# Water Quality Analysis of Lake Ziway

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**Research Article**

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## Abstract

The water quality of Lake Ziway is deteriorating due to human intervention. The objective of this research was to analyze the water quality of the lake. Analysis was done for color, odor, pH, EC, TDS, turbidity, ammonia, total hardness, sodium, potassium, total iron, manganese, calcium, magnesium, alkalinity, bicarbonate, chloride, Sulphate, nitrate, nitrite, fluoride, phosphate, DO, BOD and COD at seven sites from February to March in 21 runs. This research utilized international and national drinking water quality guidelines and standards for the statistical evaluation of experimental results. The mean values of turbidity, manganese, BOD, and COD levels exceed the WHO standards. All water quality parameters have significance values of $P \leq 0.05$ for spatial variation except BOD and COD that have P- values of 0.196 and 0.143, respectively. Whereas significant temporal variations were only observed for potassium (0.03), BOD (0.001), and COD (0.002). The cluster analysis showed two significant clusters for both water and sediment samples. This study indicated that the major causes of water quality deterioration are the inflow of effluents from the floriculture industry, domestics, agricultural practices, saline seeps, and other uncontrolled human interventions as observed in sites one, two, three, four, and five. The other cause results from people’s activities in boats and islands. Run-off, silt, waste effluents, etc. probably were the causes of the lakes' pollutions as shown in cluster one.

## Introduction

# Background

The Earth’s ecosystems variation, plants, animals, crustaceans, algae, bacteria, etc. depends on the quality and quantity of water. Surface waters provide habitat and food to many species. The food chain in the surface water is therefore interlinked and complicated, the life of an aquatic life depends on others to sustain. Over-exploitation and anthropological stresses directly influence with surface waters. Pollutants such as pesticides and herbicides can reduce the availability of plants and insects that serve as habitats and food for fishes and other aquatic animals.

Lake Ziway is one of the three largely interlinked central Rift Valley lakes of Ethiopia. Its main water inlets are via Meki and Keti rivers and the outlet is via Bulbula River. The water flow destines at Lake Abyata. The lake has a 0.8 m annual surface level reduction (Welcomme, 1972). On the other hand, there are occasions to fluctuate up to 2 meters in the dry season (Ayenew, 2004). The water volume of Lake Ziway fluctuates according to rainfall around the neighboring highlands, and the surface level of the lake becomes high during rainy seasons.

The composition and richness of the biodiversity of Lake Ziway are decreasing from time to time. Pollutants such as pesticides, growth regulators, fertilizers, etc. enter into the lake by surface runoff, atmospheric deposition, or leaching. (Jansen & Harmsen, 2010) detected pesticides, including some high-risk chemicals in the lake. The capacity of pesticides to harm aquatic life is largely a function of their toxicity, exposure time, dosage rate, and persistence in the environment (Helfrich & Specialist, 2009). There are also natural pollutions including dust deposition, evapotranspiration, natural leaching, etc.

# Statement of the Problem

The floriculture farm effluents without treatment flow via its water drainage to the lake distress its water quality, making it a harsh environment to the aquatic life. The nutrients encourage eutrophication and pesticides distract the food chain. Rainfall increases the runoff of water containing nutrients and fertilizers that increases the turbidity of the lake water, which hampers photosynthetic activity, primary production, and the breathing of fish. The irrigation schemes on the tributaries of Lake Ziway and the usage of fertilizers, pesticides, herbicides, insecticides, and fungicides by large commercial floriculture companies might be the major activities affecting the water quality of the Lake.

Relevant water quality data about the lake are important to take appropriate prevention, monitoring, and mitigation measures. There were previous research studies done in and around Lake Ziway. Research correlated the physicochemical parameters with the abundance and diversity of macroinvertebrates in the lake (Tamiru, 2007). However, nutrients and pesticides that critically affect the composition and richness of biodiversity alongside pollution sources and pathways are not studied. Besides, there were no periodic and spatial studies to trace the variation of the physicochemical and biological parameters. Another research output from Lake Ziway has indicated that the number of pesticide detections was in a decreasing trend (Jansen & Harmsen, 2010). On the contrary, reports indicated the presence of several legally banned pesticides from the lake, its tributaries, and outlets. This calls to undertake an intensive water quality study and take mitigation measures.

Surface water pollution studies should include sediment/sludge samples are also essential for the identification and quantification of the polluting agents of surface waters, particularly of lakes. Because some persistent toxic chemicals, organochlorides, and metals are found in considerable amounts in sediments than in waters.

Therefore, it is imperative to identify the root causes of the pollution driving forces and resulting environmental pressures; to restore the natural state of the environment; to minimize the environmental deterioration of the lake by increasing the effectiveness of the public or societal responses against the deterioration of the lake quality.

# Scope of Study

The research focuses on Lake Ziway, around Ziway city. It took one year of which three months are for sampling and analysis of the water composition. The study assesses the current conditions of the lake that helps to take appropriate prevention strategies and treatment technologies.

# Objectives

## General objective

The general objective of this research was to analyze the water quality of Lake Ziway.

## Specific objectives

- Determination of physicochemical/nutrient composition parameters
- Evaluating the physicochemical & nutrient values of the samples against WHO standards for the aquatic community and drinking water
- Employing ANOVA, descriptive analysis, correlation, and cluster analysis for the analysis of surface water quality data.
- Identifying pollution sources and pathways

# Significance of the Study

This research work aimed to acquire data on the pollution status of Lake Ziway and to determine and quantify pollutants. The research forwarded pollution monitoring and mitigation strategies on extended studies. It would also be a foundation to mitigate the challenges of pesticide registration, formulation, distribution, and use in Ethiopian smallholder and commercial farming in Ethiopia.

Added to that, the research output might induce awareness about surface water pollutions to concerned audiences including the community. Hence, it gives emphasis to human health and ecological concerns.

This study might serve as a baseline information for undertaking future researches. It is useful to recommend appropriate prevention and treatment options for surface water pollutants.

