hand dip. Sample containers used to collect sample for chemical analysis were rinsed before drawing water sample and were completely filled and sealed with no air space, whereas samples for bacteriological analysis were taken with container having air space. In this study no preservation was used in sample collection and samples are transported under cold box to the laboratories.

2.5.2 Water Quality Analysis

The water quality test was conducted at different centers; the chemical analysis was carried out at the Amhra

Region Bureau of Water and Energy (BoWE) water quality laboratory. The BOD test was conducted at Bahirdar University, School of Water Resource and Civil Engineering laboratory. Bacteriological test was done in the Amhara Regional Health and Research Laboratory Center. In this study different equipment and test procedures were applied, the physical analysis was carried out at field level by using the "Wagtech" products of the "Potalab" digital conductivity meter, pH meter and turbidity meter model No. "Wag – WT3020". The chemical test was analyzed with digital spectrophotometer of the "HACH" product "DR. 2800" and "DR.2010". Tests like total alkalinity and chloride were analysed with titration method in BoWE laboratory. The bacteriological analysis was done with multiple tube method at the regional laboratory.

The DO and BOD test was analysed with the help ELMETRON CO – 411 Oxygen electrode probe meter. DO was measured in the field just after sample is collected. The BOD test was processed in the laboratory. In this process initial DO was measured for every serial of dilution of sample and for the blank distilled water. The final BOD was recorded after the completion of 5 days incubation period under a temperature of 20^{o}c. The BOD test result was computed for each dilution and taking the average of serial dilution using the formula below;

BOD = [$DO_{initial}$ - DO_{final}] DF(dilution factor) (9).

The physical tests like pH, temperature, conductivity, TDS, and turbidity were analyzed at field level as soon as water sample is collected from the Lake. Instruments used for the water quality analysis were calibrated according the manufacturers instruction and the necessary accessories supplied with.

2.5.3 Personnel involved in the study

Two water technician and one Environmental health officer were involved in the sample collection and physical quality analysis with one cartographer who undertakes GPS readings of geographical locations. In addition, five water quality analysers involved to process the chemical as well as the bacteriological analysis.

2.6 Data quality management

A one day orientation and introduction session was organized for data collectors to share experience and to develop commitment. In order to maintain consistency of measurement replicate water sample were collected and analysed in each sampling sites. Double entry was applied to check for the recorded data and maintain accuracy. The test results were recorded and documented on pre-arranged check list. Skilled professionals were involved in sample collection as well as in laboratory test analysis. The instruments used for the analysis were calibrated according to the manufacturer's manual and procedure.

2.7 Data Processing and Analysis

Data was checked and entered into EPI INFO and transferred into SPSS version 20 statistical packages for analysis. Descriptive statistics with figures and tables are presented to show the facts obtained from the laboratory analysis on selected and most commonly reported parameters. The Canadian Water Quality Index CWQI model was used to summarize the findings of surface water quality analysis. This approach has been accepted by the United Nation Environmental Program Global Environment Monitoring System (UNEP GEMS) experts and was selected from its applicability to compare observations to the water quality guideline or site specific background concentration (10). The model equation expressed as;

$$WQI = 100 - \left[\frac{\sqrt{F1^2+F2^2+F3^2}}{1.732}\right]$$

F1= Represent <u>Scope</u> – the percentage of parameters that exceed the guideline value set by WHO or national guideline or standard

$$F1 = \frac{Numnber\ of\ faild\ parameters}{Total\ Number\ of\ parameters} \text{ X } 100$$

F2 = Represent Frequency – the percentage of individual tests within each parameter that exceed the guideline

$$F2 = \frac{Numnber\ of\ faild\ tests}{Total\ Number\ of\ tests} \mathbf{x}\ 100$$

F3 = Represent Amplitude – the extent (excursion) to which the failed test exceeds the guideline. F3 calculated in three stages

1st. Excursion = $\frac{Faild\ test\ Value}{Guideline\ value} - 1$

2nd. the normalized sum of excursion (nse) is calculated

$$nse = \frac{\sum \text{of excursion}}{Total\ Number\ of\ tests}$$

$$F3 = \frac{nse}{0.01nse+0.01}$$

The CWQI was mathematically calculated and shown in the annex 9 and the Canadian water quality calculator software was employed as per to specific water quality index (11). Therefore, for this study the CWQI software was applied to summarize the water quality status of Lake Tana bound to Bahirdar City Administration.

