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Thesis on Water Quality Analysis and Pollution Prevention Options of Lake Ziway, Around Ziway City

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Water Quality Analysis and Pollution Prevention Options of Lake Ziway, Around Ziway City

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Declaration

I, hereunder declare with signature that this thesis paper is my original work and has not been presented for any degree in any other university, and that all sources of material used for the thesis have been duly acknowledged.

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Confirmation

This thesis paper can be submitted for examination with my approval as a university advisor.

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List of Acronyms

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 solid

USEPA – United States Environmental Protection Agency

WHO – world Health Organization

Abstract

Water is a key factor for ecological balance and to support biodiversity. But it is getting polluted as a result of human interventions and natural phenomenon. Lake Ziway is one of the surface waters getting devastating effects from floriculture farms, agricultural practices, and irrigation schemes and usage of chemicals. The objective of this thesis is to analyze the pollution status of the Lake. Water samples were collected and laboratory 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. Sediment samples were also taken from four sampling sites and analysis was done for pH, EC, CEC, total iron, manganese, total nitrogen and total phosphorus in the same period with water quality analysis in12 runs. The results were compared with WHO's drinking water quality guide lines and also the datasets were evaluated statistically. The mean values of turbidity, manganese, BOD and COD levels exceed the WHO standards. All water quality parameters have a 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 the significant temporal variations are only observed for potassium (0.03), BOD (0.001) and COD (0.002). The dendrogram diagram shows two significant clusters for both water and sediment samples. Generally, the results revealed that the major causes of water quality deterioration are inflow of effluents from the floriculture industries, 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 and etc. also are taken to be the causes of the lakes pollutions as shown in cluster one. Constructed buffer zones, waste water treatment and recycling, integrated pest management practices, proper disposal of liquid and solid wastes and other BMPs are recommended prevention and treatment options to safeguard water quality.*

***Keywords**: Lake Ziway, Water quality, pollution, floriculture farms, statistical analysis, prevention and treatment options*

1. Introduction

1.1. Background

Water is a key factor for ecological balance and the sustainability of biodiversity. The Earth's ecosystems variation, plants, animals, crustaceans, algae bacteria etc. along with their physical and chemical environments depends on the quality and quantity of water. Water comprises of ground water and surface water. Surface waters includes streams, rivers, lakes, reservoirs, and wetlands. Surface waters and their associated ecosystems provide habitat to many plant and animal species. The fishes and aquatic life in lakes for example use plants and insects as habitat or food. The food chain in surface water is therefore interlinked and complicated, the life an aquatic life depends on others to sustain. Because surface waters are on the land surface, they are also easily developed for use and hence exposed to stresses that result from such human activities.

Lake Ziway is found 160 kms south of Addis Ababa in the Ethiopian Central Rift Valley. The area of the lake was 500 km^2 in the year 1967/68 but recently, it fluctuates between 435 to 485 km^2 with a mean depth of 2.5 meters.

Lake Ziway is one of the three largely interlinked central rift valley lakes of Ethiopia. It has inlets and outlets. The main water inlet into Lake Ziway is via Meki and Keti rivers and the outlet is via Bulbula River. The water flow destines at Lake Abyata.

The average depth of Lake Ziway is 2.5 meters with 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 seasons (Ayenew, 2004).

The water volume of Lake Ziway fluctuates according to rainfall around the neighboring highlands and obviously the surface level of the lake becomes high at rainy seasons. Upstream irrigation practices depending on the tributary rivers to the lake also impacts the amount of water of the lake to decrease.

The aquatic life or biodiversity in Lake Ziway includes different species of fish, macro invertebrates, flora and fauna, and many more. The composition and richness of the lake's biodiversity is decreasing from time to time. The candidate reasons for this decrement might be the water pollution due to the chemicals used for different purposes around the lake.

There are different sources of pollution for the lake including floriculture industries, small and large agricultural practices, and chemical industries around the lake. The pollutants (pesticides, growth regulators, fertilizers etc.) make their ways to the lake due to surface runoff, atmospheric deposition or leaching. In support to this claim, some researchers has found a range of pesticides including some high risk pesticides in the lake (Jansen & Harmsen, 2010). The detections of pesticides in the vicinity of the lake is expected to be the results of the growing trends of small and large scale agricultural practices (Zhou et al., 2017). There are also natural pollutions including dust deposition, evapotranspiration, natural leaching etc.

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.). The same is true for other pollutants.

Pollutants can reduce the availability of plants and insects that serve as habitat and food for fishes and other aquatic animals. Insect-eating fishes can lose a portion of their food supply when pesticides are applied. A sudden inadequate supply of insects can force fish to range farther in search of food where they may risk greater exposure to predation (Helfrich & Specialist, 2009). Spraying herbicides can also reduce reproductive success of fish and aquatic animals (Helfrich & Specialist, 2009).

So, such problems should be monitored or mitigated. But the main problem for taking monitoring or mitigation measures against aquatic pollutions is lack of reliable information.

Though many researches have been practiced in this area the problem is still not solved. The aim of this thesis is to compare results with previous works and determination of other pollutants in Lake Ziway. It also assesses some pollution prevention methods for surface waters particularly for Lakes.

1.2. Statement of the Problem

Lake Ziway is one of the surface waters getting the devastating effects from natural phenomena and intense human activities in the area. The irrigation schemes from the lake tributaries and the usage of toxic chemicals including fertilizers, pesticides, herbicides, insecticides, and fungicides by large commercial floriculture companies are assumed as the major human activities threatening the lake. Small holder agriculturalists have also an impact as far as they use agrochemicals for increasing productivity. The pollutants coupled with natural phenomena like regular and irregular rainfall, wind and sun aggravates the influence in the aquatic life.

Rainfall can cause runoff of nutrients (fertilizers) via the tributary rivers and lake size increment that brings flooding offshores. On the other hand, irregular rainfall may increase run off of water and increase the turbidity of the lake water, hampering photosynthetic activity, primary production and the breathing of fish.

Apart from rainfall, the floriculture farms' effluents/pollutants most of which without treatment flows via its water drainage to the lake disturbing the water quality of the lake, making it harsh environment to the aquatic life. The nutrients encourages eutrophication and the pesticides distract the food chain.

Relevant data about the lake quality are very important to take appropriate prevention, monitoring and mitigation measures. For that, several studies of analysis have been done in and around Lake Ziway though no treatment methods are studied so far. A research on the Lake has correlated the physicochemical parameters to the abundance and diversity of macro invertebrates in the lake (Tamiru, 2007). But pollutants specifically nutrients and pesticides that critically impacted the composition and richness of aquatic life were not identified by this study. The pollution sources and pathways also needs more study. Besides, the changes of the physicochemical and biological parameters need to be frequently studied so that the monitoring strategies will be understood.

Another research output from Lake Ziway indicated that the number of pesticides detections was in a decreasing trend compared to previous researches done (Jansen & Harmsen, 2010). In contrary, the presence of many registered pesticides of various function has been reported from the lake and its tributaries and outlet. But there is no information whether unregistered and banned chemicals or pesticides are present. Apart from the function of most of the pesticides as insecticides, herbicides, growth regulators, metabolites and others in the farming process; pesticides have a negative effect on the lake and its aquatic lives. The fertilizers emanated from the farm areas create eutrophication in the lake. This calls intensive study to be made and measures to be taken.

Surface water pollution studies should not be made only by using the water or soil samples. Sediment/sludge samples are also very important for the identification and quantification of the polluting agents of surface waters particularly of lakes. This is important because some persistent toxic chemicals, organochlorides and metals are found in considerable amount in sediments than in waters. This thesis proposal is therefore one part of those endeavors.

Measures taken so far for restoring Lake Ziway and safeguarding the environment and human wellbeing in general are not satisfactory. So, additional endeavors are urgently needed 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.

This study will find out the pollutants of the lake and their sources then the best available prevention and treatment options will be studied and forwarded based on the analysis results.

1.3. Scope of the Study

The scope of this study is limited for the completion of master’s degree in Environmental Engineering. The research only focuses in Lake Ziway and it will be completed in a year of which three months are for sampling and analysis of the water composition. The study will assess the current condition of the lake and appropriate prevention strategies and treatment technologies at the pollution sources will be studied and recommended.

1.4. Objectives

1.4.1. General objective

The general objective of this thesis is to analyze the water quality of Lake Ziway around Ziway town and suggest appropriate prevention and treatment options.

1.4.2. Specific objectives

- Determination of physicochemical/nutrient composition and Biological parameters
- Evaluating the physicochemical & nutrient values of the samples against WHO standards for the aquatic community and drinking water
- Employing statistical tools like ANOVA, descriptive analysis, correlation and cluster analysis for the analysis of surface water quality data.
- Identifying pollution sources and pathways
- Studying prevention strategies and treatment options
- Recommending appropriate prevention methods and treatment options at the pollution sources based on the results obtained from the study.

1.5. Significance of the Study

This thesis work is important to get data on the pollution of Lake Ziway and to determine and quantify pollutants that are not determined previously. The quantification of the pollutants of the lake will be used to forward monitoring and mitigation strategies up on extended studies. Even the challenges to pesticide registration, formulation, distribution and use in Ethiopian small holder and commercial farming might get an attention. Pesticides used in vegetable and floriculture farms are of priority concern for such challenges.

Added to that, other concerned audiences including the community may get an awareness about the devastating effects of surface water pollutions from the research output. By that, emphasis towards human health and ecological concerns from related causes will be given.

This study will give a clue on how to fill some information gap related to the pollutants and their effect which are uncovered by previous researchers in and around the lake. It is also assumed as important for undertaking similar researches in other surface waters in other similar sites like rivers and streams and even other lakes.

The final result of this study is used to recommend the appropriate prevention and treatment options for surface water pollutants at source for different water bodies in Ethiopia.

2. Literature Review

2.1. 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 and groundwater. The use of surface water is various ranging from agricultural activities to ecosystem balance and drinking. Surface water is interlinked with the ground water, its affection also affects the ground water and vice versa. Moreover, the ecosystem balance is greatly supported by surface water.

The supplies for surface water are not reliable since quantities often fluctuate widely during the course of a year or even a week, and water quality is affected by pollution sources (Weiner & Matthews, 2003). For example, if a river has an average flow of 10 cubic feet per second (cfs), this does not mean that a community using the water supply can depend on having 10 cfs available at all times (Weiner & Matthews, 2003).

Surface water ecosystems (Lakes, Rivers ...) are sensitive to the chemicals developed for the ease of life that changes water quality and quantity. The pollutants may arise from many human activities or natural phenomena within their watershed. The main pollutants include pesticides, sediments/ silts, nutrients and many more. These all affects the aquatic life in the surface water directly or secondarily. For example, less than 0.1% of applied pesticides actually reaches the targeted pests, while the rest (99.9%) has the potential to move into other environmental compartments, including ground and surface waters (David Pimentel and Lois Levitan, 1985). Surface waters can also get polluted from excessive use of fertilizers, growth regulators, and etc. The guideline for Environmental Assessment of fertilizers in Ethiopia has clearly put that the nutrients contained in fertilizers promotes algal and aquatic plants in rivers, lakes and the sea just like they do for crops. The nutrients in excess of the natural ecosystems levels disturbs plant and animal communities in surface waters by altering the composition and condition of the water in it. Natural and synthetic chemicals are essential for modern life though they may enter ground and surface waters through runoff, industrial and municipal waste discharges, atmospheric deposition, or through releases from septic systems (Anderson et al, 2012).

2.2. Types of Surface water pollution

According to surface water pollution given by K.V Ellis (1989), i.e. surface water pollution is an alteration in composition and condition of its waste, either directly or indirectly as a result of the activities of man, which initiates modification of ecological systems, hazards to human health and renders less acceptable to downstream users'(Ellis et al, 1989). Taking this definition right, surface water pollution can then be divided into nine possible sections:

(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 (a) synthetic organic compounds and (b) salts of heavy metals

(7) Enhanced eutrophication

(8) Acid depositions or discharges

(9) Radioactivity

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

(1) The 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, sulphides, fluorides, etc.)

(5) Acids and alkalis

From all of these Mason has put that the heavy metal compounds and the synthetic organic compounds-especially the pesticides are of primary concern (Mason, 1981).

The pollutants may reach the surface water arising from either point sources or nonpoint sources.