## Literature Review

# Surface Water, its pollutants and their Sources

Surface water according to S. Manahan in Fundamentals of Environmental Chemistry is the water found in Lakes, streams, and reservoirs, whereas groundwater is found in aquifers underground (Manahan, 2001). The water that humans use is primarily fresh surface water, which interlinks with groundwater.

Surface water ecosystems are sensitive to chemicals developed for ease of life that changes water quality and quantity. For example, less than 0.1% of applied pesticides reach the targeted pests, while the rest (99.9%) have the potential to move into other environmental compartments, including ground and surface waters (David Pimentel and Lois Levitan, 1985). The guideline for Environmental Assessment of fertilizers in Ethiopia has put that the nutrients contained in fertilizers promote the growth of algal and aquatic plants in rivers, lakes, and the sea. The nutrients above the levels of the natural ecosystem disturb plant and animal communities in surface waters by altering the composition and condition of the water.

In fact, natural and synthetic chemicals are essential for modern life, although they may enter ground and surface waters through runoff, industrial and municipal waste discharges, atmospheric deposition, or through release from septic systems (Anderson et al., 2012).

# Types of Surface water pollution

According to K.V Ellis (1989, surface water pollution is an alteration in the composition and condition of its waste, either directly or indirectly as a result of the modification of ecological systems hazards to human health, and renders less acceptable to downstream users'(Ellis et al., 1989). According to this definition, surface water pollution have nine divisions:

1. Thermal pollution,
2. The addition of pathogenic organisms, creating a public health hazard,
3. Oil pollution
4. The addition of inert, insoluble mineral material
5. The addition of readily biodegradable organic material that will result in the depletion or complete removal of dissolved oxygen
6. Toxicity due to the presence of synthetic organic compounds and salts heavy metals
7. Enhanced eutrophication
8. Acid depositions or discharges and
9. Radioactivity.

Different classifications of pollutants may exist by various scholars based on their assumptions in their studies. Mason (1981) suggested that five different types of major toxic pollutants commonly present in surface waters.

1. Heavy metals (cadmium, zinc, lead, mercury, copper, etc.)
2. Synthetic organic compounds (principally pesticides but also including polychlorinated biphenyls, solvents, detergents, organometallic compounds, and phenols)
3. Toxic gases, e.g. chlorine, ammonia
4. Toxic anions (cyanides, sulfides, fluorides, etc.) and
5. Acids and alkalis. Mason has put that heavy metal compounds and synthetic organic compounds especially pesticides are of primary concern (Mason, 1981).

The pollutants reach the surface water arising from either point sources or nonpoint sources. Point sources include those sources having a direct way to pollute the surface waters. These sources contribute pollutants at defined sites like the outflow from pipes, ditches, tunnels, etc. Having a defined origin, pollutants from point sources are often easy to measure and monitor. Panagopoulos and his colleagues have found that point sources contribute 17% of total nitrogen for the pollution of surface waters (Panagopoulos et al., 2011). Nonpoint sources of surface water pollution (aka diffuse sources) are various undefined ways to distribute pollution agents into the surface water. Different chemicals diffuse in different ways and hence it is difficult to measure or quantify the pollutant load unlike in point sources. Pesticide or fertilizer runoff from various agricultural fields in a lake's catchment would be examples of nonpoint sources.

Diffuse sources from agricultural land and nonagricultural land are sources of water enrichment with nutrients in surface water catchments (Panagopoulos et al., 2011). Non-point or diffuse sources of pollution are often more challenging for managers and scientists.

The Government of Western Australia, Department of Water pointed out that high levels of nutrients, pesticides, and other chemicals are contained in liquid waste and leachate from floriculture activities (Department of Water, 2006). The guideline also stated that carbohydrates in the form of sucrose used for flower preservatives contain bactericides, fungicides, and wetting agents to improve water uptake. According to the guideline, unless these pollutants are recycled and managed well, it is inevitable to pollute and distract the ecosystem.

# Sources and Impacts of pollution of Lake Ziway

Most of the recently established flower production industries are located around Addis Ababa, mainly Lake Ziway and upper awash valley (Gudeta, 2012). Small-scale local farmers and large-scale agricultural companies use pesticides, chemical fertilizers, plant growth hormones, and flower preservatives. These may affect the water quality of the lake and the surrounding surface waters through the release of trace elements and residues from the agricultural fields into the surface waters (Jansen & Harmsen, 2010).

Floriculture industries near the Lake have increased the demand for fertilizers due to the year-round production of flowers (Jansen & Harmsen, 2010). However, the crops do not absorb all applied fertilizers, and much of the excess fertilizer runs off into the Rift Valley Lake water system where Lake Ziway is located. Instead, the residue of these fertilizers can cause water pollution, eutrophication of freshwaters, and increased nitrate concentrations in ground and surface waters (FDRE ENVIRONMENTAL PROTECTION AUTHORITY, 2004).

Floriculture industries around the lake also extensively use pesticides against weed attacks, fungal diseases, or pests to boost productivity and quality. However, many of the pesticides applied leach into the nearby water bodies (Getu, 2009). Research by Wageningen University near Lake Ziway has found 30 pesticides with concentrations of 0.1 µg/L or higher out of which five of them are in high-risk category. Most of these pesticides require prior consent to enter into Ethiopia. Some of them are DDT, atrazine, Aldrin, and 2, 4, 5 - T etc. The European community blacklisted these chemicals (Keith, 1991). Additionally, natural phenomena like water runoff, climate change, landscape, etc. have a great pollution impact on the lake.

The indicators to show the water pollution impacts on Lake Ziway ca ne the reduction of water level, water quality, and quantity, species composition, and richness, etc.