2.8 Ethical considerations

Ethical clearance was obtained from the ethical review board of University of Gondar. Permission was also obtained from Tana Sub Basin Enterprise, the Blue Nile Basin Authority Federal Democratic Republic of Ethiopia and the Regional Water Resource and Energy Bureau.

3. Results

3.1. Physio-chemical parameters

The physio-chemical parameters such as Temperature, pH, Turbidity, conductivity, Nitrate, Nitrite, Phosphate, Phosphorous, TDS, Manganese, DO and BOD parameters were analysed and the result summary is presented in Table 1.

3.2. Bacteriological Analysis

Bacteriological analysis was conducted to identify the total coliform and to investigate the presence of lactose fermenting bacteria. The result of total coliform in four sites was > 180/100ml. Escherichia coli (E. coli type one) was isolated in three locations. E. coli was not identified in the reference location which is around Kibran area (Table 2).

3.3. Potential Pollution Sources of Lake Tana

In the process of identifying the potential sources of the Lake Tana bound to Bahirdar City Administration, sanitary survey was conducted in all sampling stations selected for the study. The sanitary survey report used to identify pollutions sources from different organizations and service centers (Table 3).

3.4. Water Quality Index

Canadian Water Quality Index (CWQI) (11) was used to summarize and to introduce the test result to all interested stakes. The laboratory results entered into the CWQI calculator software Excel 2000 and computed according to criteria set based on the guideline of fresh water quality. The water quality was indexed based on the parameters exceeding the guideline limits set in the criteria and presented in figure 1.

4. Discussion

In water quality analysis various parametric measures need to be considered in order to conclude on the status of the water resource. Therefore, each parameter with their relative interpretation is described below in the discussion.

PH is the most important indicator widely investigated in water quality monitoring program. In this study the mean value of pH was 7.41 ± 0.461 which is within acceptable range of drinking water quality of WHO guideline.

Temperature: Is also the other most important parameters in natural surface-water quality analysis, since surface waters are subjected to great temperature variations. Inadequately treated municipal and industrial waste discharges, leachate and runoff, cause an increase in water temperature (12). As of the United Kingdom (UK) water supply regulation of 1989 the water temperature is defined to be below 25^{o}c (13). In the current study the water temperature was found with an average of 22.8 ± 1.19^{o}c. Higher temperature was recorded at station St. George Church area. The main reason for this result may be influenced with the increase of ambient temperature in one day measurement, and waste water loading might also responsible for an increase of water temperature, since this particular location is prone for contaminant sources as explained in the sanitary survey report.

Turbidity: Is another important parameter in determining the quality status of water which is caused due to suspended particles. Enhanced surface-water regulations in the United States require that the maximum contaminant level for turbidity states not exceed 0.5 NTU in 95 % of the samples taken every month and must never exceed 1 NTU (14). In this study the minimum turbidity result was 1.54 NTU and the maximum test result was 43.3 NTU at station 03 known as Kibran area which is selected as reference site. The higher turbidity result in that particular location was due to the mixing zone of tributary rivers particularly the "Gilgel Abay''. Low turbidity result was recorded at location 04 which is around Felege Hiwot Referral Hospital. The low turbidity result may be characterised due to the dense algal vegetation cover in this particular Lake region. The colour of this particular location during the period of sample collection was turned green; this condition might contribute in sedimentation process of settle able particles present in the upper surface of the Lake.