Point 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 defined origin, pollutants from point sources are often easy to measure and monitor. Panagopoulos and his colleagues has found that point sources contribute of 17% of total Nitrogen for the pollution of surface waters (Panagopoulos et al, 2011).

Nonpoint sources: Nonpoint sources of surface water pollution (aka diffuse sources) are various undefined ways to distribute the pollution agents in to the surface water. Different fractions of 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 non-agricultural land are the different 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.

A water quality protection guideline by the Government of Western Australia, department of water has 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 sources for these chemicals/contaminants according this guideline are the following:

i. process area wash down and contaminated storm water runoff from bulk storage areas;
ii. Disinfectants such as mild bleach solution used on knives, shears and harvesting equipment;
iii. Glycerin solution or a silica gel that may be used as drying agents for preserved flowers;
iv. Dyes used to color dried flowers; and
v. Floral preservative used to enhance the flower's vase life while in storage.

The guideline also stated that carbohydrates in the form of sucrose that are used for flower preservative contain bactericides, fungicides and wetting agents. The bactericides, fungicides and wetting agents prevent the development of organisms in the vase water and improve water uptake (Department of Water, 2006). According to the guideline, unless the pollutants from the aforementioned sources are recycled and managed well, it is inevitable to pollute and distract the ecosystem.

2.3. Sources of pollution for Lake Ziway

The primary sources of pollution for Lake Ziway are Flower industries. Most of the recent established huge flower production industries are located around Addis Ababa, mainly Lake Ziway and upper awash valley (Gudeta, 2012). Flower production process around Lake Ziway is known to have greatest impact for water quality of the Lake. On top of those industries, Ziway, Meki and other small nearby towns and villages are found around Lake Ziway.

The agricultural activities by small holder horticulture farmers are also other sources pollution besides to the large-scale flower growing companies located around the Lake. Jansen and Harmsen (2011) has reported that small scale farmers and large scale agricultural companies in the area use pesticides, chemical fertilizers, plant growth hormones and flower preservatives, which may affect the water quality of the lake and the surrounding surface waters through the release of some trace elements and residues from the agricultural fields into the surface waters (Jansen & Harmsen, 2010).

Local and Commercial agricultural practices around Lake Ziway use fertilizers for increasing production. Floriculture industries near to the Lake have an increased demand of fertilizers due to the year-round production of flowers (Jansen & Harmsen, 2010). But the crops do not absorb all the applied fertilizers, and much of the excess fertilizer runs off into the Rift Valley Lake water systems where Lake Ziway is located (FDRE ENVIRONMENTAL PROTECTION AUTHORITY, 2004). The residue of these fertilizers can cause water pollution, eutrophication of fresh waters, and increased nitrate concentrations in ground and surface waters (FDRE ENVIRONMENTAL PROTECTION AUTHORITY, 2004).

Besides to using of fertilizers, floriculture industries around the Lake also extensively use pesticides against weed attacks, fungal diseases or pests to boost productivity and quality. However, much of the pesticides applied leach into the nearby water bodies (Getu, 2009). A research done by Wagenigen University near to lake Ziway has found 30 pesticides with concentrations of 0.1 µg/l or higher out of which five pesticides are categorized as having high risk (Jansen & Harmsen, 2010). Most of these pesticides require prior consent to enter the Country (Ethiopia) and many of which including DDT, atrazine, Aldrin, 2,4,5-T, etc. are black-listed in the European community (Keith, 1991).

Other pollution sources for Lake Ziway apart from agricultural activities might include natural phenomena like water runoff, climate change, land scape, etc.

2.4. Benefits of Lake Ziway

One of the advantages of Lake Ziway is for fishing purpose. The community members in and around lake Ziway utilizes fishes from the Lake. The fishermen got a daily house hold income by catching fishes from the lake and selling to retailers and local merchants. Small scale irrigation users also catch fish in their part-time for additional income.

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)

The maximum and minimum productions might be due to factors that affect fish production such as the number of gill nets, water quality, Lake water level, length of hours spent for fishing and the condition fluctuations.

From the overall fish produced in Ethiopia, around 40 % is produced in the rift valley lakes in which Lake Ziway produces the highest portion (Abera L1*, 2018; Tesfaye, 1998).

Source: (Hirpo, 2017)

Figure 1. Total fish production from 1990 to 2010

The other application of Lake Ziway is for irrigation. The floriculture industries including the biggest floriculture industry like Sher Ethiopia and other small scale farms in the area utilizes water from the Lake for irrigation.

So far, Ziway town was getting its drinking water supply from the lake. However, recently the town has brought water for drinking from a far area called tuffa because the water from Lake Ziway was deteriorated.

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. A lot of national and international tourists uses Lake Ziway as recreation and knowledge center a long their way to the south. As a result, community members in the ice lands of the lake and the town drives their daily income from such activity. There are standard hotels and resorts around the lake.

Lake Ziway also serves as the habitat or hub of biodiversity. It is hub of various aquatic lives among which are the different species of bird, hippopotamus, wetland microorganisms, fish and many more. Bird species of 233 with 52 families were recorded 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. The highest bird species diversity were recorded along transect number 4 (western habitat) side and 17 of eastern habitat

2.5. Impacts of surface water pollution

The impacts of pollutants on surface waters comprises of deterioration of water quality, endangering of aquatic life, contamination of soil and air, and affecting public health and social environments.

The effects of pollutants on water quality is dependent on both the characteristics of the pollutants and the physical, chemical and biological characteristics of the water body itself (Vandas & Winter, 2002). The leakage of chemicals used in small and large scale agriculture in to water bodies aggravates physical and chemical changes. These changes may impair water quality and affect water use by the aquatic life and humans. For example, pesticide runoff has ecological impacts by contaminating water bodies due to bio concentration and bio magnification mechanisms.

The concentration of nitrogen and phosphorus in excess may lead to occurrence and increment of algal blooms, oxygen depletion, odor and taste problems, fish death and loss of biodiversity in the water bodies

Fertilizers washed from fields into surface waters and stimulates algae growth (eutrophication), which blocks sunlight needed by aquatic vegetation putting their survival at stake that eventually disrupts the food chain and leads to the loss of economically important aquatic life.

Pesticides also have diverse effects since greater than 99.9% of the applied pesticides misses the target pests (Pimentel, 1985). Non-target organisms in the water and other compartments of the environment are therefore affected. There are about ten million non-target organisms including thousands of domestic animals that can be poisoned each year throughout the world (Hansen et al, 2003).

Trace metals can be transformed in to more toxic organometallic complexes in the aquatic environment due to physical and chemical processes in different pathways. The pathways of metals in aquatic ecosystems include sedimentation process; transport; metal adsorption by suspended matter and precipitation; surface water –deposited mud reactions; uptake of metals by organisms; and accumulation in the food chain (Eysink, 1981). The aquatic life are then in danger of the organometallic complexes that are formed as the result of these pathways.

Impacts on soil arises from the continued use of chemical fertilizers and affects nitrogen fixing bacteria and other microorganisms in the healthy soil. Moreover, chemical fertilizers affects the alkalinity of the soil.

Many pesticides can evaporate from the soil and foliage, move away from the area of application, and contaminate the environment. A conservative estimate of the total damage to the environment and public health caused by pesticides is about $9 billion each year (Hansen et al, 2003). It is imaginable to show how much of this impact is contributed by the floriculture sector, the sector that uses more fertilizer and pesticides than conventional farming.

Polluted surface water is one of the main causes of water borne diseases, non-communicable diseases like those of associated to long term exposure to toxic chemicals (Sasikala & Muthuraman, 2015). Cancer and physical defects among new births are the other results of polluted surface water.

Some pesticides, depending on their characteristics and concentrations may cause health effects like cancer, reproductive or nervous-system disorders, and acute toxicity. These effects are particularly prevalent in developing countries where 25% of the world pesticide production is under use and 99% of death due to pesticide occurs (WHO, 2008).

The use of chemical fertilizers also has health problems. It causes many diseases like Methemoglobinemia and cancer. Methemoglobinemia is a disease that occurs due to the taking up of nitrate-rich water that once was induces in to the ground water. Excess nitrates interfere with the oxygen carrying capacity of the blood, and have also been suspected to cause birth defects (Winchester & Huskins, 2009).

Nitrates are also suspected to cause cancer. Cattle are also exposed to many diseases when they graze on fields with high content of chemical fertilizers.

2.6. Impacts of Surface Water Pollution on Lake Ziway

Surface water pollution impacts on Lake Ziway can be shown by the reduction of water level, water quality and quantity, the species composition and richness and 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 by the Bulbula River has decreased from more than 200 million m^3 per year in average years to less than 50 million m^3 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 and hence less water is being discharged in to Bulbula River. The same reason works for the decrement of water in Lake Abayata. A significant decline of water level and shrinkage of Lake Ziway's water surface area was also shown by a study done by Lijalem e'tal (2007). They predicted that the lake level might decrease by 62 centi meters and water surface area might decrease by 25 square kilometers in 2051-2075 (Abraham Lijalem & Dilnesaw, 2007).

A serious threat is that further decrease of water level may turn Lake Ziway into terminal lake. This will cause that Lake Ziway eventually becomes saline. Given the relatively shallow depth critical salinity levels could already be reached 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 nitrates, less than 0.01 mg/L of phosphorus and 257 mg/L of bicarbonates (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 different water composition can be explained by the geology of the area. The main source for 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 brings other results associated consequences in and around the lake. So, it disturbs the food chain and the ecosystem as a whole.

2.7. Ethiopian Environmental policy, Regulation and Standards

Although individual and communal efforts are very important to prevent pollution of lakes, rivers and ponds, a common policy, regulation in the form of legislation is more effective for implementing the activities. Because there will be a legal power for controlling the implementations and regulating the failure for protecting the water resources. The Federal Democratic Republic of Ethiopia, 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 Minstry 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. For example, article 44 (1) declares that 'all persons have the right to a clean and healthy environment'. The right to livelihood is also guaranteed to every person with article 44 (2). Ethiopia, by virtue of article 43 (3) and/or concluded, established or conducted international agreements relations, should protect or ensure the right to sustainable development.

Article 92 states 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 the Regional Governments, along with citizens, 'to protect the environment'.

The Constitutional framework for the protection of the environment is put in various legal institutes like the 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 environmental impact' as any change to the environment or its components that may affect human health or safety, flora, fauna, soil, air, water or climate. So, such impact shall be assessed on the basis of the size, location, nature or cumulative effect in comparison with other concurrent impacts. 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 an authorization to do so from Environmental protection Agency or other authorized bodies like the regional environmental authority. It also defines a sets of environmental crimes. Therefore, the Ethiopian floriculture industries as one of the devilment activities are in charge of implementing the Ethiopian EIA ahead, during and after 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. Its objectives were enhancing good environmental governance through removing the constraints faced by public agents, individuals, civil society and the private sector to know, explore and utilize fully their own potentials to enlarge their choices for understanding their respective functions in an environmentally sound manner. It does this by mandating power to federal regional levels. The Environmental Organs Establishment Proclamation No. 295/2002 was later re-established as a federal EPA as an autonomous organization vested with expanded mandates. The 295/2002 environmental proclamation allows to establish regional environmental agencies or designate an existing agency instead for the same environmental management and protection function. The decentralization also goes to every sector or ministerial office by letting them to establish their own environmental units for the function of environmental management. The Authority has specified preconditions for importation, formulations, usage and management of fertilizers, pesticides and other chemicals. Issues related to registrations and post registrations are also of essential issues. The FDRE constitution proclaims the registration and control of pesticides in accordance with 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 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 are given in Table 2.

Table 2. Ethiopian Standard for discharges of pesticides to water

S.N	Parameter	Ethiopian EPA standard
1	pH	6 – 9
2	temperature (^{o}C)	40
3	Total phosphorus as P (mg/l)	5
4	Total nitrogen as N (mg/l)	30
5	Suspended solids (mg/l)	30
6	Oils (mg/l)	15
7	Fats (mg/l)	15
8	Greases (mg/l)	15
9	AOX (mg/l)	2
10	Organochlorines (mg/l)	0.1
12	Pyrethroids (mg/l)	0.1

Table 2. Continued

13	Phenoxy compounds (mg/l)	0.1
14	Active ingredients (mg/l)	0.05
15	Arsenic (mg/l)	0.2
16	Chromium as total Chromium (mg/l)	0.1
17	Chromium as Chromium four (mg/l)	0.1
18	Phenols (mg/l)	1
19	Copper (mg/l)	2
20	Mercury (mg/l)	0.01
21	COD (mg/l O_2)	250

Source: Ethiopian E.P. A, 2012

2.8. International Environmental Policies, Regulations and Standards

According to world health organization (WHO), water whether used for the purposes of drinking, food production, irrigation, domestic utility has an important impact on health. Therefore, standards to maintain the quality of surface water is very important. For this, world health organization and other national and international organizations have put standards of water quality to be used as reference.

