THE IMPACT OF INFRASTRUCTURE DEVELOPMENT ON LAKE TANA WATER QUALITY

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Abstract

Lake Tana is the biggest freshwater body in Ethiopia that has enormous environmental, ecological, cultural, political, and economical services. In its southern shore, one of the rapidly growing Ethiopian cities Bahir Dar is situated. The expansion of the city leads to land use changes, which in turn have adverse effects on water quality and its ecosystems. Thus, the objective of the study was to investigate the seasonal and spatial variability of Lake Tana water quality in the Bahir Dar gulf area by taking water samples in January 2017 and August 2017. The study identified factors that affect Lake Tana water quality using experimental work integrated with the questioner and key informant interview. Then the collected data was analyzed using descriptive statistics, Wilcoxon Signed Ranks Test, and Kruskal walis H-Test by BM SPSS statistics 20. According to the experimental value, the mean value of water quality parameters have been observed as pH (7.75), temperature(23.7^{0}C), dissolved oxygen (7.48mg/L), turbidity (14.35 FTU), electrical conductivity (160.14 µS/cm), total dissolved solids(76.14 mg/L), biological oxygen demand (0.41 mg/L), total hardness (97.28mg/l), nitrate (0.44mg/l), phosphate (0.3mg/l) and sulphate(5.52 mg/l). However, ammonia was not detected in both seasons. Furthermore, the statistical result has confirmed significant variation in a season ($P<0.05$) for PH, turbidity, electrical conductivity, BOD_5, total hardness, and nitrate. However, the statistical result was not significant ($P>0.05$)for temperature, DO, TDS, Phosphate and sulphate while the test result depicted significant variation in site($P<0.05$) for BOD_5, temperature, electrical conductivity, nitrate, sulphate, total hardness, total dissolved solids, turbidity, PH, dissolved oxygen and statistically non-significant ($P>0.05$)for phosphate. Therefore, according to the result obtained the most causes for Lake Tana water quality degradation are the traditional way of city waste discharges into the lake due to mounting urban infrastructure expansion, unmanageable urbanization, landfill, invasion of weed, lake water withdrawal for hydropower generation and application of inorganic fertilizer for agriculture activities nearby lake. Besides, lack of government attention for the lake, climate change, and associated service giving centers affected the water quality mainly through the impacted sites.

Keywords: Lake Tana, water quality parameter, spatial and seasonal variation, urban infrastructure

1. Introduction

The setting of infrastructures development has great importance in developing countries since it enhances the living standard of the local population and helps them to have access to scarce resources like water, education, health facilities, and other related services. Conversely, infrastructure development has interrupted millions of lives, due to their poor concentration level and in consideration of the need of local actors [1]. Furthermore, landscape alteration-accompanying urbanization where pavement and building construction produce impervious surface cause rapid runoff through concrete drains and pavement lined stream channels. Besides, the increasing imperviousness of an area increases the volume and discharge of runoff and affects the water quality and biodiversity of freshwater systems. Likewise, further construction of different infrastructures like highways and buildings resulted in the alteration of the landscape and the movement of earth materials, which may generate high sediment concentrations and loads into the water [2]. Hence, water bodies, which have a diversity of wildlife as well as nesting and breeding sites for a different kind of aquatic system, are currently endangered by human being activity due to rapid urbanization. As a result, the lakes and reservoirs are exposed to a varying degree of environmental problems [3].
Lake is one of the freshwater sources, which is a regional center of commerce and human activity, subsistence fisheries, drinking-water supply, waste disposal, and recreation. Besides, it provides habitation for fish, crustaceans,

mollusks, turtles, amphibians, birds, mammals, insects, aquatic plants and preserves biodiversity on surrounding land. Thus, the maintenance of the lake health and biodiversity is vital to the lives of human communities surrounding lakes. Nevertheless, recently the world lakes are in crises due to various factors like diversion of the lake water for irrigation and industry, invasion of plant and animal exotic species, contamination of lakes by toxic and nutrients from industry, farms, sewage, and urban runoff that threaten the urban ecosystem [4].

In Africa, since the 1960s, rapid urban growth adds to pressure on land resources within areas surrounding cities since it places enormous stress on natural resources, existing amenities, and cause environmental deterioration that led to the increased generation of waste (Edward, 2008). Besides, with the rapid development of social economy, the urban water environment and ecosystem had become increasingly serious due to disordered urban construction and a massive discharge of pollutants [5]. Ethiopia, which is one among the African countries, is gifted with a number of lakes and large rivers, which have a substantial role to overall economic development [6]. Lake Tana is Ethiopia's largest and most prominent freshwater lake and as the source of the Blue Nile signifies the water tower of Africa [7]. In the southern shore of the lake, Bahir Dar city, which is a rapidly growing city in Ethiopia, is located.