According to Hengidisijk et al., the average level of Lake Ziway has decreased by approximately 0.5 meters since 2002. At the same time, the discharge of the Bulbula River has decreased from more than 200 million m3 per year in average years to less than 50 million m3 in 2003 and 2004 (Jansen et al., 2007.). The decrease of water in Bulbula River where the lake discharges water might imply that the water levels in Lake Ziway are decreasing. As a result, the amount of water discharged into Bulbula River is small. Lijalem et al. (2007) have shown the significant decline in water level and shrinkage of Lake Ziway's water surface area. The study predicted that the lake level might decrease by 62 centimeters and the water surface area might decrease by 25 square kilometers in 2051-2075 (Abraham Lijalem & Dilnesaw, 2007).

A serious threat is that a further decrease in water level may turn Lake Ziway into a terminal lake. This might eventually turn Lake Ziway saline. Given the relatively shallow depth, critical salinity levels could reach within 5-10 years (Jansen et al., 2007).

Teklu et al. (2016) reported an average pH of 8.5, 0.64 mg/L of ammonium ion, 26 mg/L of nitrate, less than 0.01 mg/L of phosphorus, and 257 mg/L of bicarbonate (Berhan M. Teklu et al., 2016). The total dissolved solids range between 200 and 400mg/l (Jansen et al., 1999; Kebede, Mariam & Ahlgren, 1994). The geology of the area can explain the compositions of the lake. The main source of sodium is the dissolution of sodium-containing rock minerals. As there is relatively much interaction between water in the (shallow) lake and the rocks, the sodium concentration rises in the lake (Gashaw, 1999). These all changes are the reasons to impair the living components and bring other results associated consequences in and around the lake. Therefore, it disturbs the food chain and the ecosystem as a whole.

# Economic Benefits of Lake Ziway

Around 40 % of the total fish produced in Ethiopia (refer to table 1) is from the rift valley lakes in which Lake Ziway produces the highest portion (Abera L1*, 2018; Tesfaye, 1998).

*Table 1. Fish production from Lake Ziway*

| | Minimum | Maximum |
|---|---|---|
| Amount of Fish produced per year per Kg (By fishermen) | 504 | 16,800 |
| Amount of Fish produced per year per Kg (By small scale irrigation users as part time ) | NA | 2,520 |
| Total | 504 | 19,320 |

Source: (Gezahegne Seyoum G., 2016)

There are intensive irrigation activities from the tributaries of Lake Ziway and the lake itself. The floriculture industries including the biggest floriculture industry like Sher, Ethiopia, and other small-scale farms in the area utilize water from the lake for irrigation.

As the central Rift Valley lies between the two tourism zones, i.e., Addis Ababa and the far south pastoralist communities, it is the route of the south far tourist destinations from Addis Ababa. National and international tourists use Lake Ziway as a recreation and knowledge center along their way to the south.

Lake Ziway also serves as the hub of biodiversity. It is the habitat of various aquatic life like different species of birds, hippopotamus, wetland microorganisms, fish, and many more.

There are about 233 to 52 recorded families of bird species along the shores, riverine woodland, and wet grassland habitats of the Lake (Bekelle et al., 2014). Among these, 54 were migrants, 8 were threatened, and 3 were endemic bird species.

# National and International policies, Regulations and Standards

Although individual and communal efforts are essential to prevent pollution of lakes, rivers, and ponds, a common policy regulation in the form of legislation is more. Because there will be a legal power for controlling the implementation and regulating the failure for protecting the water resources. The Federal Democratic Republic of Ethiopia, the Ministry of water resources, and the former Environmental Protection Agency detail on how to utilize and protect water resources. The ministry in its water policy document entails the responsibility of industrial, water supply, livestock, agriculture sectors, and individual users (FDRE, Ministry of Water Resources, 2011).

The FDRE Constitution guarantees the fundamental right to live in a clean and healthy environment, the right to livelihood, and the right to sustainable development. Article 92 states the government shall endeavor to ensure that all Ethiopians live in a clean and healthy environment. It also imposes a corresponding constitutional ‘duty on the Federal and Regional Governments, along with citizens ‘to protect the environment. Article 44 (1) declares that ‘all persons have the right to a clean and healthy environment’. Every person has the right to livelihood by article 44 (2). Ethiopia, by article 43 (3) concluded, established or conducted international agreement and relations, which should protect or ensure the right to sustainable development.

Various legal institutes have constitutional framework for the protection of the environment. These legal institutions include Environmental Protection Organs Establishment Proclamation No. 295/2002, the Public Health Proclamation No. 200/2000, the Environmental Pollution Control Proclamation No. 300/2002, the Environmental Impact Assessment (EIA) Proclamation No. 299/2002, the Development Conservation and Utilization of Wildlife Proclamation No. 541/2007, and the Forest Development, Conservation and Utilization Proclamation No. 542/2007.

According to the EIA Proclamation definition of environmental impact, EIA is a legal requirement devised to implement the rights granted by the Constitution and protects against the violation of these by any person or development project. EIA puts a provision that it is not possible to render any development activity without getting authorization to do so from the Environmental Protection Agency or other authorized bodies like the regional environmental authority. It also defines a set of environmental crimes. Therefore, the Ethiopian floriculture industry as one of the devilment activities are in charge of implementing the Ethiopian EIA ahead during and after the implementation of their projects.

The Ethiopian Environmental Protection Authority Establishment Proclamation No. 9/1995 established the Environmental Protection Authority to prepare environmental protection policies and laws. The Environmental Organs Establishment Proclamation No. 295/2002 which reestablished later as a federal EPA as an autonomous organization to establish regional environmental agencies or designate an existing agency instead for the same environmental management and protection function. The Authority has specified preconditions for importation, formulation, usage, and management of fertilizers, pesticides, and other chemicals. Issues related to registration and post-registrations are essential issues. The FDRE constitution proclaims the registration and control of pesticides by Article 55 sub article (1) under proclamation number 674.2010.

FDRE government, under the Ministry of Water Resources, has established policies including aquatic resources policies as part of the water resources management policy. Added to that, the former Ethiopian EPA (now Ministry of Environment, Forestry and Climate change) has set limit values for discharges of pesticides to water.