Table 3. International standards of drinking water quality

S/N	Parameter	WHO Standards	US EPA Standards
1	PH	6-8.5	6-8.5
2	Electrical Conductivity	1000 µs/cm	2500 µs/cm
3	Colour	15 TCU	--
4	Turbidity	5 NTU	0.5 – 1 NTU
5	TDS	500 mg/l	500 mg/l
6	Nitrate	10 mg/l	50 mg/l
7	Nitrite	1 mg/l	3 mg/l
8	Ammonia	1.5, 35 mg/l	--
9	Phosphate	0.3 mg/l	1.5 mg/l
10	Calcium	75 mg/l	--

Table 3. Continued

11	Fluoride	1.5 mg/l	2 – 4 mg/l
12	Chloride	250 mg/l	250 mg/l
13	Arsenic	0.7 mg/l	10microg/l
14	Sulphate	400 mg/l	250mg/l
15	Iron	1 mg/l	300 micro g/l
16	Total hardness	300 mg/l $CaCO_3$	300 mg/l $CaCO_3$
17	Sodium	200 mg/l	--
18	Potassium	--	--
19	Manganese	0.1 mg/l	50 micro g/l
20	Magnesium	150 mg/l	--
21	Alkalinity	200 mg/l $CaCO_3$	--
22	Bicarbonate	150 -350 mg/l	--
23	BOD	2 mg/l	--
24	DO	4- 6 mg/l	--
25	COD	10 mg/l	--

Sources: WHO (2009); U.S. Environmental Protection Agency (1994a)

In addition to the above standards of water quality, there are also other physicochemical standards like physicochemical standards for supporting fresh water ecosystems. See Table 4.

Table 4. Physicochemical standards for supporting fresh water ecosystems

S/N	**Parameter**	**High Integrity (Category 1)**	**Extreme Impairment (Category 4)**
1	Dissolved Oxygen Saturation (%)	80 – 120	< 30 or > 150
2	BOD5 (mg/l)	-	>10
3	Total Phosphorus (μg/l) - lakes and reservoirs - rivers and streams	 < 10 < 20	 >125 >190
6	Total Nitrogen (μg/l) - lakes and reservoirs - rivers and streams	 < 500 < 700	 >2500 > 2500

Table 4. Continued

9	Chlorophyll a (µg/l) - lakes and reservoirs - rivers and streams	 < 3.0 < 5.0	 > 165 > 125
12	pH	6.5 – 9.0	< 5
14	Temperature	No deviation from background value or reference systems or optimum temperature ranges of relevant species	Large deviations from background value or the thermal tolerance range for characteristic species
16	Un-ionized Ammonia (µg NH3/l)	15	100
17	Aluminium (µg/l) - pH <6.5 - pH >6.5	 5 10	 --- 100
18	Arsenic (µg/l)	10	150
19	Cadmium (µg/l)	0.08	1
20	Chromium (µg/l) - III - VI	 10 1	 75 40
21	Copper (µg/l)	1	2.5
22	Lead (µg/l)	2	5
23	Mercury (µg/l)	0.05	1
24	Nickel (µg/l)	20	50
25	Zink (µg/l)	8	50

Source: International Water Quality Guidelines for Ecosystems (IWQGES); Draft for regional consultations 15 march 2016.

2.9. Practices to prevent and restore surface water pollution

Pollution prevention of surface waters is any practice that reduces, eliminates or prevents pollutions at the sources that otherwise could affect the quality of surface waters.

Prevention of Eutrophication

Phosphorus and nitrogen are the main factors for the formation of eutrophication in waters. Phosphorus is taken as the limiting nutrient for the primary production but nitrogen also plays a pivotal role for the net production, especially in lakes having low Nitrogen: Phosphorus loading ratios (Camargo & Alonso, 2006). There are also other nutrients that have an aggravating impact for the growth of algae and diatoms in surface waters but with a lesser extent than nitrogen and phosphorus nutrients.

Prevention of Eutrophication or Algal/bacterial Blooms

All responsible stake holders and community members need to have a motivation to reduce the development of algal, microbial or bacterial blooms in lakes. Reducing or eliminating the use of fertilizers and If using fertilizers is inevitable, guiding the community for using very low or even no-phosphorous fertilizer products is very important (Habs, 2009.).

After usage of fertilizers or nutrients, formation of algal blooms and/or bacterial blooms in lakes can be prevented to the best level by controlling the amount of nutrients that feeds into the water body from the sources. Most preventive measures focus on an input of external nutrient from point sources like discharges from sewage treatment plants and non-point sources like diffuse runoff from agricultural fields, roads and storm water. On the other way. the sediment layer of water bodies can also be an internal sources of nutrients and this contributes to algal bloom formation as a result of internal loading (US EPA, 2017).

Restoration of Algal or bacterial Blooms

Once the proliferation of algae or bacteria reaches higher stage, it turns in to bloom which needs an immediate restoration activities. Restoration activities may include biological control methods, physical control methods and chemical control methods. Biological control methods are control methods including Floating Treatment Wetlands (FTW) and Riparian Vegetation. Physical control methods also includes Aeration, Mechanical Circulation, and Hypolimnetic oxygenation. Chemical control methods comprises using of alum, ferric salts, clay (coagulation and flocculation) and barely straw.

Pollution interception and remediation

Protecting, restoring and constructing wetlands for intercepting water pollutants before entering in to lakes are becoming good ways of water quality safeguarding methods (Yang & Liu, 2010). Constructed wetlands are engineered systems used for the utilization of natural wetland vegetation, soil and their microbial vegetation for treating contaminants in surface water, ground water and waste streams (Helmer, Hespanhol, 1997.). Plants used for wetland construction have to have high capacity of nutrient removal by assimilating them in to their body functions. Besides the wetlands are very important for ecology protection while using them as a buffer zone for water quality improvement.

Dredging

Many pollutants originate from point and nonpoint sources from urban and rural areas collect in rivers and then sediment in to lakes. Boats and winds can disturb and distribute the sediments and/or particulates that accumulates in lakes. Altogether the sediments will be collected underneath of the lake. So, such collections should be dredged out from lakes for keeping water quality standards in the range. The dredged out material can be used as fertilizers for farmlands (Helmer et al., 1997.). Using the dredged wastes as fertilizers may seem hazardous but when there is no hazard in the agricultural utilization as the concentration pollutants gets low. Because the dredging process is done at a given intervals of time, the concentration of pollutants decreases. In contrary, the hazardous pollutants increases if the sediments or silts accumulates in the lake for a long period of time without dredging.

Buffers to protect lakes from pollution

If there are sources of pollution around water resources, buffer zones as protectors should be used. These serves as a buffer between the water resource and the sources of pollution. In other words they are a transition point between the pollutant source and the marine ecosystems. Riparian forest and vegetation buffers are one of the effective buffers for conserving water quality goals (Kate MacFarland, 2017). The best effective location, size, and composition of the buffer zone depends on the site conditions and water resource objectives (Correll, 2005).

Plant buffer zones around rivers, lakes or ponds apart from their water quality conservation goals, can be designed for various single or multiple goals. However, the multi-purpose buffers are a little bit complicated for designing and management though they have many advantages.

Large trees and small vegetation can be used but choice of plant type depends on the intended time to see the results. For example, riparian forest buffers particularly using large trees takes time to function their very purpose. But for those expecting immediate results, vegetation and grasses are recommended. So, a good planning, designing, and managing steps are crucial for providing buffers with long time services in to the future.

Plant or vegetation buffers are not the only buffers used. We can also have buffers by excavating long striped holes between the water resources and the pollution sources. The holes will serve to contain the polluted water some distance ahead of the water resources. Because the more distance the stripped holes are the less leaks will reach the water body.

Over all water quality improvement by Constructing By-Pass Canal (BPC)

This method can improve water quality of lakes by allowing only clean water to enter the lake. Pollution sources in the upstream of lakes specially that involves rivers should be controlled to clarify the entering water and sediment in to the lake (Zhang, Zhang, & Gao, 2011). This is dictated by the characteristic of the water content entering in to the lake.

3. Methodology

3.1 Study Area

The study area, Lake Ziway is found 160 kms south of Addis Ababa 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 km^2. The surface area of the lake fluctuates between 435 to 485 km^2 with a mean depth of 2.5 meters.

The climatic conditions are not uniform throughout the watershed. The minimum and maximum annual precipitation in the watershed is 729.8 mm and 1227.7 mm respectively with the mean annual temperature of 18.5 °C. The wet season – June to September – accounts for about 55% of the annual precipitation, while the dry season contributes 15% (Paolo Billi & Franceska Caparrani, 2006).

The temperature in Ziway is relatively constant throughout the year. The daily maximum temperature is 24.2 to 30.5 ^{o}C and the daily minimum temperature varies between 10.4 and 16.8. Ziway is relatively sunny with an average sunshine hours of 8.6 per day. But there is a distinct decrease in sunshine hours during wet periods.

Data collection

The data (including baseline data) in and around the lake were collected by field visits and official reports, convenience interviews, laboratory experiments, and literature reviews.

Sampling Sites

Convenient interview was used to get general overview of the lake status and pollution sources before directly executing the sampling procedures. A questionnaire with eleven questions (attached at the back) was prepared for the interviewees to answer. The interviewees consisted of Ziway town residents, boat sailors, health workers and particular persons from monasteries.

In addition to the general information found from the convenient interview, the choice of sampling location was made based on specific pollution driver's intensity, the imposed pressures and impacts in the environment and community, state of the environment and societal responses. So, the samples were determined based on specific potential risk areas, topology of the lake and intensity of human activities. The tributary rivers, which are expected to carry the pollutants in to the lake were also taken as a factor for the choice of sampling location. The sites for sampling were generally located at the upstream, middle and downstream of the lake.

Accordingly, 7 sites were selected to collect 7 water samples every month from February to April 2018. Additionally, four sludge samples were taken from sites 2, 3, 5, and 6. These sites were selected to take additional sludge/sediment samples because there is a suspicion of soil contamination in the sites. The sampling sites are defined as follows.

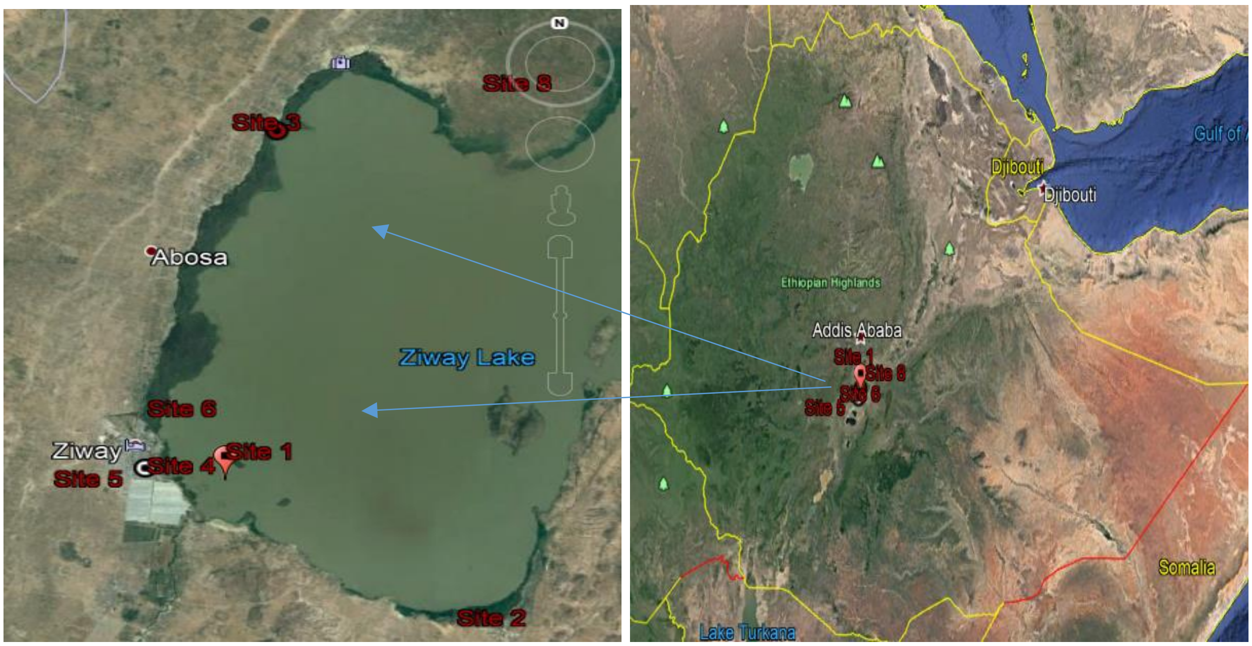


Figure 2. Sampling sites in and around Lake Ziway

Sample 1 was taken from Lake Center (Site 1) at 4 – 5 meters. Activities being undertaken near to this site are boat washing, water mixing by boats and hippopotamus and cloth washing by the dwellers of the island community.