Today the city is one of the fast growing and largest cities in the country. In line with its growth, different infrastructures such as education, health, transport, and communication system etc have grown and nowadays sewage discharge into Lake Tana has become a severe and significantly manifested problem [8]. Likewise, uncontrolled urbanization, population growth, the expansion of private, and government-owned infrastructures are also increasing and lead to a change of land use patterns, which have adverse effects on water quality and its ecosystems [9]**.** Besides, the population of Bahir Dar city has grown rapidly at an average rate of five percent per annum, mainly after 1991 when it was made the capital of the Amhara Region. As a result, Bahir Dar city and its surroundings have become the focus of industrial and commercial development and inward investment growth in the city. The expansion of the city and the consequent demand for more and better infrastructure services have created business opportunities in construction, manufacturing activities, service trade, and non-formal trade opportunities. Consequently, new hotels and industrial plants with high potential pollution effects are built on the shores of Lake Tana [10]. On the other hand, while the Environmental Impact Assessment (EIA) policy is in place for new hotels, some of the old hotels could not be having proper sewerage disposal systems in place and no cleaner production practices [11]. This worsens the environmental deterioration of the lake.

The greater part of Bahir Dar city population use dry pit latrines since there is no centralized sewerage system and a large amount of the households use open fields due to lack of specified disposal sites and sanitary facilities. The existing factories also dispose of the waste matter without any treatment and no organized site for its solid waste disposal. Consequently, the majority of the households in the city dispose wastes into the compound, open field, and the streets. Thus, more than 50% of the households release their wastes into open fields while approximately only 39% have a sort of garbage pit [12]. Moreover, Mekonnen [13] also indicated 20% of Bahir Dar households do not have access to latrines and disposing wastewater into the accessible open spaces and only 35% of the city's liquid waste was being collected due to lack of latrines, waste disposal sites and poor collection practices. So, Bahir Dar city generates more wastes and will continue to produce more with its ever-increasing populations [14]. Furthermore, the growth of the city with modern buildings that use flush toilets will increase the generation of more wastewater that needs treatment. On the other hand, waste handling and treatments have not yet installed with the rate of waste production, which is posing the threat of accumulation in the environment.

Hence, the waste management practice of different institutions in the city is not environmental friendly. Institutions like Felegehiwot Referral Hospital, Bahir Dar Prison, Bahir Dar University Technology Institute wastewater from students' cafeteria, and the old hotels like Ghion, Tana and recently built hotels like Avanti and Grand etc, release their wastewater directly towards the Lake, which in turn produces bad smells [13]. Therefore, Lake Tana is becoming a sink for dumping municipal, industrial, and domestic wastes of a growing urban population. Therefore, assessing its water quality across spatiotemporal scale using selected water quality parameters is important. Hence, the study initiated with an objective to investigate the impacts of urban infrastructure development on seasonal and spatial variability of water quality parameters between the impacted and less impacted sites in Bahir Dar gulf by taking water samples in January 2017 and August 2017.

2. *Material and Methods*

2.1. Description of the Study Area

The study was conducted in the southern part of Lake Tana in the Bahir Dar Gulf area. Lake Tana, which is located at the Northwestern part of Ethiopia adjacent to Bahir Dar city with coordinates of $11^0$36'N, $37^0$23' E and an altitude of about 1800 m above sea level. It is the source of the Blue Nile, shallow, oligotrophic, and freshwater. The lake occupies a wide depression in the Ethiopian plateau formed due to the volcanic blocking of the Blue Nile River, probably in the early Pleistocene period [15]. It is a Crater Lake formed two million years ago [16]. Lake Tana is 78 km long and 67 km wide with an area of 3150-3500 km^2. The lake constitutes about 50 percent of the total inland water area of Ethiopia. It is a shallow lake, with a maximum depth of 14 m and a mean depth 8.9 m. Based on the chemical parameters, its trophic status could be categorized as mesotrophic volcanic basalt mostly covered with a muddy substratum with only little organic matter [16, 9, 17].

2.2. Sample Site Selection Criteria and water sampling procedure

Six sampling sites were selected to take water samples for assessing the physicochemical water quality. Four sites were taken as impacted sites in which the anthropogenic activities are high whereas the remaining two sites are considered less impacted sites which is considerably less affected by anthropogenic activities. In line with this, water samples were collected twice a year in January 20l7 and August 2017 to investigate the seasonal and spatial variability of the physicochemical water quality parameters in selected sites. Grab water sampling method was employed during collection i.e. a single volume of water taken all at one time from a single point using acid-washed polyethylene bottles for chemical analysis. Before sample collection, bottles were washed with concentrated nitric acid and distilled water to avoid contamination. Then samples were collected directly from the Lake after washing the bottle for about 3-5minutes. After that, the bottles were preserved using icebox and transported to the laboratory for analysis. Twelve physicochemical water quality parameters including pH, dissolved oxygen, temperature, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), nitrate, ammonia, sulphate, phosphate and BOD_5 were taken for analysis of January 2017 as a representative of dry season and August 2017 for rainy seasons in the selected sites.