According to the World Health organization (WHO), water, whether used for drinking, food production, irrigation, domestic utility has an important impact on health. Therefore, standards to maintain the quality of surface water are essential. The World Health Organization and other international organizations have prepared standards of water quality for reference purposes.

# Methodology

### Study Area

The location of Lake Ziway is in the Ethiopian Central Rift Valley. Its watershed falls in between 7° 15' N to 8° 30' N latitude and 38° E to 39° 30' E longitude. The altitude is 1636 meters above sea level. The lake covers a catchment area of about 6834 km2. The surface area of the lake fluctuates between 435 to 485 km2 with a mean depth of 2.5 meters.

The minimum and maximum annual precipitation in the watershed are 729.8 mm and 1227.7 mm, respectively, with the mean annual temperature of 18.5°C. The wet season accounts for about 55% of the annual precipitation, while the dry season contributes 15% (Paolo Billi & Franceska Caparrani, 2006). In Ziway, The daily maximum temperature is 24.2 to 30.5 oC and the daily minimum temperature varies between 10.4 and 16.8. Ziway has average sunshine hours of 8.6 per day. However, there is a distinct decrease in sunshine hours during wet periods.

### Data collection and Sampling

The study acquired primary and secondary data by field visits and official reports, convenience interviews, laboratory experiments, and literature reviews.

The study first assessed the general overview of the lake status and pollution sources before directly executing the sampling procedures by using a convenient interview method. Interviewees comprising of Ziway town residents, boat sailors, health workers, and persons from monasteries filled a prepared questionnaire.

The criteria to select the sampling sites were specific pollution drivers' intensity, imposed pressures, and impacts on the environment and community, state of the environment, and societal responses. Therefore, specific potential risk areas, the topology of the lake, and the intensity of human activities determined the samples. The other criteria for choosing sampling locations availability of tributary rivers, which probably carries pollutants into the lake. Accordingly, the number of sites to collect water samples every month from February to April 2018 were seven. Additionally, the number of sites to collect sediment or sludge samples were four. The later four sites helped to take additional sludge/sediment samples because there was a suspicion of soil contamination in the sites. The following figure illustrates the sampling sites.

The study period for sample collection and laboratory analysis was from February 2018 to April 2018 with monthly frequency of sampling.

### Sample size Determination

The number of samples for this study satisfied the sample size requirements of 95% confidence level using Pearson Correlation. The experimented samples were 21 water samples and 12 sediment samples. The number of representative water and sediment/sludge samples taken at one time were seven water samples and four sludge samples from seven locations. The representative locations are those locations that receive high pollutant loads because of extensive human activities and natural phenomena. The amount of each sample for water and sludge samples were taken to be 1000 ml and 250–500 grams, respectively, as recommended by the American Scientific Testing of Materials (ASTM) and standards for the testing of water and wastewater (American Public Health Association, American Water Works Association, 1999)

## Sampling Procedures

The research utilized grab sampling technique to collect test samples from sampling sites every month for the period of three months. The use of Global Positioning System (GPS) helped to determine the sampling sites. The sites were at the inlet, middle, and outlet of the lake. The study disregarded the use of composite or integrated sampling techniques to prevent the loss of analytes during compositing or mixing.

The equipment used for water sample collection was one-liter polyethylene bottles after cleaning each bottle with detergent and rinsed it with deionized water. Then, I rinsed the bottles with lake water three times before taking the samples at each sampling site and took 1000 ml water samples based on the stratification of the lake. The degree of stratification was determined by measuring DO, conductivity, turbidity, pH, and temperature in an incremental depth of the lake. Then the samples preserved under $4^{o}C$ temperature before reaching the laboratory analysis. I used a sediment sampler to collect the sediment samples from the specified sites of the lake by preparing of 250–500 grams of wet mass samples. Then I sealed the sediment samples in clean polyethylene bags and preserved before taking them to the laboratory.

Finally, I determined the physical, chemical, and biological characteristics of the samples in laboratory. Parameters such as total phosphorus, total nitrogen, ammonia nitrogen, COD, BOD, total dissolved solids and metals, etc. were determined.

## Statistical Data Analysis

Descriptive statistics, explore tool, ANOVA, correlation, multivariate analytical techniques (Cluster analysis), and other statistical tools were used for data analysis. The standards for comparison used were those of WHOs', US EPA and Ethiopian Ministry of Health standards.

## Materials

The study utilized polyethylene sampling vessels and bottles, pH meter, thermometer, conductivity meter, digital turbidity meter, and photometer, glasses, flasks, hot plates, autoclave, glass scoop, HACH spectrophotometer (to analyze orthophosphate and Nitrate-N), K, Mg, Ca, and Na; HACH photometer to measure COD, DO meter; BOD instruments, atomic absorption spectrometer for cat ion/metal determination and 500-micrometer sifter. It also used palintest automatic wavelength photometer for multi-parameter determination.

The chemicals and reagents used in the research includes blank water, phenolphthalein indicator, methyl orange, Sodium hydro oxide, mercuric chloride, sodium thiosulfate, and 2, 6-Dimethyl phenol, sulfuric acid, potassium persulfate crystals, ascorbic acid, nitric acid, hydrochloric acid, Dicholoro-methane, petroleum ether and others unlisted. It also used unique palintest tablet reagents during a photometric multi-parameter determination experiment.

### Laboratory Analytical Procedures

I performed the laboratory activities at Addis Environmental Services PLC., Addis Ababa Institute of Technology, Chemical and Bio-Engineering Laboratory, and Ethiopian Water development construction enterprise.

### Surface water samples

I filtered out each water sample through filter paper (white Mann N0. 42) for metal/heavy metal analysis and analysed the remaining unfiltered samples for total nitrogen and total phosphorus. Total nitrogen measured by converting all nitrogen into nitrate by alkaline persulfate oxidation (ASTM. 1999). Subsequent analysis of nitrates was done by the 2, 6 dimethyl phenol method using a spectrophotometer (8500II, Bio-Crom). Nitrogen ammonia measured using the automated phenate method 4500 NH3 - G. Total phosphorus measured using the spectrophotometric ascorbic acid method after persulfate digestion.