Sample 2 was taken from southern shoreline site (Site 2). This site is characterized by high public activities including agricultural and washing activities. The depth is 1 – 1.5 meters.

Sample 3 was taken from north-west of the lake (Site 3). Its depth is 2.5 – 3 meters. This site has small scale irrigation practices where the water used is abstracted from the lake.

Sample 4 was taken from floriculture outlet, Sher Ethiopia outlet (Site 4). This site is characterized by its shallowness and deteriorated water. The deterioration is suspected that Sher Ethiopia flower farm is discharging effluents to the lake.

Sample 5 was taken from Sher Ethiopia buffer zone (Site 5). This site is very shallow and characterized by the concentrated effluents from Sher Ethiopia. It is 50 – 100 meters far from the lake.

Sample 6 was taken from the site between Lake Ziway and Meki (Site 6). This area is shallow and full of silts that come from the Meki River and the slight sloppy landscapes around the lake.

Sample 7 was taken from Battu raw water inlet (Site 7). This water inlet, especially during rain has a prominent impact by bringing silts, wastes, and other effluents from upstream of the lake. But this sample was lost in the laboratory and hence not analyzed.

Sample 8 was taken from Meki River (Site 8). This site is characterized by its extensive human intervention. All human activities upstream of the Meki river bridge (on the road from Meki to Mojo) affect the water composition.   Rain is also another factor for the water entering into the lake.

The samples taken from the above specified sites were analyzed from February to April 2018.

Study Period and Sampling frequency

The study period for sample collection and laboratory analysis was carried out from February 2018 to April 2018. The frequency of sampling was done every month.

Sample size Determination

Sample size should be designed considering the representativeness of population, desired level of confidence to achieve, reliability, parameters interest in the study and cost constraints.

The number of samples for this study were determined based on the sample size requirements for 95% confidence level using Pearson Correlation. The total number of samples taken were 21 for water and 12 for sediment. The number of representative water and sediment/sludge samples taken at one time were seven water samples and four sludge samples from seven locations that were understood to receive pollutant loads as a result of extensive human activities and natural phenomena. The amount of 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) standards for testing of water and waste water (American Public Health Association, American Water Works Association, 1999).

Sampling Procedures

Samples for experimentation based on standard procedures were taken using grab sampling technique from the Lake every month for three months. The sampling sites were determined using Global Positioning System (GPS). The sites were at the inlet, middle and outlet of the lake. Composite or integrated sampling techniques were not used to prevent loss of analytes during compositing or mixing.

One liter polyethylene bottles were used for sample collection. Each bottle was cleaned with detergents and rinsed with deionized water before sampling time. During sampling, right at each sampling site, the bottles were rinsed with the lake water three times before taking the samples. Water samples 1000 ml each were collected after noticing the stratification of the lake was the same. The degree of stratification was determined by measuring DO, conductivity, turbidity, pH and temperature in an incremental depth of the lake. Then the samples were preserved under $4^{o}C$ before taking them to the laboratory.

The sediment samples were collected from the specified sites of the lake using sediment sampler. Samples of wet mass of 250 – 500 grams each were prepared. The sediment samples were then sealed in clean polyethylene bags and preserved before taking them to the laboratory.

The physical, chemical and biological characterization were done in laboratory for the samples taken. Parameters such as total phosphorus, total nitrogen, ammonia nitrogen, COD, BOD, total dissolved solid and metals etc. were determined in the laboratory.

Statistical Data Analysis

Descriptive statistics, explore tool, ANOVA, correlation, multivariate analytical technique (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.

Correlation analysis was used to correlate the water quality variables and reduce them in to smaller set of important composite independent variables.

Cluster analysis was used to check whether the grouping of the sampling sites based on the parameters to be studied was right. This enables to point out the alignment of the similar sampling sites. Discriminate analysis technique was used for verification of the cluster analysis results.

Descriptive statistics in excel was used for each site to compare the quality of water at the sites within the lake.

Materials

The materials used for executing the experiment for this thesis work were polyethylene vessels/samplers and sampling bottles to take samples from the lake; pH meter, thermometer, conductivity meter, digital turbidity meter and photometer to measure turbidity; Glasses, flasks, hot plate, autoclave, glass scoop; HACH spectrophotometer to analyze nutrients (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 micro meter sifter. Palintest automatic wavelength photometer was also used for multi-parameter determination.

Chemicals and reagents that were used are 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. Unique palintest tablet reagents were utilized for analyzing each parameter during multi-parameter investigation by palintest photometer.

Laboratory Analytical Procedures

All collected samples were transported to laboratory for analysis. The laboratory activities were performed at Addis Environmental Services PLC., Addis Ababa Institute of Technology: Chemical and Bio Engineering Laboratory and Ethiopian Water development construction enterprise.

Surface Water samples: A 250 ml aliquot of each water sample were filtered through filter paper (whit Mann N0. 42) for metal/heavy metal analysis and the remained unfiltered samples were analyzed for total nitrogen and total phosphorus. Total nitrogen was measured by converting all the nitrogen into nitrate by alkaline persulfate oxidation (ASTM., 1999). Subsequent analysis of nitrates was done by 2, 6 dimethyl phenol method using spectrophotometer (8500II, Bio-Crom). Nitrogen ammonia was measured using automated phenate method 4500 NH_3 - G. Total phosphorus was measured using ascorbic acid method spectrophotometrically after persulfate digestion.

For metals, there was two analysis; one for dissolved metals and the other for suspended metals. The dissolved metals were first filtered and then acidified to pH less than 2 before analysis. The suspended metals was determined also by filtering sample but with subsequent digestion of the filter sample and the material on it. Atomic absorption spectrometer was used to analyze metals and heavy metals. Other parameters like pH, COD, BOD, turbidity, conductivity, and dissolved solid were determined.

Sediment samples: The collected sediment samples were first air dried and stones, leaves, rags, twigs, plants and other fragments were removed. The next procedure was powdering sample using mortar and pestle. Then sieving was continued and then stored in glass bottles. Finally, analysis was done for total nitrogen using nitrogen analyzer, total phosphorus and metals were analyzed by digesting sub-samples in Teflon vessels with an acid or couple of acids in a microwave oven based on ASTM standards (ASTM, 1999). Total phosphorus was measured using ascorbic acid method spectrophotometrically after persulfate digestion. Atomic absorption spectrometer was used to analyze metals. The pH, EC and CEC were also determined as per the US EPA standards.

After finding the result for the samples, data were manipulated using statistical analytical tools for understanding the individual and interaction effects of water quality variables on the environmental matrices and human beings.

Finally, the severity of the pollutants to the lake as well as to the wellbeing of the ecology and humans at large were evaluated. For the solutions, different water pollution prevention methods and treatment options were studied so as to choose and recommend appropriate prevention strategies and treatment technologies.

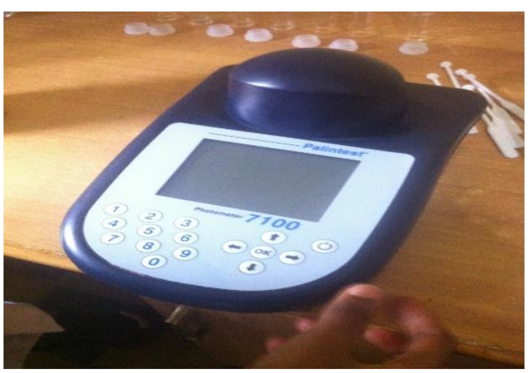
Alternatively, photometric plainest procedures were used in Addis Environmental Services private limited company for comparison purpose. Unique tablet reagents were used for the determination of individual concentrations of the each physicochemical tests. Color intensity produced was used to know the concentration of nutrients and metals.

The physicochemical tests including TDS, alkalinity, ammonia, bicarbonate, calcium, carbonate, chloride, fluoride, magnesium, manganese, nitrate, nitrite, phosphate, potassium, Sodium, Sulphate, total hardness and total iron were analyzed using palintest photometer.

For all physicochemical tests, each test tube was filled with the water sample up to 10 ml mark. After that the respective palintest tablets were added, crushed and mixed for dissolution and then waited for full color development was allowed after waiting for their respective full color forming times, as indicated in the table below. The intensity of the color produced is proportional to the concentration of the corresponding physicochemical parameter and was measured using a Palintest Photometer (Palintest Test Procedures Book). The detail procedures are given in appendix E.

The following figures illustrate collected samples, used reagents and palintest automated photometer in Addis environmental services PLC. Figure a displays the collected samples, figure b shows reagents being mixed with the samples and figure c shows the automated palintest photometer that was used to determine concentration of parameters based on wavelength and reagent.

a b



c

Figure 3. a) Samples in laboratory b) mixing of palintest tablet reagents with water sample c) palintest photometer

4. Result and Discussion

4.1 Results

4.1.1 Results from Interviews

Before directly executing the sampling procedures around Lake Ziway convenient interview method was used for further detail information. This was very helpful 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 helpful for selecting appropriate sample collection sites.

The interviewees who gave a convenient interview comprised of boat sailors, health professionals, dwellers and particular persons from the monasteries in the lake.

According the interview result from the prepared questionnaire, there are above 30,000 workers only in Sher Ethiopia Floriculture Farm. The interviewee are aware that there are individual and national economic advantages of the flower farms. However, they did not say anything about awareness of the community around Lake Ziway regarding pollutions devastative effects on the lake, the lives in it and the ecology of the environment.

The interviewees implied that there was a direct discharge of effluents from the biggest floriculture farm called Sher Ethiopia and it was one of the worst causes of Lake Ziway's pollution among other causes. The other polluting sources were the agricultural practices and human activities in Ziway town.

One of the interviewee said that the flower farm workers are the primary victims of health risks. There are a lot of cancer, birth defects among new born children and other associated diseases.

The drinking water source for Ziway town was from around the St. Gabriel monastery which is found near the Sher Ethiopia's floriculture outlet. However, it is currently out of service. Because it was known to have detections of undesired chemicals for health and as a result it is changed to Tuffa which is 62.4 Kilo meters distance from the town.

Generally, the interview gave me an overall image of the lake and its threatening causes. So, it helped me for further analytical study by taking samples from chosen locations.

4.1.2 Laboratory Results

The laboratory results for both the water and sludge samples are summarized in the tables below. The samples are indicated in the row by site1, site2, site3, site4, site5, site6 and site8. Site7 was not analyzed in the laboratory because it was missed and hence not included in the results section. The distance interval between measurements in the different sampling sites was not uniform. The water and sediment/sludge quality parameters are put in the column.