2.3. Data analysis technique

Data analysis, which is an important part of the research, was done using IBM SPSS statistics 20. To analysis, the water quality parameters using the measured value the non-parametric Wilcoxon Signed-Ranked Test and Kruskal–Wallis H tests were employed. The Wilcoxon Signed-Ranked Test was used for pairwise comparisons of water quality between dry and rainy seasons whereas their differences among the sampling sites were tested by Kruskal–Wallis H tests. Furthermore, descriptive statistics like minimum, maximum and mean was used to analyse the descriptive information. In addition, the data collected through questioner and interview about the recent water quality of Lake Tana and causes for water quality decline was analyzed using multiple response analysis and narration.

3. **Results and Discussion**

3.1. *Seasonal and Spatial variability of Physico-chemical water quality parameters*

Water quality is used to express the chemical, physical, and biological characteristics of water in relation to all other hydrological properties, usually in respect to its suitability for particular importance [18]. To test the water quality and comparing the obtained results with standard values, the physicochemical water quality parameters which are taken for the study are: (a) temperature, (b) pH, (c) Turbidity, (d) Total Dissolved Solids, (e)Electrical conductivity, (f)dissolved oxygen (DO) concentration,(g)Phosphate, (h) Sulphate, (i)BOD_5, (j)Nitrate, (k)Total Hardness and (L) Ammonia. These parameters are selected taking into consideration as it has an influence on the lake aquatic life presence.

Water Temperature

Water temperature is one of the factors that affect the physical characteristics of aquatic ecosystems and influence various water quality parameters [19]. The water temperature of Lake Tana has a mean value of 23.7^{0}C in which a minimum value of the 20.7^{0}C and maximum value of 26.8^{0}C recorded in the rainy season. However, the Wilcoxon Signed Ranks Test result showed the variation of Lake Tana water temperature between seasons is not statistically significant with the value of P>0.05(Z= -1.505, n=18, p=0.132). whilst the Kruskal Wallis Test value (P=0.012, Chi-square=14.5, df=5) showed the temperature of Lake Tana among sampling sites is statistically significant in which the lowest and the highest mean rank temperature recorded in the less impacted and impacted sites, respectively.

Water temperature is a controlling factor for aquatic life. Aquatic organisms can survive in water temperature less than 28^{0}C. Thus, the mean water temperature of Lake Tana in this study is 23.7^{0}C that ranges from 20.7^{0}C-26.8^{0}C. Hence, currently, Lake Tana water temperature is suitable for aquatic life and the value of temperature is within the range reported by Wondim [20], which varies between 16.4^{0}C to 31.3^{0}C. However, the temperature value of Lake Tana is a bit higher compared Lake Hawassa in Southern part of Ethiopia, which varied between 20.98^{0}C and 21.33^{0}C with an average value of 21.23^{0}C to the lake system [21].

Dissolved Oxygen (DO)

The dissolved oxygen in water has basic importance to the life and health of any surface water. It is on the dissolved oxygen that fish and other aquatic organisms depend for their respiration. It is also important to allow aerobic microorganisms to stabilize any biodegradable organic material present [22]. Thus, dissolved oxygen is one of the significant parameters in water quality evaluation and reflects the biological and physical processes existing in the water [19]. The overall dissolved oxygen concentration of Lake Tana ranges from a minimum 5.9 mg/L in the rainy season and a maximum value of 8.71 mg/L in the dry season with a mean value of 7.48 mg/L. Nevertheless, the Wilcoxon Signed Rank Test result showed the variation of Lake Tana dissolved oxygen between seasons is not statistically significant with the value of $P>0.05$($Z= -1.422$, $n=17$, $p=0.155$). On the other hand, the Kruskal Wallis Test value ($P=0.013$, Chi-square=14.515, df=5) confirmed that the dissolved oxygen in Lake Tana among the sampling sites is statistically significant in which the lowest and the highest mean rank DO value recorded at the impacted and less impacted sites, respectively. These may be due to the discharge of high wastes and other effluents containing high organic matter into the impacted sites whereas relatively reduced organic waste amount in less impacted sites. Likewise, the pilot study on anthropogenic fecal pollution impact in Bahir Dar Gulf of Lake Tana, Northern Ethiopia [12] indicated DO concentration is highest in the less impacted sites than impacted sites.