Conductivity: Is a measure of the capacity of water to pass an electrical current. In this study the mean conductivity measure was 171.42±23.53µSCm^{-1} ranging between 84 – 230 µSCm^{-1}. The lowest measurement recorded in areas of the reference site which is far from anthropogenic activities and highest result was recorded at location 08 known as Avantie Hotel area. Although the test result of conductivity was found with a range that classifies water bodies as fresh water, the variation at different location may be an indication for the crude mixing of wastewater into Lake.

Total Dissolved Solid (TDS): The mean test result of TDS was 102.54 ± 14.07mg/l minimum 50mg/l and maximum 138mg/l. According to TDS classification Lake Tana is categorized under fresh water. The TDS result was varied from location to location the higher result was recorded in areas where there is a possibility of sewage discharge and less concentration was observed at the location selected as reference site.

Total Alkalinity: The mean of Total Alkalinity of water was 106.31±21.78mg/l where the minimum was 85mg/l and the maximum was 159mg/l. Water with Alkalinity below 80 parts per million (ppm), known with rapid fluctuation in pH and when high alkalinity reached to 200 ppm, the water is said to be buffered (15, 16). According to the test result Lake Tana was found with acceptable range. These results also determine the status of pH to be stable.

Phosphorus: The phosphorous concentration was found with the range of 0.01 – 0.92mg/l, where the mean value was 0.14 ± 0.11mg/l. In freshwater lakes levels approaching or exceeding 0.5 mg/l are associated with cultural eutrophication with excessive growth of algae and aquatic plants (17). A study conducted at Pushkar Lake India 2008, phosphorus was reported with the range of 0.4 – 2.03mg/l, where the result was much higher in the event of annual celebration characterized with dumping of waste as and bones (18). In the current study higher concentration was recorded at location 06 around St. George Church. The reason for high concentration might be resulted due to loading of untreated wastewater through the sewer line connected with surface runoff drainage system, directed into Lake Tana and also prone for contaminant sources as explained in the sanitary survey report.

Phosphate: The phosphate test result at different locations ranges between 0.05 – 2.82mg/l. higher concentration of phosphate result was identified at location 06 known as St. Gorge church area. This result might be influenced due to wastewater discharged from the central part of the city and anthropogenic activities at the lakeshore. This result in conformity with a study conducted in variations of water quality of urban river in Nigeria 2013, the phosphate level was reported with the range of 0.81 – 1.14mg/l, where the main reason for high concentration report was due to human pressure in the urban centers which affect the downstream (19).

Nitrate: Is one of the major anions in natural waters, and concentrations can be greatly elevated due to leaching of nitrogen from fertilizer, feedlots, and septic tanks. The mean concentration of nitrate nitrogen (NO_3 as N) in a typical surface water supply is around 0.2 to 2 mg/l (20) , where the WHO drinking water guideline 2006 defines Nitrate Nitrogen as 11mg/l and nitrate 50mg/l (21). In the current study the nitrate level ranges between 2.7 – 12.05 mg/l and the mean value was 6 ± 2.92mg/l. The nitrate – Nitrogen concentration ranges from 0.61 – 2.72mg/l as multiplied with conversion factor to nitrogen: 1 mg/l as nitrate = 0.226 mg/l as nitrate-nitrogen; 1 mg/l as nitrite = 0.304 mg/l as nitrite-nitrogen (22). Higher Nitrate concentration was recorded at location 07 known as Tana Hotel area, this result may indicate the crude loading practice of sewage into the Lake.

Manganese : Man-made sources of manganese includes industrial wastes, discarded batteries and agricultural products (20). In this study manganese concentration was found within the range of 0.1 – 1.30 mg/l with the mean value of 0.58 ± 0.37 mg/l. Higher concentration was recorded in the locations around Felege Hiwot Referral Hospital, Tana Hotel, Avantie Hotel and Shum Abo recreational area. The WHO guideline Value to manganese is 0.4 mg/l, from aesthetic and in the basis of staining laundry, UK and the United States Environmental Protection Agency (USEPA) limit the manganese Secondary Maximum Concentration Level (SMCL) to 0.05 mg/l (20). A study conducted in Egypt on Water Quality and Heavy Metal Monitoring in River Nile 2010, manganese concentration was found with the range of 0.033 – 0.099 mg/l on the analysis of water (23). The concentration in the current study is high as compared to the guideline and from the study conducted in Egypt. This may be due to crude dumping of waste from nearby institutions and service centers. The other may associate to anaerobic or low oxidation conditions (20, 24).