Table 5. Spatial and temporal results of water quality parameters

S/N	Parameters	February							WHO Standard
		Site1	Site2	Site3	Site4	Site5	Site6	Site8	
1	Color	-	-	-	-	-	-	-	Colorless
2	Odor	-	-	-	-	-	-	-	Unobjectionable
3	pH	8.50	7.81	7.45	7.65	9	8.20	8.23	6.5-8.5
4	EC	520	470	415	440	1009	120	121	1000 µs/cm
5	TDS	260	210	154	183	970	200	177	1000 mg/l
6	Turbidity	73.4	30.23	8	10.1	66	70.31	80	5 NTU
7	Ammonia	1.68	0.98	0.23	2.30	3	0.78	1.09	1.5 mg/l
8	T.Hardness	89	96	61	70	211	127	100	300 mg/l $CaCO_3$
9	Sodium	110	50.1	12.52	79.65	195.7	73	65.9	200 mg/l
10	Potassium	44	21	5.22	30.47	41.14	31	29.97	1.5 mg/l
11	Total iron	0.82	0.29	0.11	0.81	1.01	0.92	1.19	0.3 mg/l
12	Manganese	1.62	0.13	0.09	1.96	0.7	2	1.91	0.1 mg/l
13	Calcium	84	74.5	58.19	76	80.4	101	98	75 mg/l
14	Magnesium	90	64.3	9.58	12.13	146.8	40	37	150 mg/l
15	Alkalinity	330	201	189	214.5	323.17	224	219	200 mg/l $CaCO_3$
16	Carbonate	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
17	Bicarbonate	400.7	244.7	200.5	251	265.3	260	253.6	150 -350 “”
18	Chloride	10.2	7.1	11.8	6	57.9	28.82	25.3	250mg/l
19	Sulfate	0.52	2	1.05	10.31	21	0.71	0.55	400 mg/l
20	Nitrate	1.3	0.77	0.1	2.1	13.22	0.26	0.15	10 mg/l
21	Nitrite	0.20	0.35	0.02	0.89	0.98	0.62	0.49	1 mg/l
22	Fluoride	1.03	1.41	1	1.54	0.43	1.32	1.66	1.5 mg/l
23	Phosphate	0.07	0.09	0	0.28	0.36	0.45	0.45	0.3 mg/l
24	DO	1.3	1.49	1.01	2.42	4.2	2.52	2.3	4 – 6 mg/l
25	BOD	15	19.11	21.32	26.7	31	20.1	25.2	2 mg/l O_2
26	COD	80.38	98.2	100	112	153.2	122.93	131.54	10 mg/l O_2
		March							
1	Color	--	--	--	--	--	--	--	Colorless
2	Odor	--	--	--	--	--	--	--	Unobjectionable

Table 5. Continued

3	pH	8.32	7.5	7.2	7.45	8.6	8	7.97	6.5-8.5
4	EC	477	461	401	340	850	90	33	1000 µs/cm
5	TDS	239	159.23	133.4	168	770	183	166	1000 mg/l
6	Turbidity	78	54.46	6.7	11.36	43.71	53	97	5 NTU
7	Ammonia	0.34	0.18	0.1	0.68	1.78	0.5	0.04	1.5 mg/l
8	T. Hardness	80	76	54.4	60	180.3	110.6	90	300 mg/l $CaCO_3$
9	Sodium	84	38.45	9.9	48.81	152	59.4	37	200 mg/l
10	Potassium	11	8.12	3.58	7.75	29.26	23	7.7	1.5 mg/l
11	Total iron	0.93	0.41	0.08	0.38	0.67	0.48	0.92	0.3 mg/l
12	Manganese	0.34	0.17	0.01	0.45	0.51	0.44	0.45	0.1 mg/l
13	Calcium	69	55.31	40.9	61	60.7	84.37	79	75 mg/l
14	Magnesium	43	23.4	7.88	5	108.9	37.06	17	150 mg/l
15	Alkalinity	215	170.3	147.13	140.2	302.43	206	140	200 mg/l $CaCO_3$
16	Carbonate	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
17	Bicarbonate	262.3	200	185.2	170.8	218.2	217.39	170.8	150 -350 “”
18	Chloride	48	4.4	5.33	5	41.53	22.57	130	250mg/l
19	Sulfate	0	0.39	0.37	6	9.8	0.61	0	400 mg/l
20	Nitrate	0.46	0.35	0.07	0.66	5.14	0.19	0.04	10 mg/l
21	Nitrite	0.01	0.16	0	0.19	0.41	0.24	0.09	1 mg/l
22	Fluoride	0.93	0.87	0.98	1.24	0.22	0.6	1.3	1.5 mg/l
23	Phosphate	0	0.04	0	0.25	0.3	0.28	0.25	0.3 mg/l
24	DO	.89	1.2	0.4	1.93	3.17	2.1	2	4 – 6 mg/l
25	BOD	6.55	9.26	12.32	19.53	21.3	14	19.74	2 mg/l O_2
26	COD	69.63	81.6	86	90.21	121.3	94.	110	10 mg/l O_2
		April							
1	Color	--	--	--	--	--	--	--	Colorless
2	Odor	--	--	--	--	--	--	--	Unobjectionable
3	pH	8.31	7.85	7.51	7.9	8.38	7.9	8.14	6.5-8.5
4	EC	490	442	297	380	699	99.2	70	1000 µs/cm
5	TDS	310	181	110	198	900	171	187	1000 mg/l
6	Turbidity	55	24.53	10.22	10.36	58.95	76	111	5 NTU
7	Ammonia	0.88	0.7	0.11	1.7	2.21	0.48	0.13	1.5 mg/l
8	T. Hardness	118	77	67	100	177.69	102.7	132	300 mg/l $CaCO_3$
9	Sodium	140	41.3	11.31	81.62	150	48.34	71.51	200 mg/l
10	Potassium	21.1	16.43	4.33	15.33	33.92	20	14.8	1.5 mg/l
11	Total iron	1.1	0.12	0.08	0.7	0.91	0.52	1.3	0.3 mg/l
12	Manganese	1.04	0.1	0	1.41	0.62	1.5	1.36	0.1 mg/l
13	Calcium	90.46	63.3	34.58	81.9	54.5	72.52	98.76	75 mg/l
14	Magnesium	97	59.6	10	12.3	113.7	33.04	40	150 mg/l
15	Alkalinity	300	160	157	220	256	200	230	200 mg/l $CaCO_3$
16	Carbonate	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
17	Bicarbonate	400	222.8	188.46	270.9	210	261	279	150 -350 “”
18	Chloride	100	4.78	7.83	9	37.46	32	250	250mg/l

Table 5. Continued

19	Sulfate	0.13	0.99	0.29	8.4	16	0.55	0	400 mg/l
20	Nitrate	1.37	0.34	0.04	1.56	11.44	0.19	0.24	10 mg/l
21	Nitrite	0.09	0.15	0	1.07	0.64	0.2	0.19	1 mg/l
22	Fluoride	1.7	1.03	0.07	2.42	0.7	1.02	2.03	1.5 mg/l
23	Phosphate	0	0	0	0.35	0.14	0.08	0.37	0.3 mg/l
24	DO	1.98	2.4	1.7	4.11	6.24	3.32	3.04	4 – 6 mg/l
25	BOD	21.7	24.87	27.91	27.92	37.18	26	25.4	2 mg/l O_2
26	COD	110.2	109.3	141.32	169.3	203.76	157.36	162.44	10 mg/l O_2

Table 6. Spatial and temporal results of sludge/sediment quality parameters

S/N	Parameters	February				Standards
		Site2	Site3	Site5	Site6	
1	pH	6.44	6.21	7.16	6.63	6 – 8
2	EC	380	198	672	92	2000 – 4000 µs/cm
3	CEC	78.47	60	113.6	107.5	5 – 24 cmol/kg
4	Total iron	0.29	0.11	1.01	0.92	2.1 – 4.5 mg/l
6	Manganese	0.13	0.09	0.7	2	
6	Total nitrogen	0.09	0.02	0.16	0.05	
7	Total Phosphorus	27	19	33	36	26 – 70 mg/l
		March				
1	pH	6.72	6.51	7.72	6.9	6 – 8
2	EC	321	154	540	76	2000 – 4000 µs/cm
3	CEC	65	46.7	101.2	79.6	5 – 24 cmol/kg
4	Total iron	0.22	0.1	0.9	0.74	2.1 – 4.5 mg/l
5	Manganese	0.08	0.08	0.05	1.2	
6	Total nitrogen	0.07	0.01	0.12	0.03	
7	Total Phosphorus	16	13	18	21	26 – 70 mg/l
		February				
1	pH	6.65	6.43	7.04	6.54	6 – 8
2	Electrical Conductivity	430	234	721	153	2000 – 4000 µs/cm
3	CEC	101.71	93.2	141.2	115.2	5 – 24 cmol/kg
4	Total iron	0.41	0.19	1.63	1.42	2.1 – 4.5 mg/l
5	Manganese	0.17	0.1	0.95	2	
6	Total nitrogen	0.87	0.04	0.91	1	
7	Total Phosphorus	32	25	37	44	26 – 70 mg/l

4.2 Discussion

Table 7. Descriptive statistics (Range, mean, maximum, minimum, standard deviation and variance) for water quality parameters. (Note: The units for all parameters are consistent with the units given in the WHO standards column.)

	Range	Minimum	Maximum	Mean	Std. Error	Std. Deviation	Variance	WHO Standards
pH	1.80	7.20	9.00	7.9938	.09761	.44731	.200	6-8.5
EC	976.00	33.00	1009.00	391.6286	55.69838	255.24204	65148.497	1000 µs/cm
TDS	860.00	110.00	970.00	287.1252	55.34932	253.64245	64334.490	500 mg/l
Turbidity	104.30	6.70	111.00	48.9681	6.99907	32.07379	1028.728	5 NTU
Ammoinia	2.96	.04	3.00	.9471	.18530	.84917	.721	1.5, 35 mg/l
T.Hardness	156.60	54.40	211.00	103.7948	9.21056	42.20807	1781.522	300 mg/l $CaCO_3$
Sodium	185.80	9.90	195.70	74.3081	10.93086	50.09149	2509.158	200 mg/l
Potassium	40.42	3.58	44.00	19.9581	2.65577	12.17026	148.115	--
T.Iron	1.22	.08	1.30	.6548	.08343	.38230	.146	1 mg/l
Manganese	2.00	.00	2.00	.7705	.15618	.71571	.512	0.1 mg/l
Calcium	66.42	34.58	101.00	72.2805	3.95915	18.14310	329.172	75 mg/l
Magnesium	141.80	5.00	146.80	48.0376	8.94302	40.98205	1679.529	150 mg/l
Alkalinity	190.00	140.00	330.00	216.4157	12.64651	57.95359	3358.619	300 mg/l $CaCO_3$
Bicarbonate	229.90	170.80	400.70	244.4119	13.48519	61.79693	3818.860	150 – 350 mg/l
Chloride	245.60	4.40	250.00	40.2390	12.70108	58.20365	3387.665	250 mg/l

Table 7. Continued

Sulphate	21.00	.00	21.00	3.7938	1.30189	5.96602	35.593	400 mg/l
Nitrate	13.18	.04	13.22	1.9043	.79886	3.66085	13.402	10 mg/l
Nitrite	1.07	.00	1.07	.3343	.07220	.33086	.109	1 mg/l
Floride	2.35	.07	2.42	1.1190	.12428	.56954	.324	1.5 mg/l
phosphate	.45	.00	.45	.1790	.03563	.16328	.027	0.3 mg/l
DO	5.84	.40	6.24	2.3676	.29109	1.33396	1.779	4 – 6 mg/l
BOD	30.63	6.55	37.18	21.5290	1.60119	7.33758	53.840	2 mg/l
COD	134.13	69.63	203.76	119.3400	7.53265	34.51895	1191.558	10 mg/l

Comparing the mean of each water quality parameters and the WHO guideline values as a reference shows that parameters such as turbidity, manganese, BOD and COD levels exceed the standards of WHO guidelines for drinking water quality. The Ethiopian standards are not as strong as that of WHO standards and hence not used in this section’s comparison. Total hardness, magnesium and Sulphate have maximum limit values at some sites that exceed the WHO limit values.

Table 8. Range, mean, maximum, minimum, standard deviation and variance of sediment/sludge quality parameters

	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Standard
pH	1.51	6.21	7.72	6.7458	.11782	.40815	.167	6 – 8
EC	645.00	76.00	721.00	339.0833	66.77625	231.31972	53508.81	2000-4000 μs/cm
T.Iron	1.53	.10	1.63	.6617	.15082	.52246	.273	2.1 – 4.5
Manganese	1.95	.05	2.00	.6292	.21605	.74842	.560	
T.Nitrogen	.99	.01	1.00	.2817	.11324	.39226	.154	
T.Phosphorus	31.00	13.00	44.00	26.7500	2.79644	9.68715	93.841	26 – 70 mg/l
CEC	94.50	46.70	141.20	91.9483	7.77912	26.94765	726.176	5 – 24 c mol/Kg

Though there are different data interpretation methods of soil quality data, here it is simply compared with provisional guidelines values of soil quality for agriculture. With this regard, the pH seems that it lies in the limit range but the values are almost in upper and lower extreme values. Some values of the total phosphorus and CEC are below the provisional limit values. The EC and total iron are within the standard.