In the present investigation, DO have a mean value of 7.48 mg/L ranged from 5.90 mg/L to 8.71 mg/L. This value of DO is within the permissible limits of EPA and WHO (1993) (>5mg/l) standard in all sampling sites for the drinking and aquatic life. Therefore, presently Lake Tana DO value is ideal for aquatic life and drinking, however, in the future if proper care is not taken Lake Tana will become unsuitable even for aquatic life.

pH (Potential of hydrogen)

A pH test measures the alkalinity or acidity of water. Pollution from an accidental spill, agricultural runoff, and sewer overflow can change the pH of the water in the lake [23]. This change greatly influences the availability and solubility of all chemical forms in the water and this might exacerbate nutrient problems leading to a destabilization of the ecosystem [24]. Lake Tana mean PH value is 7.75 of which the minimum 5.9 and the maximum 9.2 value recorded in dry and rainy seasons. The maximum PH value in the rainy season may be due to the rainfall, which may dilute the alkaline substances or the dissolution of the atmospheric carbon dioxide. Moreover, the Wilcoxon Signed Ranks Test result showed the pH of Lake Tana between seasons is statistically significant with the value of $P<0.05$($Z= -3.724$, $n=18$, $p=0.000$). On the other hand, the Kruskal Wallis Test value ($P=0.043$, Chi-square=11.449, df=5) showed the pH of Lake Tana among the sampling sites is statistically significant in which the highest and lowest mean rank pH value recorded on less impacted and impacted sites, respectively. This might be attributed to the microbial decomposition of organic matter due to the release of wastes from septic tanks, sewage and domestic waste into the lake mainly along impacted sites than less impacted sites. Furthermore, the soap and detergents used for washing eventually get into the lake mainly in impacted sites. Correspondingly, Gosh [12] confirmed the highest pH concentration of Lake Tana in less impacted sites and lowest concentration in the impacted sites of Lake Tana.

In the present investigation, the mean pH value of Lake Tana is 7.75, which is slightly alkaline ranged between 5.9-9.2. Thus, the pH of Lake Tana in some sites is not within the permissible limits for drinking, recreation, agricultural and aquatic life water uses (6.5-8.5/9) [25, 26, 27]. Correspondingly, Wondim (2016) study depicted Lake Tana water is slightly alkaline with acceptable pH range(pH range 6.98 to 9.97) whilst compared with pH values of Lake Hawassa in Southern part of Ethiopia which ranged 7.00 to7.7 average values of 7.5 [21], the pH value of Lake Tana was found to be higher.

Turbidity

Turbidity refers to water clarity that appears murkier when there is a larger amount of suspended solids and the higher the measured turbidity in the water [28]. The mean turbidity value of Lake Tana is 14.35NTU in which the minimum 10.22NTU and maximum of 21.1NTU value recorded in dry and rainy seasons respectively. This is because, during the rainy season, the lake receives a large volume of water with retained suspended materials and other wastes. Besides, the human being activity mainly around the Lakeshore may cause the loose topsoil to easily erode due to accelerated runoff facilitated by washing soil and other wastes into the lake in the rainy season, which consequently increases the lake turbidity. Furthermore, Wilcoxon Signed Ranks Test result showed that the turbidity of the Lake between seasons is statistically significant with P<0.05(Z=-3.333, n=18, P<0.001). Whereas the Kruskal Wallis Test value (P=0.04, Chi-Square=11.426, df=5) depicted the turbidity value of Lake Tana among the sampling sites is statistically significant in which the highest mean rank turbidity value recorded in the impacted sites and the lowest mean rank turbidity value recorded in the less impacted sites. This may be associated with the discharge of urban wastes, liquid and solid waste effluents from lakeside hotels, lodges, and car washing centers, construction debris, and urban areas into the impacted sites but relatively less amount of it in the less impacted site.

The turbidity of Lake Tana in this investigation has a mean value of 14.35 NTU ranged from 10.22 to 21.10 NTU which is beyond the permissible limit of lake water turbidity<5NTU [29] and less than 1NTU for drinking purpose [25]. However, the turbidity value of this study is within the range of Lake Tana turbidity value indicated in Wondim [20]. The value was in the ranges of 5.1 to 989 NTU whereas compared with turbidity values of Lake Naivasha in Kenya (the mean value varied between 10.05 to 67.17NTU with the overall mean value of 30.86 NTU[30], the turbidity value of the study was lower. On the other hand, compared with the turbidity values of Lake Hawassa in Southern part of Ethiopia, which ranges between 6.82 to 20.98 NTU with a mean value of 8.44 NTU [21], the turbidity value of this study was relatively higher.

Electrical conductivity

Electrical conductivity (EC) is the water quality parameter used to evaluate the purity of water and measures the capability to transfer electric current [31]. The mean electrical conductivity value of Lake Tana was 160.14 µS/cm with a minimum value of 127.8 µS/cm and the maximum value 182 µS/cm recorded in the same rainy season. The high electrical conductivity in the rainy season can be due to the anthropogenic activities around the lakeshore including runoff from farmlands and domestic wastes. Besides, Wilcoxon Signed Ranks Test result indicated electrical conductivity between seasons was statistically significant with a value of P<0.05(Z=-3.398, n=18, p=0.001). Likewise, the Kruskal Wallis Test value (p=0.000, Chi-square=29.462, df=5) showed the electrical conductivity value of lake Tana among sampling sites is statistically significant in which the highest and lowest mean rank value recorded in the impacted and less impacted sites respectively. The high electrical conductivity value in the impacted site may be due to urban wastes, which come from urban infrastructures like streets, hotels, parking lots and other buildings. In line with this pilot study on anthropogenic fecal pollution impact in Bahir Dar Gulf of Lake Tana, Northern Ethiopia [12] indicated the high concentration of conductivity in the impacted sites than less impacted sites.