For metals, there were two analyses: one for dissolved metals and the other for suspended metals. First, the filtration of dissolved metals happened and then and then acidified to pH less than 2 before analysis. Filtration with subsequent digestion of the filtered sample helped to determine suspended metals and heavy metals in the sample with the aid of an atomic absorption spectrometer. Other parameters analysed were pH, COD, BOD, turbidity, conductivity, and dissolved solid.

### Sediment samples

I removed stones, leaves, rags, twigs, plants, and other fragments after drying the sediment samples on air. The next procedure was powdering the sample using mortar and pestle. Then sieving the powdered sampled continued and stored it in glass bottles. Finally, analyses for total nitrogen using a nitrogen analyzer, total phosphorus and metals performed by digesting subsamples in Teflon vessels with an acid or a couple of acids in a microwave oven based on ASTM standards (ASTM, 1999). Spectrophotometric ascorbic acid method helped to measure total phosphorus after persulfate digestion and atomic absorption spectrometer analyzed the metals. The pH, EC, and CEC were also determined as per the US EPA standards.

The study used statistical tools to manipulate the resulted data for understanding the individual and interaction effects of water quality variables on the environmental matrices and human wellbeing. Finally, evaluation on the severity of the pollutants in the lake and the wellbeing of the ecology and humans at large took place.

Alternatively, the research utilized photometric plainest procedures with the aid of unique tablet reagents for the determination of individual concentrations of each physicochemical test. The determination of nutrient and metal concentration depends on the color intensity produced. The physicochemical tests for TDS, alkalinity, ammonia, bicarbonate, calcium carbonate, chloride, fluoride, magnesium, manganese, nitrate, nitrite, phosphate, potassium, Sodium, Sulphate, total hardness, and total iron followed similar procedures.

For all physicochemical tests, each test tube filled with water sample up to the 10 ml mark and then each of them received their respective plain-test tablets, crushed, and mixed for dissolution and then waiting for full-color development. Each test had its own allowed waiting time for full-color formation, as indicated in the table below. The intensity of the color produced is proportional to the concentration of the corresponding physicochemical parameter and a palintest photometer measured it (Palin-test Test Procedures Book).

# Result And Discussion

The research applied convenient interview method to gather background information, opinions, perceptions, and attitudes of the communities towards the state of the lake and their linkage with it. The interview result was an input for selecting appropriate sample collection sites. The interviewees comprised boat sailors, health professionals, dwellers, and particular persons from the monasteries in the lake.

According to the interview results, there are above 30,000 workers in Sher, Ethiopia Floriculture Farm. The interviewees are aware that there are individual and national economic advantages of flower farms. However, the community around Lake Ziway has little awareness regarding the pollution effects on the lake and the ecology of the environment.

The interviewees implied that there was a direct discharge of effluent from the floriculture farm called Sher, Ethiopia, and it was one of the causes of Lake Ziway's pollution. The other polluting sources indicated were agricultural practices and domestic activities in Ziway town. One of the interviewees said that floriculture farmworkers are the primary victims of health risks. There are a lot of cancer victims, birth defects among newborn babies, and other associated diseases.

The drinking water source for Ziway town was from around the St. Gabriel monastery, which is close to Sher Ethiopia's floriculture effluent outlet. It is currently out of service after the detection of hazardous chemicals in the lake. Nowadays, Ziway town is using Tuffa, which is 62.4 kilometers away as the source of drinking water for Ziway town.

Comparing the mean of each water quality parameter and the WHO guideline values as a reference shows that parameters such as turbidity, manganese, BOD, and COD levels exceeded the standards of WHO guidelines for drinking water quality. Total hardness, magnesium, and Sulphate had maximum limit values at some sites that exceeded the limit values.

Although there are different data interpretation methods of soil quality data, this research simply compared values of soil quality with agriculture provisional guidelines. In this regard, the pH seems that lye in the limit range, but the values were almost in the upper and lower extreme values. Some values of total phosphorus and CEC were below the provisional limit values. The EC and total iron are within the standard.

The water and soil quality parameters were dependent variables and the time and station were as independent variables or factors. Explore tool helped to test the normality of each variable in seven stations and three months separately. Although the explore command gives bulky results of data description using numerical and graphical representations via tests of normality table (Shapiro – Wilk test) and Normal Q-Q plots respectively to check the normality test. In addition to the tables and plots, kurtosis, skewness, and standard error checked the normality test. Almost half of the parameters did not show zero quotient of kurtosis to standard error and skewness to standard error and hence kurtosis and skewness were not enough methods for normal distribution testing.

For the water quality, the significance values of the Shapiro – Wilk test except for TDS, nitrate, and Sulphate were above 0.05 and hence this shows the data distribution is normal. The soil quality data is normally distributed.

The normal Q-Q plot distributions of water quality parameters except TDS, chloride, sulphate, and nitrate concentrated on the diagonal line and hence the data generally have a normal distribution. See the figure below. See the figure below.

On the other hand, the Q-Q plot distributions for soil quality parameters except for manganese and total nitrogen (as shown in the figure below) showed almost the data is normally distributed.

The figures above show parameters that do not fit the normal distribution data. Therefore, the normal distribution tests all show that using a parametric test in the study is relevant.

**One-Way ANOVA**

For the spatial comparison of means, all continuous water quality parameters had significance values of ≤ 0.05 except BOD and COD. The P- values for BOD and COD were 0.196 and 0.143, respectively. This implies that the means of BOD and BOD had no variation, whereas the other variables had a difference of means between groups.

For the temporal comparisons of means, only potassium (0.03), BOD (0.001), and COD (0.002) had a significant difference of means between groups. The remaining variables had no difference of means.

The significant difference of means for the sediment quality parameters showed that there was a more significant difference in the station-based comparison than the time-based comparison. The pH (0.006), EC (0.000), Total Iron (0.003), and Manganese (0.001) had a P-value of less than 0.05, which implies that their variation with station or sites was apparent. On the contrary, the time-based variation of means was visible for total nitrogen (0.011) and total phosphorus (0.013).