The above descriptive statistics could be detailed more using further statistical evaluations and normality test was applied before analyzing further statistical studies on the water and soil quality data. Checking the normality of the data was important whether to use parametric or nonparametric tests. Basically, normally distributed data have to be tested using parametric tests unless the tests are nonparametric or the data need to be transformed to use parametric tests.

The normality of the data was tested using the explore tool. The water and soil quality parameters were taken as dependent variables and the time and station were taken as independent variables or factors. The normality of each variable was tested in the seven stations and three months' time separately. Though the explore command gives bulky results of data description, the normality test was checked using numerical and graphical representations via Tests of Normality table (Shapiro – Wilk test) and Normal Q-Q plots respectively. Kurtosis, Skewness and standard error were used in addition to the two for normality test but 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 are above 0.05 and hence this shows the data distribution is normal. The soil quality data is normally distributed for all parameters. This is clearly indicated in Appendix A.

Q-Q plots (quantile – quantile plots) are very important probability plots for comparing variables distribution against that of test distribution because the sample size for this thesis work is small. Normal distribution from Q-Q plots is determined by simply observing the clustering pattern of the data points around the straight line for both the variables and test distribution.

The detrended normal Q-Q plots show the deviations of data points from the normal distribution. The deviation value of each parameters at its corresponding time and space can be shown in appendix B. The perfect normal distribution is shown by the diagonal line.

Accordingly, the normal Q-Q plot distribution for most water quality parameters except TDS, Chloride, Sulphate and Nitrate are concentrated to the diagonal line and hence the data generally have normal distribution. See the figure below.

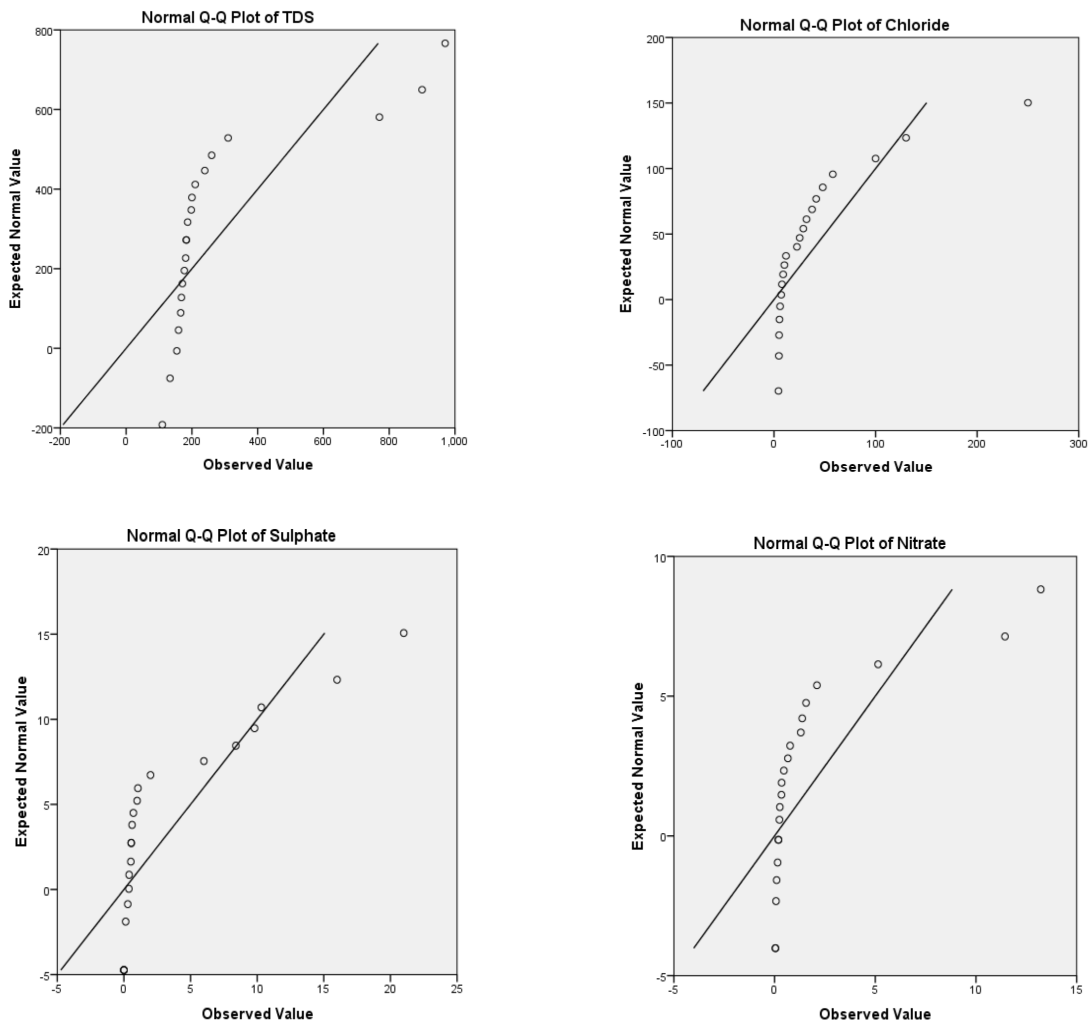
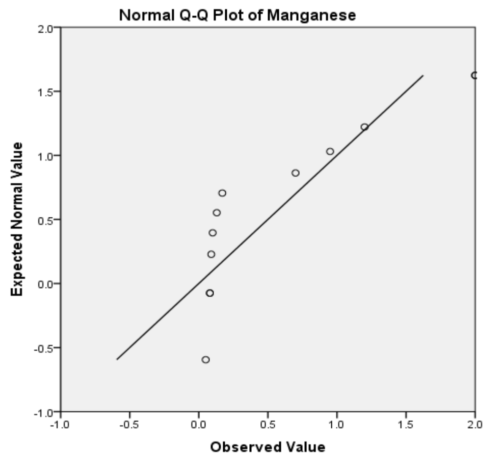


Figure 4. The normally unfitted Q – Q plots of water quality parameters

On the other hand, the Q-Q plot distribution for soil quality parameters except manganese and total nitrogen (as shown in in the fig below) are also clustered at the diagonal line and hence we have almost normally distributed data.



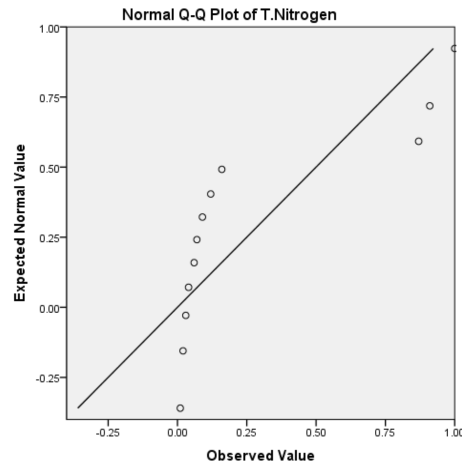


Figure 6. The normally unfitted Q – Q plots of sludge/sediment quality parameters

The figures above shows parameters that do not fit the normal distribution data. The Normal Q-Q plots that satisfy normal distribution of data are excluded because they need huge space. The Detrended Normal Q-Q plot of each parameters that shows the deviations in each time and space of study are also omitted in this section for the same reasons as the normal Q-Q plots though deeply studied. But they are in included in the appendix.

Therefore, the normal distribution tests all show that using parametric test in the study is relevant.

One Way ANOVA

Station and time were explained in an independent Factor box for dealing at how a single categorical variable explains the variance in a continuous variable. So, the water and soil quality parameters are explained with regard to the spatial and temporal variables using one way ANOVA.

The significance value which is read from the last column of the ANOVA table tells us whether the hypothesis (no difference between means) is to be accepted or not. If the P-value is above 0.05, we say there is no significance difference between means. However, if it is below 0.05, then we say we have rejected the null hypothesis of no difference between the group means, and that there is a significant difference.

For the station based comparisons of means, all continuous water quality parameters have a significance values of ≤ 0.05 except BOD and COD. The P- values for BOD and COD are 0.196

and 0.143 respectively. This implies that the means of BOD and BOD have no variation whereas the other variables have difference of means between groups.

For the time based comparisons of means, only potassium (0.03), BOD (0.001) and COD (0.002) have significance difference of means between groups. The remaining variables have no difference of means.

Table 9 Oneway ANOVA of water quality variables by Station at constant time

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	3.471	6	.578	15.247	.000
	Within Groups	.531	14	.038		
	Total	4.002	20			
EC	Between Groups	1235772.183	6	205962.030	42.910	.000
	Within Groups	67197.760	14	4799.840		
	Total	1302969.943	20			
TDS	Between Groups	1260066.988	6	210011.165	110.437	.000
	Within Groups	26622.815	14	1901.630		
	Total	1286689.804	20			
Turbidity	Between Groups	18737.358	6	3122.893	23.797	.000
	Within Groups	1837.196	14	131.228		
	Total	20574.554	20			
Ammoinia	Between Groups	10.332	6	1.722	5.894	.003
	Within Groups	4.090	14	.292		
	Total	14.422	20			
T.Hardness	Between Groups	31685.419	6	5280.903	18.741	.000
	Within Groups	3945.013	14	281.787		
	Total	35630.432	20			
Sodium	Between Groups	45532.574	6	7588.762	22.845	.000
	Within Groups	4650.578	14	332.184		

Table 9. Continued

	Total	50183.153	20			
Potassium	Between Groups	1641.088	6	273.515	2.898	.047
	Within Groups	1321.215	14	94.372		
	Total	2962.303	20			
T.Iron	Between Groups	2.485	6	.414	13.218	.000
	Within Groups	.439	14	.031		
	Total	2.923	20			
Manganese	Between Groups	5.722	6	.954	2.952	.045
	Within Groups	4.523	14	.323		
	Total	10.245	20			
Calcium	Between Groups	4608.339	6	768.056	5.444	.004
	Within Groups	1975.104	14	141.079		
	Total	6583.443	20			
Magnesium	Between Groups	29658.972	6	4943.162	17.602	.000
	Within Groups	3931.601	14	280.829		
	Total	33590.573	20			
Alkalinity	Between Groups	46716.190	6	7786.032	5.329	.005
	Within Groups	20456.192	14	1461.157		
	Total	67172.382	20			
Bicarbonate	Between Groups	47503.186	6	7917.198	3.839	.018
	Within Groups	28874.014	14	2062.430		
	Total	76377.201	20			
Chloride	Between Groups	38089.245	6	6348.207	2.996	.043
	Within Groups	29664.061	14	2118.862		
	Total	67753.306	20			
Sulphate	Between Groups	637.545	6	106.258	20.016	.000
	Within Groups	74.322	14	5.309		
	Total	711.867	20			

Table 9. Continued

Nitrate	Between Groups	230.271	6	38.378	14.227	.000
	Within Groups	37.765	14	2.698		
	Total	268.036	20			
Nitrite	Between Groups	1.356	6	.226	3.798	.019
	Within Groups	.833	14	.060		
	Total	2.189	20			
Fluoride	Between Groups	4.023	6	.670	3.808	.018
	Within Groups	2.465	14	.176		
	Total	6.488	20			
Phosphate	Between Groups	.406	6	.068	7.437	.001
	Within Groups	.127	14	.009		
	Total	.533	20			
DO	Between Groups	24.513	6	4.085	5.164	.005
	Within Groups	11.076	14	.791		
	Total	35.589	20			
BOD	Between Groups	452.529	6	75.422	1.691	.196
	Within Groups	624.272	14	44.591		
	Total	1076.802	20			
COD	Between Groups	10773.846	6	1795.641	1.925	.147
	Within Groups	13057.318	14	932.666		
	Total	23831.164	20			

Table 10 Oneway ANOVA of water quality parameters by Time ignoring spatial variation

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	.232	2	.116	.553	.585
	Within Groups	3.770	18	.209		
	Total	4.002	20			