In this study, the EC has a mean value of 160.1 µS/cm ranged from 127.8 to 182.0 µS/cm which is under the WHO guideline value prescribed for drinking purpose(1500 µS/cm) and EPA guideline (1000 µS/cm). Moreover, the EC value of the study is within the range of Lake Tana EC value between 60µS/cm to 1000µS/cm [20]. However, the EC value of Lake Tana was found to be much lower compared with Lake Naivasha in Kenya(the mean value of EC varied between 251 to 421µS/cm with the overall mean value of 302.28µS/cm [30] and Lake Hawassa with an average value of 750.1µS/cm[21],

Total Dissolved Solid (TDS)

Dissolved solids are important to aquatic life by keeping cell density balanced. The mean TDS value of Lake Tana was 76.14 mg/L with a minimum value of 64.6 mg/L and a maximum value of 89.1 mg/L recorded in the same rainy season. This may be due to the discharge of urban wastes into the lake by rain runoff. Moreover, the Wilcoxon Signed Rank Test result indicate that nearly statistically significant test of TDS value concentration between seasons with a value of Z=-1.938[b], n=18, p=0.053. On the other hand, the Kruskal Wallis Test value (p=0.000, Chi-square=24.274, df=5) demonstrated the TDS value of Lake Tana is statistically significant in site with highest mean rank value in impacted sites and lowest mean rank value in less impacted sites. This may be due to the large amount discharges either inorganic or organic matter to the lake from urban areas, agriculture wastes, and construction materials into the impacted sites. In the same way, the pilot study on anthropogenic fecal pollution impact in Bahir Dar Gulf of Lake Tana, Northern Ethiopia [12] shows the high concentration of total dissolved solids in the impacted sites than less impacted sites. According to WHO (2008), freshwater has TDS values lower than 1000 mg/L. Thus, the TDS value of the study fits with this value since its mean value of 76.14 mg/L ranged from 64.60 mg/L to 89.1mg/L. Similarly, the TDS value of this study is within the TDS value range of Lake Tana that range from 20 to 500mg/l [20] and TDS value ranged 20 to 490mg/l [32].

Biological Oxygen Demand (BOD5)

BOD measures oxygen quantity that bacteria will use while decomposing organic matter under aerobic conditions [33]. It directly affects the amount of dissolved oxygen in lakes. If the BOD concentration becomes increased, oxygen declined rapidly in the lakes, which in turn make the availability of oxygen for aquatic life to be reduced. The mean BOD_5 value of Lake Tana is 0.41 mg/L in which the minimum value 0.1mg/L and the maximum value of 0.97 mg/L recorded in rainy and dry seasons respectively. Besides, the Wilcoxon Signed Ranks Test result indicated the BOD_5 concentration between seasons is statistically significant with the value of $P<0.05$($Z= -2.727^b$, n=17, p=0.006). whilst the Kruskal Wallis Test value (p=0.001, Chi-square value=21.392, df=5) indicated the BOD_5 value of Lake Tana among sampling sites is statistically significant in which the highest BOD_5 mean rank value was recorded in the impacted sites while relatively low BOD_5 mean rank value in the less impacted site. The presence of high BOD_5 mean rank value in the impacted site can be due to organic and inorganic waste concentrations.

High biological oxygen demand level causes dissolved oxygen depletion, which could be detrimental to aquatic life. The concentration of BOD_5 in this study have a mean value of 0.41 mg/L ranged from 0.10 to 0.97 mg/L which is within the acceptable limit of EPA guideline (<5 mg/L) for aquatic organisms in all sites; which indicates the lake is still suitable for aquatic life existence in terms of BOD_5.

Total hardness (TH)

The total hardness of water is the sum of calcium and magnesium concentrations, both expressed as milligrams of calcium carbonate equivalent per liter [34]. The mean total hardness value of Lake Tana was 97.28 mg/L with a minimum value of 74.4 mg/L in the dry season and the maximum value of 153.4 mg/L in the rainy season. Besides, the Wilcoxon Signed Rank Test showed the total hardness value is statistically significant between seasons with a value of $P <0.05$($Z= -2.940^{b,}$ n=18, P=0.003). On the other hand, the Kruskal Wallis Test value (p=0.001, Chi-sqare=21.405,df=5) indicated the total hardness value of lake Tana among sampling sites is statistically significant with high mean rank value recorded in both the impacted site and less impacted site while the lowest mean rank value recorded in the impacted site. The occurrence of high total hardness values is most likely due to regular addition of large quantities of sewage and detergent into the lake from the Bahir Dar city residents and infrastructure waste and this mix to the less impacted site due to the polymictic behavior of Lake Tana.