Therefore, the mean differences between groups show that the variation of values for the water quality parameters was more visible with time than station-based variation, whereas the station-based variation was visible than the time-based variation for the soil parameters. However, this only considered for the period and space under this study. Taking more spatial and temporal samplings for the study could lead to another conclusion.

## Correlations

Correlation analysis describes the closeness of the relationship of two or more parameters to ±1. The closeness to ±1 shows the probability of a linear relationship between the water quality parameters. If the correlation coefficient, r is ±0.75 - ±1, the correlation is strong. Moderate correlation has a value of ±0.5 - ±0.75. Weak correlation is in the range of ±0.25 - ±0.5 while values ≤0.25 do not correlate.

The study employed the following formula to compute Pearson correlation coefficients.

$$r = \frac{\Sigma(x-\bar{x})(y-\bar{y})}{\sqrt{\Sigma(x-\bar{x})^2\,(y-\bar{y})^2}} \quad \text{-----------------} \quad (1)$$

Or

$$r = \frac{Sxy}{SxSy} \quad \text{----------------} \quad (2)$$

$$Sxy = r.SxSy \quad \text{----------------} \quad (3)$$

The relations between water quality and sediment/sludge quality parameters of Lake Ziway were determined for the seven sites. Significance correlations among the water and soil/sludge quality parameters showed $P < 0.05$ and $P < 0.01$ significance levels. More correlated parameters are important for studying parameters at times laboratory studies become a problem. The correlation between pH and sodium is with a Pearson correlation coefficient of 0.880 at 0.05 significance level. This means that their correlation is strong and the variables can be interchangeably determined. The same is true for other variables.

*Table 2. . Correlation matrix between sediment/sludge quality parameters*

| Parameters | pH | EC | CEC | T.Iron | Manganese | T.Nitrogen | T.Phosphorus |
|---|---|---|---|---|---|---|---|
| pH | 1 | .676* | .457 | .517 | .001 | .059 | -.018 |
| EC | .676* | 1 | .546 | .401 | -.312 | .301 | .157 |
| CEC | .457 | .546 | 1 | .872** | .525 | .667* | .829** |
| T.Iron | .517 | .401 | .872** | 1 | .706* | .631* | .740** |
| Manganese | .001 | -.312 | .525 | .706* | 1 | .367 | .726** |
| T.Nitrogen | .059 | .301 | .667* | .631* | .367 | 1 | .727 |
| T.Phosphorus | -.018 | .157 | .829** | .740** | .726** | .727 | 1 |

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

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

## Cluster Analysis (CA)

The cluster analysis (CA) classified the datasets by applying to 29 parameters for seven water samples and 7 sediment/soil quality parameters for 4 samples based on Pearson correlation and then cluster analysis (CA) correlations.

The study found two significant sampling locations or clusters for the water samples. Cluster 1 includes sites one, two, three, four, and five, and Cluster 2 includes sites six and eight based on the similarity of water quality parameters.

The dendrogram diagram for the soil quality parameters showed that there were a classification two clusters. The emergence of sites two, three, and five-formed cluster one formed, while the emergence of sites five and six formed cluster two. As shown in the dendrogram sub clusters form clusters one and two for the water quality, i.e., sites one to five and sites six and eight are distant and hence the values of water quality parameters vary between cluster one and cluster two.

In general, the results revealed that the major causes of water quality deterioration, inflow of effluents from the floriculture industry, domestics, agricultural practices, saline seeps, and concentrated effluent inflow from Sher Ethiopia into the lake at sites one, two, three, four, and five. Because the samples taken from sites with these interventions show that there are at least above detection limit measurements for all parameters. The other cause results from activities in boats and islands. The sampling sites used, mainly sites six and eight, involve runoff, silt, waste effluents, etc., and hence these could be the causes of the lake's pollution.

The details of the water and sludge sampling sites and their clusters were in Figures 2 and 3, respectively. The cluster analysis of temporal data shows that there were two clusters, one was the result found from samples taken in both February and April 2018 and the second is the result found from samples taken in March 2018. There is a considerable difference in concentration between cluster one and cluster two. This might be because of rain around Ziway in March and was probably a reason to find low concentration values because of dilution compared to February and April that made cluster one.

# Conclusion And Recommendation

# 5.1. Conclusion

This study showed that the water quality parameters vary with both time and space. However, the variation of the parameters at each site concerning time was not enough for the conclusion, as the study period was short. Unlike the pollution source identification, there was no full information from the study to know the exact pollution pathways.

The water quality parameters at the southern shoreline, floriculture outlet, Sher, Ethiopia buffer zone, Meki River, and specific sampling sites deviate from the WHO guideline values. The ANOVA table also shows that there were significant variations of water quality parameters' values between sampling sites except for the BOD and COD.

There were two significant clusters for the water samples; cluster one includes sites one, two, three, four, and five, whereas cluster two includes sites six and eight. The sediment quality parameters had similarly two clusters; cluster one consists of sites two, three, and five, and cluster two consists of sites five and six.

Generally, the major sources of water quality deterioration for Lake Ziway might emanate from the activities of upstream of the lake. These include effluents from the floriculture industry, domestics, small and large-scale agricultural practices, and saline seeps into the lake at sites one, two, three, four, and five. The other causes of pollution were from people's activities in boats and islands, runoff, silt, waste effluents, etc. As shown in cluster one, formed by sites six and eight.

# 5.2. Recommendation

This study recommends undertaking comprehensive research on the lake to acquire sufficient data that helps to take appropriate pollution restoration techniques. The study particularly forwards to particularly research the association of high-quality habitat with deeper lake areas as well as wetland areas. The government should enact environmental impact assessment of floriculture development and other interventions ahead of their establishment. Moreover, assessing the introduction of banned chemical products by identifying organic pollutants that could threaten human, animal, and aquatic lives is crucial in the lake.