Iron: The concentration of iron level was found within the range of 0.05 – 0.8 mg/l, where the mean value was 0.37 ± 0.18mg/l. higher result was recorded at the around Felege Hiwot Referral Hospital and at Shumabo recreational area. The USEPA SMCL and WHO guideline level is 0.3 mg/l, the goal is to limit less than 0.05 mg/l to prevent reddish-brown staining of laundry (14, 21). A study conducted in Egypt at the River Nile 2009 Iron concentration on water analysis was ranged from 0.19 to 0.49. In the current study the iron concentration in selected location was beyond the permissible limit, this might associate to the presence of organic matter that produce anoxic reducing conditions and an increases dissolved Iron (25).

Dissolved Oxygen: The DO was found with range of 3.5 and 8.5 mg/l, where the mean was 6.62 ± 1.75mg/l. Low DO was recorded at the locations ''Maremiabiet'' West Gojjam prison area and Felege Hiwot Referral Hospital. This result was similar with a study conducted on assessment of physicochemical characteristics and suggested restoration measures for Pushkar Lake Ajmer Rajasthan, India 2008 (18) where the dissolved oxygen varied from 4.1 – 7.3 mg/l. Another study conducted on variations of water quality in urban river of Nigeria 2013, the DO concentration ranges from 0.8 to 7.4mg/l. The main reason for low DO was reported as dumping of waste from agricultural practice such as piggery, fish farm, snailry, Wastewater discharge and organic waste dumped from abattoir, indiscriminate dumping of waste from marketing center were the main source of pollution and contributing factor for low DO level in the rivers (19). Changes in dissolved oxygen concentrations can be an early indication of undesirable conditions in physical, chemical and biochemical factors in the water bodies (8). In the current study low dissolved oxygen level, in the two locations may be associate to loading of sewage and other waste directly in to the Lake. The survey result supports how the condition is critical in these particular locations.

Biochemical Oxygen Demand (BOD): In this study the BOD test was investigated within the range of 3.2 mg/l in less impacted area of the sampling stations and 23.7mg/l in highly stressed areas of sampling locations. Low BOD result was recorded at location 3 known as Kibran area selected as reference site. Higher BOD result was recorded in areas with highly stressed locations Marmiabiet or West Gojjam prison area and Felege Hiwot

Referral Hospital. The UK Royal commission on sewage disposal in 1915 observed that unpolluted rivers rarely had BOD value of more than 2 mg/l and could accept added pollution up to a total BOD of 4 mg/l without apparent determent. This gave to raise the maximum permissible BOD of 20 mg/l in a sewage effluent entering a watercourse with an 8:1 dilution fresh water (26). In this study the BOD level particularly in selected locations was found very high even the permissible level of effluent. The main reason may associate to crude dumping of waste and untreated wastewater loading. The survey report supports how the condition in these particular locations was very critical and the result was coinciding with the current physical condition.

Bacteriological analysis: In this study the total coliform count was found over 180 /100 ml in four locations. Out of the four positive samples analyzed for confirmative test, three sample were found positive for Escherichia coli type one (E.coli type one). E.coli was not isolated around Kibran area selected as reference site. The presence of E. coli 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.

Sanitary survey: Sanitary survey in water quality analysis is a best mechanism that enables to evaluate the condition and to demonstrate the real picture of pollution status. The survey report clearly indicates the crude dumping of waste and the way how the lake is being polluted from different institutions and service providing centers. The survey also enables to identify the conditions that enhance siltation because of wetland tillage and construction activities.