Thus, the total hardness value of Lake Tana in this study has 97.28 mg/L mean value ranged from 74.4 mg/L to 153.4 mg/L. According to WHO (1984) standards for drinking water (<500mg/L), the result obtained within the acceptable value. Besides, the total hardness value of Lake Tana obtained in the study is agreed with Wondim [20], which is from 65 mg/l to 5300 mg/l. However, compared with the total hardness values of Lake Naivasha in Kenya (the mean value varied between 26 to 48mg/l with the overall mean value of 33mg/l[30], a total hardness value of Lake Tana was found to be much higher. On the other hand, compared with the total hardness values of Lake Hawassa in Southern part of Ethiopia with values 106.07 to 137.16 mg/l with an average value of 121.87 mg/l[21], the total hardness value of Lake Tana was found to be lower.

Nitrate (NO_3-N)

Nitrate is the most essential and major nutrient for phytoplankton growth. It is also considered as the most predominate inorganic compound in the aquatic system [35]. The mean nitrate value of Lake Tana was 0.44 mg/L with a minimum value of 0.11mg/L and a maximum value of 1.1 mg/L recorded in the dry season and rainy season, respectively. Besides, the Wilcoxon Signed Rank Test result depicted the nitrate value between seasons is statistically significant with the value of $P<0.05$($Z= -3.725^{b,}$ n=18, P=0.000). Furthermore, the Kruskal Wallis Test value (p=0.001, Chi-square value=20.715, df=5) indicated the nitrate value of lake Tana among sampling sites is statistically significant in which the highest mean rank value recorded in the impacted site while the lowest mean rank value recorded in the less impacted sites. The high nitrate concentration in the impacted site may be associated with the release of sewage and other domestic wastes, industrial pollutants, runoff from fertilized croplands and lawns into the lake and poorly functioning septic systems around lakeside hotels and other infrastructures that discharge the wastewater into the lake.

According to Murdoch [36], high nitrate content (>1 mg/L) is not favorable for aquatic life. Thus, in uncontaminated waters, the level of nitrate-nitrogen is usually less than 0.1 mg/L [37]. The nitrate value of Lake Tana in this study has a mean value of 0.44 mg/L ranged from 0.11mg/L to 1.10mg/L. Thus, the nitrate value of the lake is ideal for aquatic life except for one site, which has a value of 1.10mg/L. Likewise, the nitrate value of this study is within the nitrate value range of Lake Tana, which is between 0.003 mg/L to 4.7mg/L [20].

Phosphate (PO_4-P)

As phosphates increases, the growth of aquatic plants are encouraged and algal blooms can occur. With the increase in algae growth and decomposition, the dissolved oxygen levels will decrease [18]. The mean Phosphate value of Lake

Tana was 0.3 mg/L in which the highest mean value 0.63 mg/L and the lowest mean value 0.13 mg/L recorded in rainy and dry seasons, respectively. The high value of phosphate during the rainy season is essentially due to precipitation, surface water overflow, agricultural runoff, washing activity of the human beings that contributed to the inorganic phosphate content; as well as the entry of domestic sewage into the lake are responsible for the increase in the amount of phosphate. Nevertheless, the Wilcoxon Signed Ranks Test value of phosphate between seasons is not statistically significant with the value of P>0.05(Z= -1.548[b,] n=18, P=0.122). Furthermore, the Kruskal Wallis Test value (P=0.093, Chi-square value=9.433,df=5) indicated the phosphate value of lake Tana among sampling sites is not statistically significant. Though the test result is not statistically significant highest and lowest phosphate means rank value recorded in the impacted and less impacted sites respectively. This may be due to the release of domestic sewage particularly those containing detergents, industrial effluents and fertilizer run-off from lakeside infrastructures and agricultural activities into the lake mainly through impacted sites.

Thus, the concentration of phosphate in this study have mean value of 0.3 mg/L ranged from 0.13 mg/L to 0.63 mg/L which is above the maximum permissible limits according to WHO (1984) and EPA (2003) that may range from 0.005-0.02 mg/L in surface water for different purposes and the healthiness of the water ecosystem. In line with this, the presence of large algal blooms in Lake Tana Bahir Dar gulf is an indication of the eutrophication process, which degrades the quality of its water chemistry and its aquatic organisms. With further increasing infrastructures near to lakeshore high sewage wastes released and on the other hand agro-chemical, excessive fertilizer uses in the farm side results sever degradation of the lake water quality. Moreover, the use of detergents and soaps to wash their clothes and for bathing has resulted in phosphate concentration in the lake. This would harmfully affect the multiple uses of the lake water for drinking, fishery, recreation, aesthetic value, and ecological functions. However, the phosphate value of the study is lower compared with the phosphate value of Lake Tana, which varies between 1.55 mg/L to 15.8mg/L [20]. Whereas, the phosphate value of Lake Tana was found to be higher compared with the phosphate values of Lake Naivasha in Kenya (the mean value varied between 0.021 to 0.025mg/L with the overall mean value of 0.022mg/L [30].