Table 10. Continued

EC	Between Groups	28975.280	2	14487.640	.205	.817
	Within Groups	1273994.663	18	70777.481		
	Total	1302969.943	20			
TDS	Between Groups	8509.633	2	4254.817	.060	.942
	Within Groups	1278180.170	18	71010.009		
	Total	1286689.804	20			
Turbidity	Between Groups	5.047	2	2.523	.002	.998
	Within Groups	20569.507	18	1142.750		
	Total	20574.554	20			
Ammoinia	Between Groups	3.000	2	1.500	2.364	.123
	Within Groups	11.422	18	.635		
	Total	14.422	20			
T.Hardness	Between Groups	1243.533	2	621.766	.325	.726
	Within Groups	34386.899	18	1910.383		
	Total	35630.432	20			
Sodium	Between Groups	1889.834	2	944.917	.352	.708
	Within Groups	48293.318	18	2682.962		
	Total	50183.153	20			
Potassium	Between Groups	943.040	2	471.520	4.203	.032
	Within Groups	2019.263	18	112.181		
	Total	2962.303	20			
T.Iron	Between Groups	.122	2	.061	.391	.682
	Within Groups	2.801	18	.156		
	Total	2.923	20			
Manganese	Between Groups	2.177	2	1.089	2.429	.116
	Within Groups	8.067	18	.448		
	Total	10.245	20			
Calcium	Between Groups	1072.338	2	536.169	1.751	.202
	Within Groups	5511.106	18	306.173		

Table 10 Continued

	Total	6583.443	20			
Magnesium	Between Groups	1940.702	2	970.351	.552	.585
	Within Groups	31649.871	18	1758.326		
	Total	33590.573	20			
Alkalinity	Between Groups	10307.150	2	5153.575	1.631	.223
	Within Groups	56865.232	18	3159.180		
	Total	67172.382	20			
Bicarbonate	Between Groups	17687.452	2	8843.726	2.712	.093
	Within Groups	58689.749	18	3260.542		
	Total	76377.201	20			
Chloride	Between Groups	6304.155	2	3152.078	.923	.415
	Within Groups	61449.151	18	3413.842		
	Total	67753.306	20			
Sulphate	Between Groups	25.713	2	12.856	.337	.718
	Within Groups	686.155	18	38.120		
	Total	711.867	20			
Nitrate	Between Groups	9.361	2	4.680	.326	.726
	Within Groups	258.675	18	14.371		
	Total	268.036	20			
Nitrite	Between Groups	.429	2	.214	2.193	.140
	Within Groups	1.760	18	.098		
	Total	2.189	20			
Fluoride	Between Groups	.638	2	.319	.982	.394
	Within Groups	5.849	18	.325		
	Total	6.488	20			
Phosphate	Between Groups	.045	2	.023	.831	.452
	Within Groups	.488	18	.027		
	Total	.533	20			
DO	Between Groups	9.182	2	4.591	3.129	.068

Table 10. Continued

	Within Groups	26.407	18	1.467		
	Total	35.589	20			
BOD	Between Groups	569.462	2	284.731	10.102	.001
	Within Groups	507.340	18	28.186		
	Total	1076.802	20			
COD	Between Groups	11718.523	2	5859.262	8.707	.002
	Within Groups	12112.641	18	672.925		
	Total	23831.164	20			

The significance difference of means for the sediment quality parameters seems that there is more significance 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) have P-value of less than 0.05 which implies that their variation with stations or sites is apparent. On the contrary, the time based variation of means is visible for total nitrogen (0.011) and total phosphorus (0.013).

Therefore, the mean differences between groups shows that the variation of values for the water quality parameters is more visible with time than station based variation whereas the station based variation is visible than the time based variation for the soil parameters. But this is only for the period and space that is taken into account in the study. If more stations and more time period are considered for study, we might find different conclusion. So, taking additional samples is necessary for validating our conclusion.

Table 11 Oneway ANOVA of sediment quality parameters by time ignoring spatial variation

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	1.408	3	.469	8.848	.006
	Within Groups	.424	8	.053		
	Total	1.832	11			
EC	Between Groups	572738.917	3	190912.972	96.311	.000
	Within Groups	15858.000	8	1982.250		
	Total	588596.917	11			

Table 11. Continued

CEC	Between Groups	4610.892	3	1536.964	3.641	.064
	Within Groups	3377.041	8	422.130		
	Total	7987.933	11			
T.Iron	Between Groups	2.421	3	.807	11.105	.003
	Within Groups	.581	8	.073		
	Total	3.003	11			
Manganese	Between Groups	5.299	3	1.766	16.381	.001
	Within Groups	.863	8	.108		
	Total	6.161	11			
T.Nitrogen	Between Groups	.271	3	.090	.509	.687
	Within Groups	1.421	8	.178		
	Total	1.693	11			
T.Phosphorus	Between Groups	352.917	3	117.639	1.385	.316
	Within Groups	679.333	8	84.917		
	Total	1032.250	11			

Table 12 Oneway ANOVA of sediment quality variables by station at constant time

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	.288	2	.144	.838	.464
	Within Groups	1.545	9	.172		
	Total	1.832	11			
EC	Between Groups	15151.167	2	7575.583	.119	.889
	Within Groups	573445.750	9	63716.194		
	Total	588596.917	11			
CEC	Between Groups	3177.936	2	1588.968	2.973	.102
	Within Groups	4809.997	9	534.444		

Table 12. Continued

	Total	7987.933	11			
T.Iron	Between Groups	.395	2	.197	.681	.530
	Within Groups	2.608	9	.290		
	Total	3.003	11			
Manganese	Between Groups	.471	2	.235	.372	.699
	Within Groups	5.691	9	.632		
	Total	6.161	11			
T.Nitrogen	Between Groups	1.077	2	.538	7.864	.011
	Within Groups	.616	9	.068		
	Total	1.693	11			
T.Phosphorus	Between Groups	636.500	2	318.250	7.238	.013
	Within Groups	395.750	9	43.972		
	Total	1032.250	11			

Correlations

Correlation analysis describes the closeness of relationship of two or more parameters to ±1. The closeness to ±1 shows the probability of linear relationship between the variables, the water quality parameters. So, it describes both the strength and the direction of linear association between the variables. Positive correlations indicate direct linear association whereas negative correlation tells inverse linear relationship.

As the value of the correlation coefficient, r goes to zero, the association becomes weak while degree of association increases as r goes to ±1. The perfect correlation between variables is indicated by ±1.

Table 13. Correlation values and their strength

Correlation coefficient, r	Correlation strength
±0.75 - ±1	Strong

Table 13. Continued

±0.5 - ±0.75	Moderate
±0.25 - ±0.5	Weak
≤0.25	No Correlation

Pearson correlation coefficient can be computed using the following formulas:

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

Or

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

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

The relations between the tested water quality and sediment/sludge quality parameters of Lake Ziway were determined for the seven sites for three months as shown in tables 14 and 15 respectively. The strength and direction of correlation can be observed from these tables based on the values given in Table 13. Significance correlations among the water and soil/sludge quality parameters are shown at $P<0.05$ and $P< 0.01$ significance levels. More correlated parameters are important for studying parameters at times laboratory studies become a problem. So, we can study, determine and interpret some variables in terms of the other variables. For example, the correlation between pH and Sodium is with Pearson correlation coefficient of 0.880 at 0.05 significance level (see Table 14). This means that their correlation is strong and the variables can be interchangeably determined. The same is true for other variables. Furthermore, it is important to classify similar sites according to their correlation score.

Table 14. Correlation matrix between water quality variables

Parameters	pH	EC	TDS	Turbidity	Ammoinia	T.Hardness	Sodium	Potassium	T.Iron	Manganese	Calcium	Magnesium
pH	1	.434*	.719**	.610**	.610**	.836	.880*	.775**	.716**	.244	.522	.850*
EC	.434*	1	.784**	-.260	.692**	.506*	.681	.398**	-.025	-.367**	-.324*	.713
TDS	.719**	.784**	1	.163	.742**	.887**	.859**	.595	.333	-.164**	-.047**	.855**

Table 14. Continued

Turbidity	.610**	-.260	.163	1	-.069	.431**	.317	.329	.750	.338	.612**	.329
Ammoinia	.610**	.692**	.742**	-.069	1	.637**	.806**	.807**	.366	.259	.189**	.661**
T.Hardness	.836**	.506*	.887**	.431	.637**	1**	.856*	.660**	.547	.072**	.307**	.834*
Sodium	.880**	.681**	.859**	.317	.806**	.856**	1**	.765**	.630	.182**	.334**	.886**
Potassium	.775**	.398	.595**	.329	.807**	.660**	.765	1**	.538	.499**	.502**	.730
T.Iron	.716**	-.025	.333	.750**	.366	.547**	.630	.538	1**	.609	.759**	.405
Manganese	.244	-.367	-.164	.338	.259	.072	.182	.499	.609	1	.702	-.065
Calcium	.522*	-.324	-.047	.612**	.189	.307*	.334	.502	.759**	.702	1*	.190

Parameters	Alkalinity	Bicarbonate	Chloride	Sulphate	Nitrate	Nitrite	Fluoride	phosphate	DO	BOD	COD
pH	.848**	.533**	.324**	.459	.625*	.403**	-.115**	.393**	.513	.260*	.321**
EC	.572**	.135	-.255**	.725*	.760	.341**	-.418	-.171**	.287*	.185	.068**
TDS	.661	.069	.077**	.843**	.957**	.483	-.413	.215**	.694**	.470**	.476
Turbidity	.336	.334	.683	-.144**	.086	-.072	.114	.327	.193**	-.058	.171
Ammoinia	.697**	.313	-.189	.870**	.794**	.829**	-.046	.383	.637**	.540**	.406**
T.Hardness	.718**	.208	.334**	.680**	.815*	.528**	-.216	.470**	.749**	.489*	.593**
Sodium	.883**	.498	.196**	.716**	.804**	.556**	-.105	.325**	.621**	.366**	.373**
Potassium	.814**	.554	-.047**	.517**	.582	.607**	-.062	.435**	.499**	.352	.285**
T.Iron	.581	.524**	.626	.223**	.302	.388	.402**	.587	.412**	.214	.341
Manganese	.325	.527	.152	-.061	-.156	.425	.576	.545	.233	.217	.262
Calcium	.427	.585**	.458	-.081*	-.071	.349	.605**	.645	.171*	.060	.117

Parameters	pH	EC	TDS	Turbidity	Ammoinia	T.Hardness	Sodium	Potassium	T.Iron	Manganese	Calcium	Magnesium	Alkalinity
Magnesium	.850	.713*	.855**	.329**	.661**	.834	.886*	.730**	.405**	-.065**	.190	1*	.829**
Alkalinity	.848*	.572	.661**	.336	.697**	.718*	.883	.814**	.581	.325**	.427*	.829	1**
Bicarbonate	.533**	.135**	.069	.334	.313**	.208**	.498**	.554	.524	.527**	.585**	.457**	.742
Chloride	.324**	-.255	.077	.683	-.189	.334**	.196	-.047	.626	.152	.458**	.144	.172
Sulphate	.459**	.725**	.843**	-.144	.870	.680**	.716**	.517**	.223	-.061	-.081**	.567**	.456**
Nitrate	.625**	.760*	.957**	.086	.794**	.815**	.804*	.582**	.302	-.156**	-.071**	.774*	.580**
Nitrite	.403**	.341**	.483**	-.072	.829**	.528**	.556**	.607**	.388	.425**	.349**	.306**	.413**
Floride	-.115**	-.418	-.413**	.114	-.046**	-.216**	-.105	-.062**	.402	.576**	.605**	-.312	-.058**
Phosphate	.393**	-.171	.215	.327**	.383	.470**	.325	.435	.587**	.545	.645**	.073	.224
DO	.513	.287	.694	.193	.637	.749	.621	.499	.412	.233	.171	.502	.395

Table 14. Continued

BOD	.260*	.185	.470	-.058**	.540	.489*	.366	.352	.214**	.217	.060*	.312	.228
COD	.321	.068*	.476**	.171**	.406**	.593	.373*	.285**	.341**	.262**	.117	.286*	.239**

Parameters	Bicarboate	Chloride	Sulphate	Nitrate	Nitrite	Floride	phosphate	DO	BOD	COD
Magnesium	.457**	.144**	.567	.774*	.306**	-.312**	.073**	.502	.312*	.286**
Alkalinity	.742	.172**	.456*	.580	.413**	-.058	.224**	.395*	.228	.239**
Bicarbonae	1	.207**	-.072**	.034**	.128	.354	-.020**	.029**	-.002**	-.003
Chloride	.207	1	-.100**	.023	-.132	.326	.279	.182**	.133	.294
Sulphate	-.072	-.100	1**	.919**	.760**	-.206	.350	.730**	.605**	.524**
Nitrate	.034	.023**	.919**	1*	.584**	-.351	.215**	.732**	.563*	.539**
Nitrite	.128	-.132**	.760**	.584**	1**	.260	.658**	.685**	.568**	.549**
Floride	.354	.326**	-.206**	-.351	.260**	1	.323**	.035**	.071	.121**
Phosphate	-.020**	.279	.350**	.215	.658	.323**	1	.448**	.325	.388
DO	.029	.182	.730	.732	.685	.035	.448	1	.812	.894
BOD	-.002**	.133	.605*	.563	.568	.071**	.325	.812*	1	.887
COD	-.003**	.294**	-.003**	.524	.539*	.549**	.121**	.388**	.894	1

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

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

Table 15. 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)

Cluster Analysis (CA) was applied to 29 parameters for 7 water samples and 7 sediment/soil quality parameters for 4 samples. The data were generated from February to April 2018. Correlations were found based on Pearson correlation and then Cluster analysis (CA) was used for classifying the data.