The sanitary survey report and the laboratory findings clearly indicated in the indexed figure, which shows the quality of Lake Tana, bound to Bahirdar city Administration is critically impaired.

5. Conclusion

The findings of this study showed that the water quality of Lake Tana bound to Bahirdar City Administration was found unsatisfactory because of pollutants loaded into the lake.

The sanitary survey report signifies how the condition is serious around the southern region of Lake Tana. Indiscriminate dumping of solid waste, connection of untreated sewage into the surface runoff drainage system and other anthropogenic activities attribute in deteriorating the quality of the lake. The under construction runoff drainage across Bata church and the tillage of the natural wetland may result serious effect in siltation load.

6. Author's contribution

Dagnew A. Ewnetu, was responsible for generating the concept of this research paper, literature review and organization, preparation of draft research proposal document, organizing data collection process, and preparation of draft data analysis and interpretation.

Bikes D. Bitew is participated in research topic preparation process, proposal research design process, data analysis, and interpretation process.

Daniel H. Chercos participated in proposal research design process, data analysis, and presentation and interpretation process of result, preparation of scientific paper or the manuscript, and corresponding author of the manuscript.

All the authors read and approve the draft manuscript.

7. Competing interests

The authors declare that they have no competing interests.

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Table 1 Water quality summary result of Lake Tana bound to Bahirdar City Administration from June 7 - July 19/2013

. Parameters	Unit	Min	Max	Range	Mean	SD	WHO Guideline	EU/EEC
pH		6.48	8.34	1.86	7.41	0.46	6.5 - 8.5	6.5 -8.5
Temperature	^{o}c	20.20	25.60	5.40	22.80	1.19		$25^{o}c$**
Conductivity	μScm^{-1}*	84.00	230.00	146.00	171.42	23.53	1492	-
TDS	mg/l	50.00	138.00	88.00	102.54	14.07	1000	-
Turbidity	NTU	1.54	43.30	41.76	18.70	9.00	5	4
Nitrate	mg/l	1.10	12.05	10.95	6.18	3.24	50	50
Nitrite	mg/l	0.01	0.32	0.31	0.07	0.07	3	0.01-0.03
Ammonia	mg/l	0.08	0.62	0.54	0.24	0.17		0.2 –1.5**
Phosphate	mg/l	0.02	2.82	2.80	0.43	0.70		0.5 – 0.7**
Phosphorous	mg/l	0.01	0.92	0.91	0.14	0.11		0.005 – 0.01
Total Alkalinity	mg/l	78.00	159.00	81.00	99.31	24.92		No reference
Sulfate	mg/l	0.00	10.00	10.00	3.75	3.17	250	250
Irion	mg/l	0.05	0.80	0.75	0.37	0.18	0.3	0.2
Manganese	mg/l	0.10	1.30	1.20	0.58	0.37	0.4	0.05

*μScm^{-1} (micro Siemens per centimeter)
**EEC – European Economic Commission
Source: - Environmental Protection Agency (EPA) of Ireland Parameters of water quality interpretation and standards, 2001
EU – European Union
Source: - UNESCO, WHO, UNEP ©1992 1996 – water quality assessment, A guide to use of Biota sediments and water in Environmental Monitoring 2nd edition.

Table 2 Bacteriological analysis test result of Lake Tana at selected locations From June 2013.

Locations	Total coliform org/100ml	Escherichia coli (E.coli type 1)	Method of analysis
Shum Abo Recreational area	> 180/100ml	present	Multiple tube
Maremiabiet	> 180/100ml	present	Multiple tube
Kibran Area	> 180/100ml	Absent	Multiple tube
Felege Hiwot Referral Hospital	> 180/100ml	Present	Multiple tube

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Table 3 Summary of Sanitary survey report conducted at Lake Tana Bound to Bahirdar City Administration June 2013.