Sulphate (SO_4^{2-})

Sulphates happen in water due to leaching from sulphate mineral and oxidation of sulphides. It is generally associated with calcium, magnesium, and sodium ions [34]. The mean Sulphate value of Lake Tana was 5.52 mg/L in which both maximum value 24.8 mg/L and minimum values zero recorded in a rainy season. On the other hand, the Wilcoxon Signed Ranks Test indicated the sulphate value between seasons is not statistically significant with the value of P>0.05(Z= -.501[b,] n=18, P=0.616). However, the Kruskal Wallis Test value (P=0.019, Chi-square value=13.544,df=5) indicated the sulphate value of lake Tana among sampling sites is statistically significant in which the highest and lowest mean rank value recorded in the impacted sites. Thus, the sulphate value of Lake Tana has a mean value of 5.52 mg/L ranged from zero to 24.8 mg/L. Sulphates found in all natural waters, the quantity differs according to the nature of the terrain through which they flow. They are usually derived from the sulphides of heavy metals (iron, nickel, copper, and lead). The function of water for the domestic purpose will, therefore, be severely hampered by high sulfate concentrations, hence the limit of 250 mg/l SO4 (EPA,2001).

Ammonia (NH_4-N)

Ammonia is usually found in natural waters, even if it is in very small amounts, because of microbiological activity, which causes a decrease of nitrogen-containing compounds. When found in levels above 0.1 mg/l N, sewage or industrial pollution may be indicated (EPA, 2001). However, the concentration of ammonia in this study was not detectable in all sampling sites either in the rainy or dry season.

3.2. Factors that affect the Water quality of Lake Tana

Lake Tana is a big lake and one of the largest in Africa that feeds the Blue Nile River. It is most important for the existence of Bahir Dar city [38]. Thus, imagining Bahir Dar city without Lake Tana is very difficult and unthinkable. However, Bahir Dar city expansion became a challenge to the ecological and socio-economic activity of the lake. Regarding these issues, when the respondents asked about the impact of urban infrastructure development on Lake Tana water quality, the majority replied as the impact is not good. Since it affects the water quality through discharge of their solid and liquid wastes, encroachment, and lack of lakeside infrastructure owner's responsiveness for the lake as their own resource and degrades it by giving priority for their benefit. Besides, the interviewed officials expressed the urban infrastructure wastes create a suitable condition for expansion of invasive weed and other problems like wetland loss, lake recession and biodiversity loss. They also stated lakeside car washing, construction material demolition, and boat transportation pollute the lake and its aquatic life. Moreover, when their economy improves, people start to use chemical soap, detergent, plastic, and other substances, which are not organic and have influences on the environmental resources including the lake. Thus, wastes discharged in to the lake through different canals and tubes due to sewerage system master plan absence of the city and these wastes produced from different sources create eutrophication on the lake and form suitable condition for occurrence of invasive species, make the lake to become hot and make the aquatic life to take heavy metals.

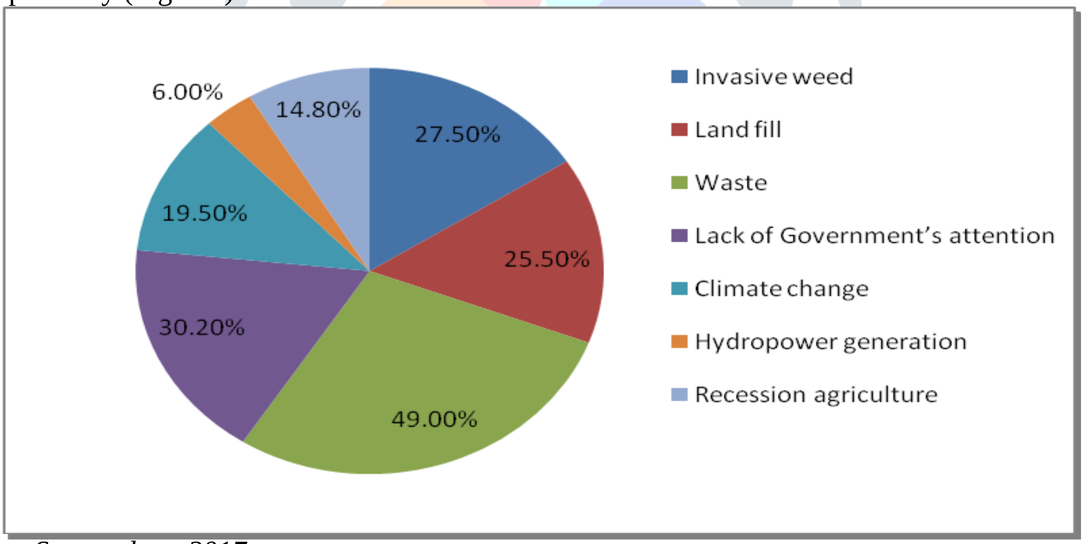
Furthermore, when respondents asked about the recent water quality of Lake Tana relative to the past 1986, 80.1% of them replied the water quality is decreased followed by 18.8% as undetermined whereas the remaining 1.1% replied increased (Table1).