Promoting public awareness regarding the health and safety of agrochemicals to humans, animals, and ecology should be a prior concern.

No wastewater or solid waste of floriculture industries or else should dispose effluents before receiving treatment or pollution reduction methods. Floriculture industries particularly have to recycle wastewater before treatment. Constructing buffer zones at a safe distance away from the pollution sources is mandatory. Vegetation buffer is especially excellent for use in the upstream of the lake where pollutions might emanate. Advising ordinary farmers to plant trees and vegetation in their farmyard as a buffer zone to minimize environmental risks from their fertilizer and pesticide usage is also crucial. Besides, the government have to incentivize floriculture and horticulture farm owners for the use of environmentally friendly agrochemicals.

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## Declarations

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# Abbreviations

AOX – Alcohol Oxygenase

APHA – American Public Health Association

ASTM – American Scientific Testing of Materials

BOD – Biological Oxygen Demand

COD – Chemical Oxygen Demand

DO – Dissolved Oxygen

FDRE – Federal Democratic Republic of Ethiopia

ISO – International Standard Organization

LC-MS – Liquid Chromatography-Mass Spectrometer

PCBs – Polychlorinated Biphenyls

TSS - Total Suspended Solids

USEPA – United States Environmental Protection Agency

WHO – World Health Organization

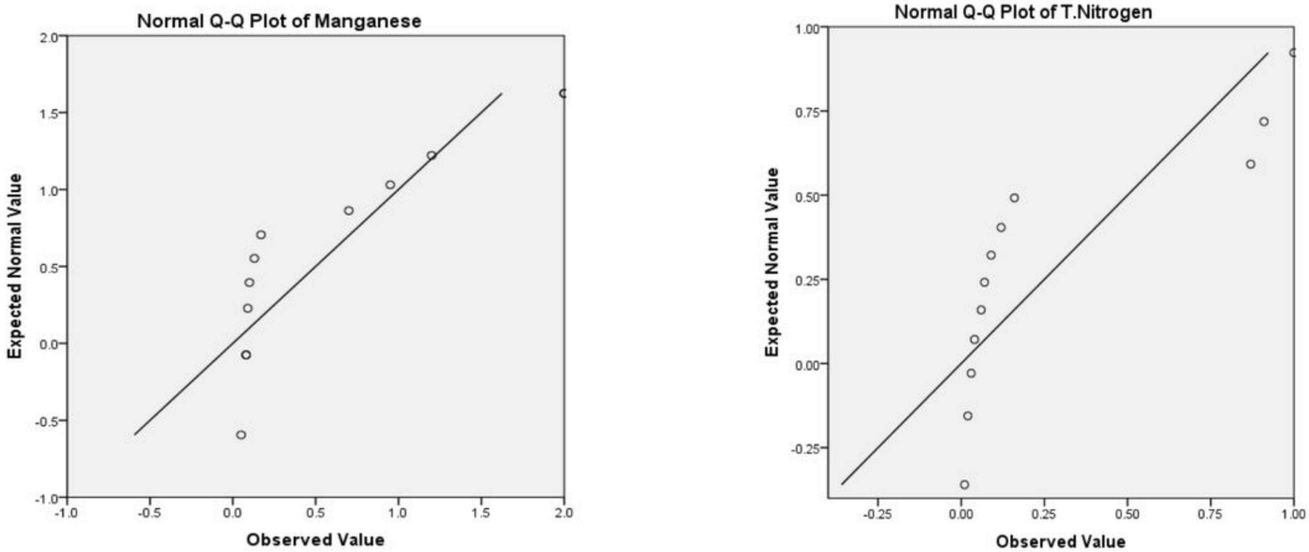
# Figures

### Figure 1

Sampling sites in and around Lake Ziway

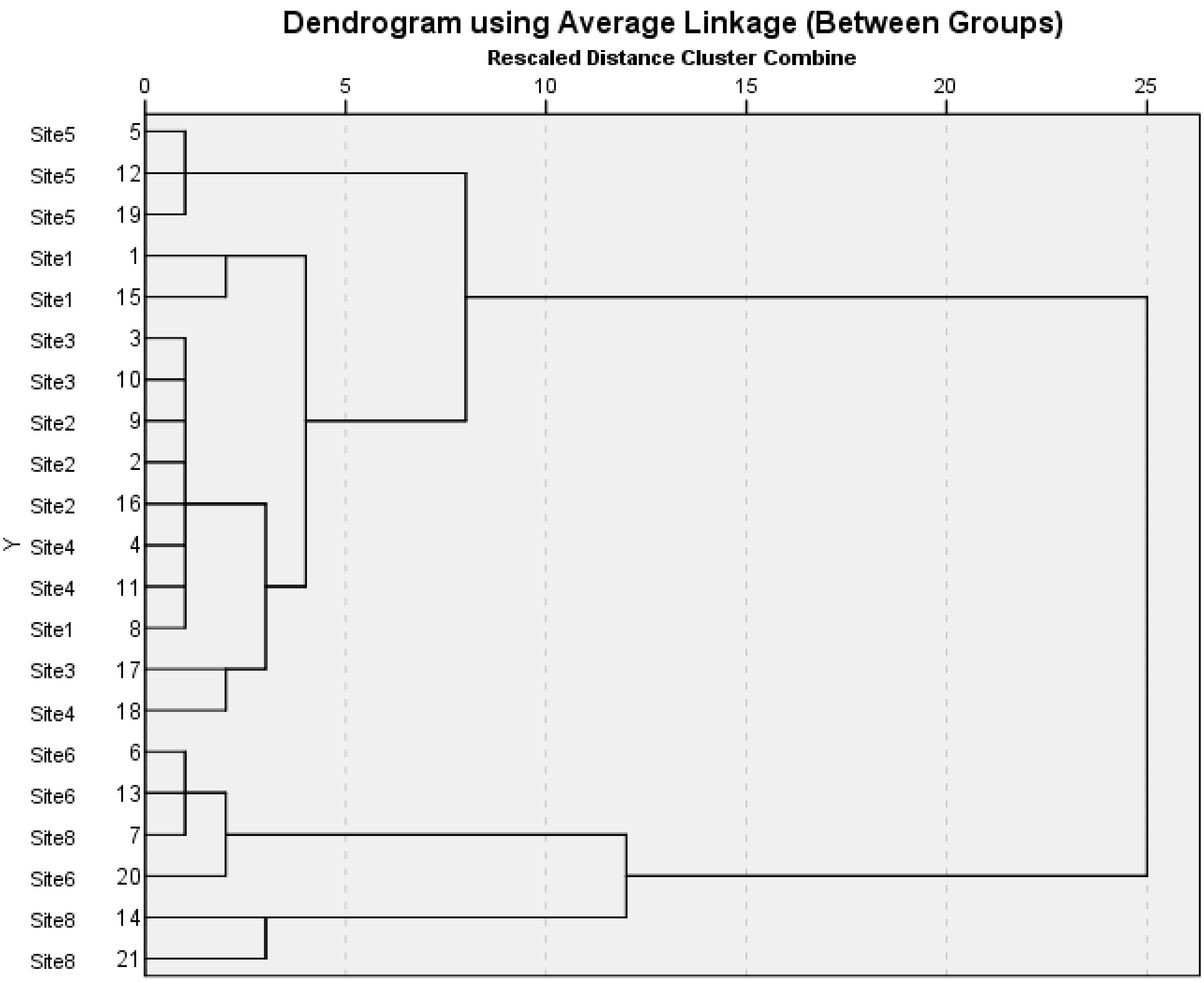
### Figure 2

The normally unfitted Q – Q plots of water quality parameters




## Figure 3

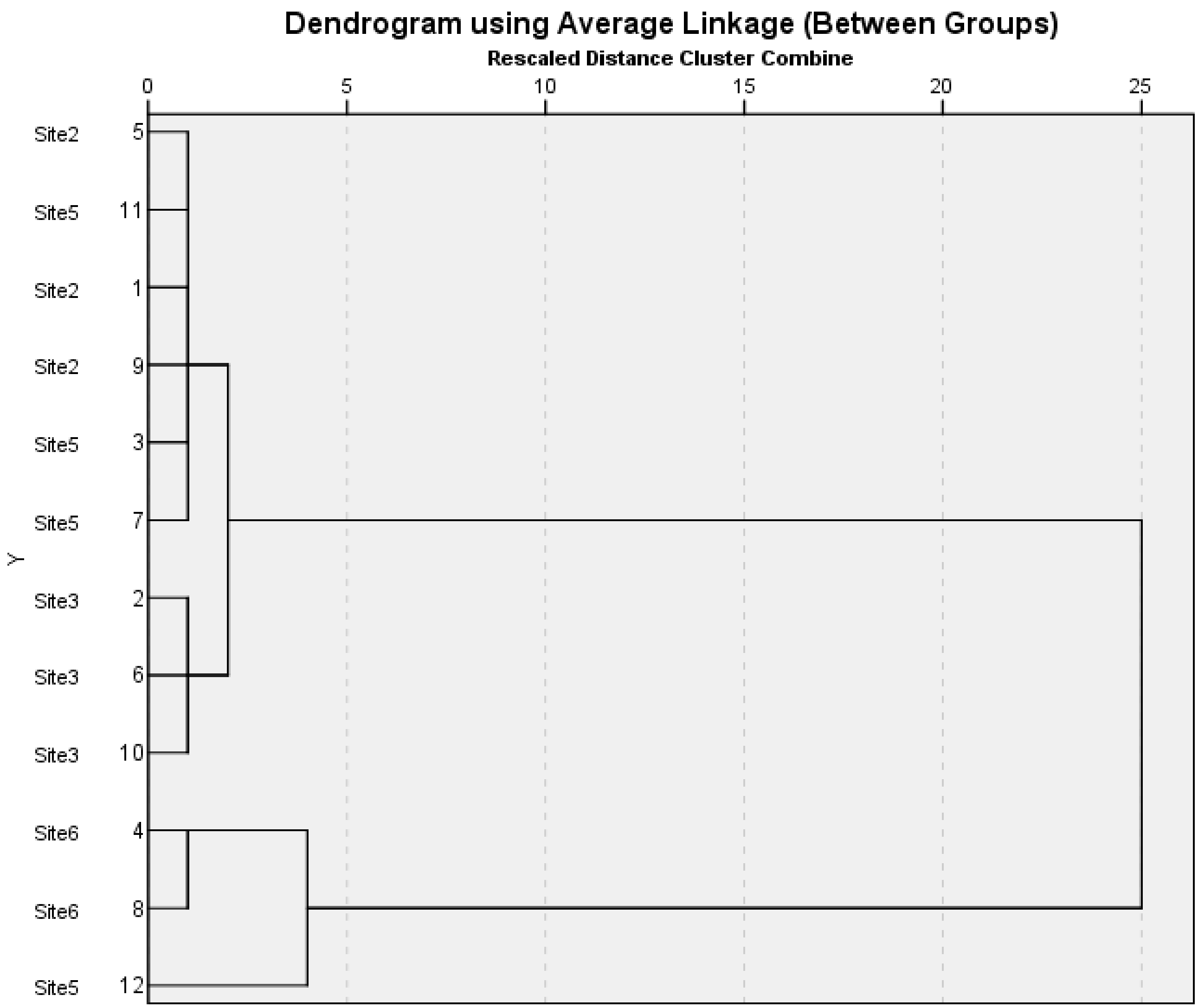
The normally unfitted Q – Q plots of sludge/sediment quality parameters



## Figure 4

Dendrogram showing clusters of the surface-water samples

**N.B**: The total sampling sites (N) are 21 for water and 12 for sludge. Because the sampling frequency (f) is three. For water samples and sludge/soil samples. Thus, clusters and sub clusters may encounter sampling site repetitions.




## Figure 5

Dendrogram showing clusters of the sediment/sludge samples