S N	Potential pollutant sources and observed changes	Observed	
		Yes	No
1	Is there direct waste discharge mixing index into the lake?	7(87.5%)	1(12.5%)
2	Is there a practice of dumping solid waste nearby the lake?	7(87.5&)	1 (12.5%)
3	Is there industrial waste discharge into the lake?	0	8(100%)
4	Is there a practice of connecting sewer line into surface runoff drainage system?	7(87.5%)	1(12.5%)
5	Is there a chance of oil spill into the lake?	8(100%)	0
6	Is there undesirable vegetation growth in the lake?	7(87.5%)	1(12.5%)
7	Is there any filthy and unaesthetic condition in the visited site?	7(87.5%)	1(12.5%)
8	Is dead fish observed?	0	8(100%)
9	Is there fish and other animal offal or carcass observed in the visited site?	7(87.5%)	1(12.5%)
10	Is there any risky condition to pollution that threatens aquatic life?	8(87.5%)	1(12.5%)
11	Is the visited site found impaired for recreation?	7(87.5%)	1(12.5%)

Category of risk of pollution

	Category to risk of pollution	Number	%
	No risk	0	0
	Low risk	1	12.5%
	High risk	5	62.5%
	Very high risk	2	25%
	Total	8	100%

Figure 1

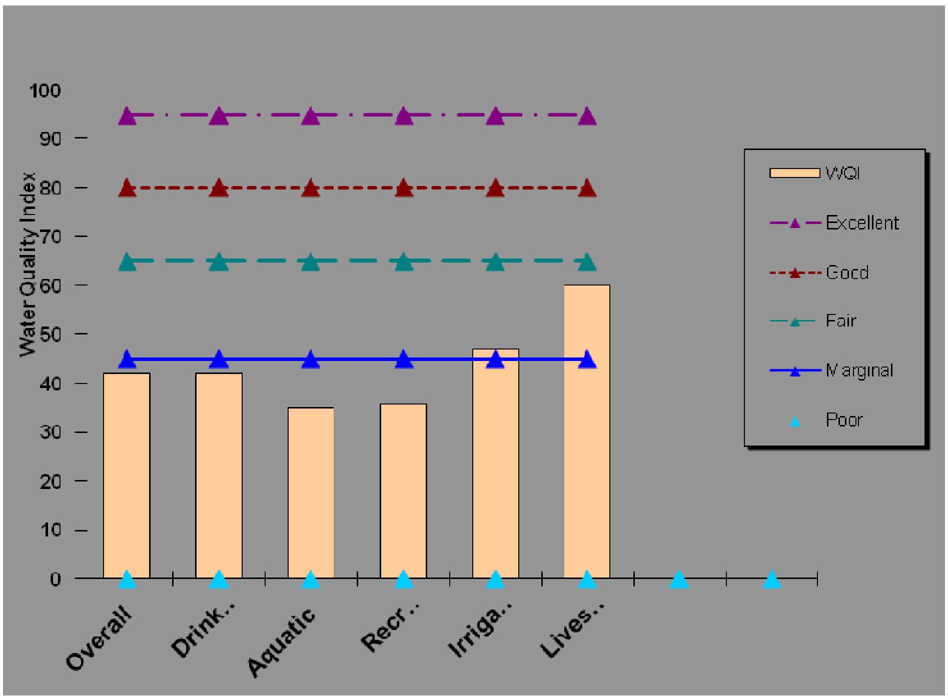

Figure 2 Canadian Water Quality Index of Lake Tana bound To Bahirdar City Administration from June 7 - July19/2013.

Figure legends

Figure 3 Canadian Water Quality Index of Lake Tana bound To Bahirdar City Administration from June 7 - July19/2013. .

WQI (water quality index): the water quality results based on common parameters.

Excellent: WQI value, 95-100, Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels; these index values can only be obtained if all measurements are within objectives virtually all of the time.

Good: WQI value, 80-94, Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: WQI value 65-79, Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal: WQI value 45-64, Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels

Poor: WQI value, 0-44, Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.