Table 1: Recent water quality of Lake Tana relative to 1986

		Frequency	%
How do you express recent water quality of Lake Tana relative to 1986?	Increased	2	1.1
How do you express recent water quality of Lake Tana relative to 1986?	Decreased	149	80.1
How do you express recent water quality of Lake Tana relative to 1986?	Undetermined	35	18.8
How do you express recent water quality of Lake Tana relative to 1986?	Total	186	100.0

Source: Own Survey data, 2017

Multiple response analysis of those respondents who replied as the water quality of Lake Tana decreased expressed different factors. From the total response, 49% of the cases indicated wastes generated by urban socio-economic activities are major factors followed by 30.2%, 27.5%, 25.5%, 19.5%, 14.8%,6% of responses as lack of government attention for the lake, happening of invasive weed, landfill, climate change, recession agriculture, and hydropower generation respectively (Figure1).



Source: Own Survey data, 2017

Figure 1: Multiple response analysis for causes of recent water quality decrease relative to 1986

Besides, the interviewed officials expressed the water quality of Lake Tana recently decreased and stated the reasons like urban expansion and irrigation, liquid and solid waste discharges, lakeside landfill by urban infrastructures, withdrawal of water for hydropower generation, recession agriculture and loss of wetlands. As well, the officials depicted the wetlands, which have waste filtration capacity and serve a buffer for the lake became reduced and due to their loss, the water quality of Lake Tana endangered. The officials also mentioned different institutions that deteriorate Lake Tana water quality such as Bahir Dar University, Zenzilima campus, discharge their waste through Chinible River to the lake, Felige Hiwot referral hospital and Bahir Dar technology institute wastes from student's cafeteria enter into the lake in different ways. Furthermore, the officials point out Bahir city waste which comes from Kebele 13 and 16 enter into the lake through dippo, Kebele 15 and 3 through kuriftu, Kebele 6 and 12 wastes through Dib anbessa hotel and Alma hotel. According to them, the other challenge of the lake is water hyacinth invasive weed, which reproduces itself every fifteen days. This is a great enemy for the lake and due to its fast expansion; it prohibits the people to use the lake for different purposes, changes the fish taste and productivity, and affects the overall

economic, socio-cultural activity of the lake. When wastes are discharged from the urban areas and surrounding hotel and lodge, it forms phosphate and nitrate by feeding it the weed expanded fastly and now it becomes a great challenge for the lake. Consequently, they expressed now the lake water is below the standard for drinking purpose.
The interviewed elderly community members also expressed the recent water quality reduced relative to the past 1986. For this, they explained during the Derge regime on Lake Tana washing of clothes, bodies, and excretion in the surrounding area was not allowed but now it is considered as democratic right and people washed their clothes, bodies and lakeside excretion becomes common. Likewise, the city wastes are released into the lake through tubes and ditches.

4. Conclusion

This study has been conducted to assess the impact of urban infrastructure development on Lake Tana water quality status using physicochemical water quality parameters for the management of the Lake aquatic life. Moreover, it examines the factors affecting the water quality of Lake Tana relative to 1986. The analysis result about the spatial variability of lake Tana water quality tested using Kruskal-Wallis H-Test ($P<0.05$) showed significant differences in temperature, DO, PH, Turbidity, EC, TDS, BOD_5, total hardness, nitrate and sulfate among impacted and less impacted sampling sites while there is no significant difference($P>0.05$) in phosphate concentration among impacted and less impacted site. However, the Wilcoxon Signed Ranks Test($P<0.05$) of physiochemical characteristics of water quality in the southern shore of Lake Tana between rainy and dry seasons confirmed that PH, turbidity, electrical conductivity, BOD_5, total hardness, and nitrate has significant variation whereas temperature, DO, TDS, Phosphate and sulfate are not statistically significant($P>0.05$) in seasons. The identified causes that affect the water quality of Lake Tana were liquid and solid wastes generated by urban socio-economic activities, lack of government attention for the lake, happening of the invasive weed, landfill, climate change, recession agriculture, and hydropower generation. Thus, Lake Tan is the vital resource of the country severing multiple purposes. However, recently the lake is highly affected due to unplanned and unmanageable Bahir Dar city infrastructure expansion and associated socio-economic activities near the lake. Hence, there should be an effort to protect the lake from pollution and reduce the impact of urbanization in order to enhance its sustainability and ecological benefits.

Conflicts of interest

The authors has no conflicts of interest

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