From the hierarchical cluster analysis, the horizontal lines represent the sites where individual samples were taken. A cluster forms when samples/sites become connected or merged. This implies that bigger cluster is formed by the merging up of similar sub clusters which are shown by vertical lines. The distance between the two clusters being merged is represented by the X-axis. Clusters that do not merge until the right end of the x-axis represent water-quality samples that are distant from each other in squared Euclidean distance. This is interpreted as the samples have much differing constituent concentrations.

Two significant sampling locations or clusters were found 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.

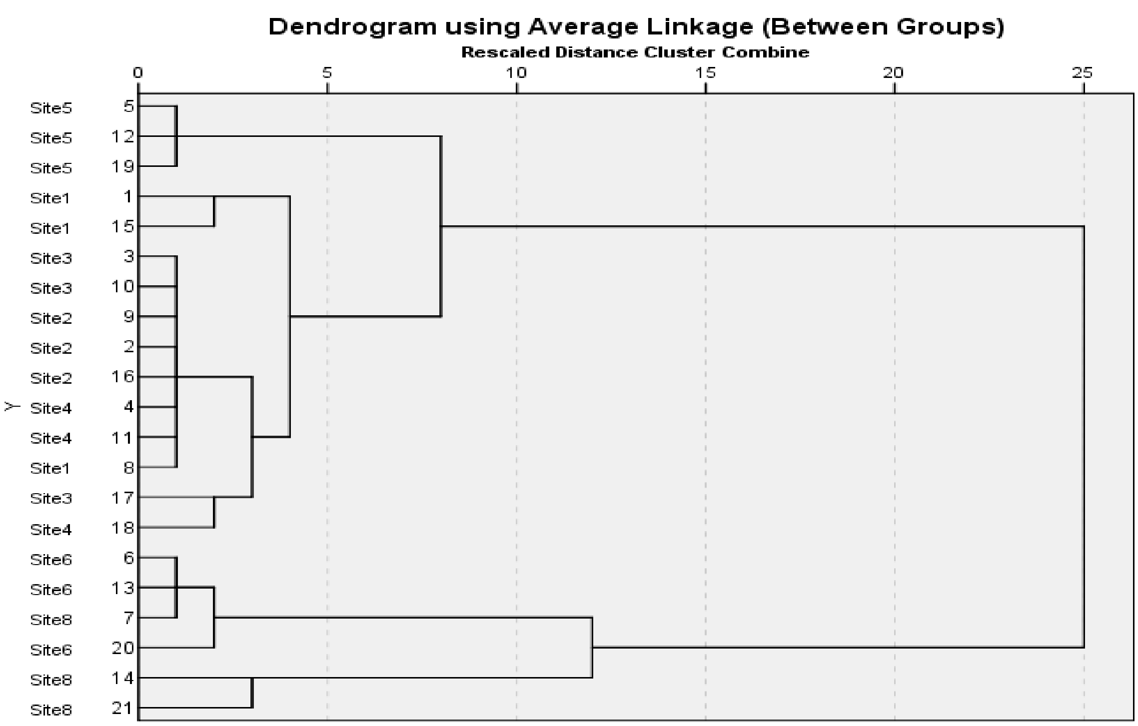


Figure 7. Dendrogram showing clusters of the surface-water samples

N.B: The total sampling sites (N) are 21 for water and 12 for sludge. Because the sampling frequency (f) is three. For the water samples $N = fn = 3 * 7 = 21$ and for the sludge/soil samples$N = fn = 3 * 4 = 12$. So, clusters and sub clusters may encounter sampling site repetitions.

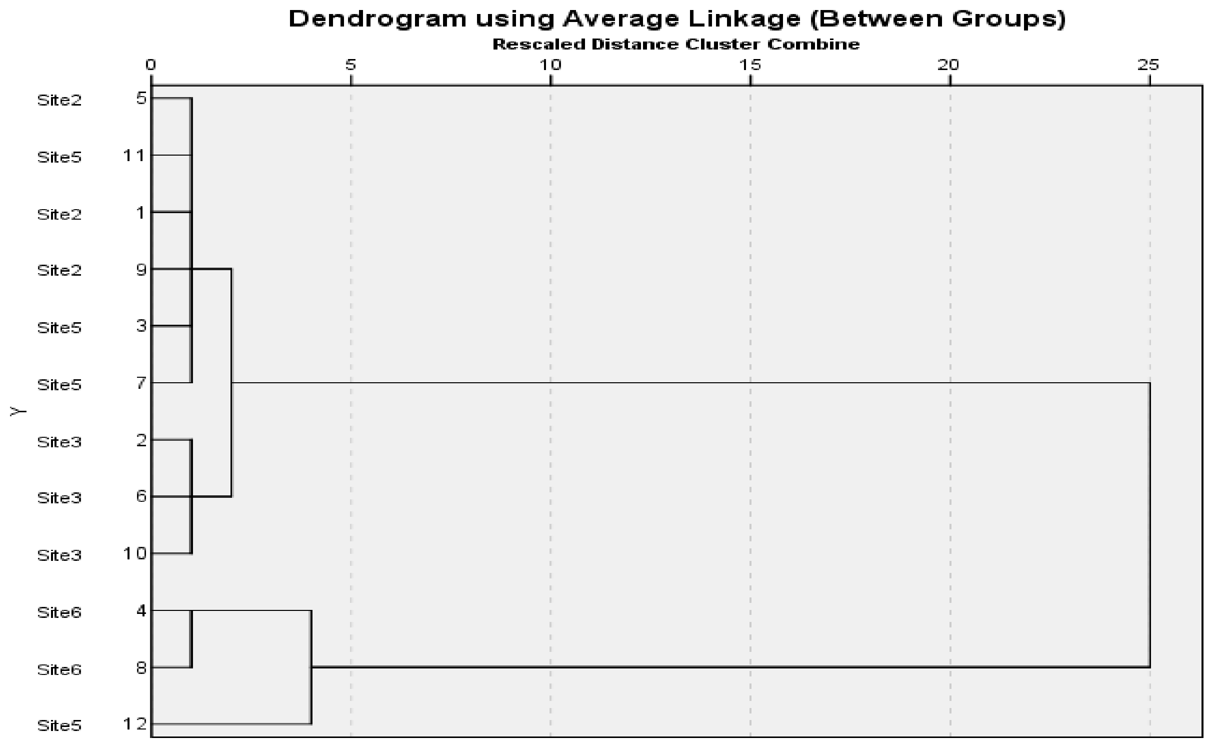


Figure 8. Dendrogram showing clusters of the sediment/sludge samples

The dendrogram diagram for the soil quality parameters studies also shows that the sites are classified into two clusters. Cluster one is formed by the emergence of sites two, three and five while cluster two is formed by the emergence of sites five and six.

As shown in the dendrogram sub clusters forming cluster one and two for the water quality i.e. sites one to five and sites six and eight are distant and hence is to mean the values of water quality parameters variable between cluster one and cluster two.

In general, the results revealed that the major causes of water quality deterioration are interventions such as inflow of effluents from the floriculture industries, domestics, agricultural practices, saline seeps and concentrated effluent inflow from Sher Ethiopia in to the lake at sites one, two, three, four and five. Because the samples taken from sites with these interventions show that there is at least above detection limit measurements for all parameters. The other cause results from people's activities in boats and islands. The sampling sites used, mainly sites six and eight involve run off, silt, waste effluents and etc. and hence these can also be taken as the causes of the lake's pollution. The details of the water and sludge sampling sites and their clusters are given in Figures 7 and 8 respectively.

There is no need to apply cluster analysis to the temporal data because it is simple to have temporal clusters by simply observing the raw data. There are two clusters, one is 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 considerable difference of concentrations between cluster one and cluster two. This might have been emanated because of rain around Ziway in the month of March and was probably a reason to find low concentration values as a result of dilution compared to the months of February and April that made cluster one.

5. Preventive and treatment Options

Previous researches around Lake Ziway have shown that Ziway Lake with its aquatic life and human consumers could be in dangerous conditions unless the pollution sources are controlled. For example a research by Berhane et al. has clearly indicated that most parameters in most of the sampling sites were found to be generally above the maximum permissible limits of WHO standards (Teklu, Hailu, Wiegant, Scholten, & van Den Brink, 2016). However, after two years period it was found that the parameters' values did not exceed the WHO standards by far. Though not enough to generalize, this research's result shows that the trend is decreasing from previous years. This might be the result of the regional government's action. From the informal interviews the local dwellers gave, the regional government has imposed responsibilities on the floriculture companies either to leave the leased land or to refrain from any form of environmental crimes.

As a result, the companies in cooperation with the regional government are in search of another less sensitive site of flower investment as an option. The companies are also firmly responsible to construct buffer zones far from the lake and to have a constructed dumping sites in their own flower development fields. Actually, there is a vegetated buffer zone constructed by Floriculture Company called Sher Ethiopia in 25- 100 meters away from the lake. But this distance of buffer zone in between the lake and the company is too short to prevent the direct and after effects of pollutants' discharge into the lake. The minimum standard for the construction of buffer zones is explained in section 5.1 of this chapter.

In addition to the above options, there are other several options of prevention for safeguarding surface water pollutions. Buffer Zones, dumping sites and other options are discussed below.

5.1 Constructed Buffer Zones

Buffer zones benefits are immense including runoff filtering, shoreline stabilization, preservation of fish and shoreline habitat, screening noise and preservation of aesthetic values. It filters runoff generated by surrounding land uses, removing harmful chemicals and nutrients. It also serves as a habitat for critical aquatic insects, microorganisms, fish and other animals by maintaining a balance in sensitive aquatic ecosystems. But due to different reasons, natural shoreline vegetation get damaged or destroyed. So, buffers become important, i.e. a naturally vegetated buffer strip along the periphery of lakes or streams or wetlands is essential to the health and quality of the water body. The buffer is advised to comprise of the type of vegetation that naturally exists in the shoreline, setting. It is not advised to use fertilizers or pesticides for buffers. And about the size, it may be 25 feet wide around a small urban pond or hundreds of feet wide along a pristine rural lake (Illinois Environmental Agency and the Northeastern Planning Commission, Lake Notes, 1996).

Noting the characteristic of the water body with its local conditions is critical before building any buffer zone so as to understand what types of buffer zones to construct. Therefore, the characteristics of the common types of buffer zones like prairie, forest or vegetative wetland depends on the local conditions. However, there are basic minimum criteria to depend on.

The minimum width requirement is 25 feet though wider buffers with the width of 50 – 100 feet are established for wider and sensitive lakes. The U.S department of agriculture recommends filter strips of 66 – 100 feet for water quality protection. If any sort of access to lakes is needed, it is recommended to be done with very least interruptions. Any movement via the buffer zone must be restricted. The buffer vegetation should be native species of plants because they can easily get acclimated to the soils, hydrology and climate of the area. Buffer vegetation should also reflect its purpose. For example, a forested buffer is preferred if the purpose is to screen noise. In contrary, it may not be appropriate if local residents need an obstructed lake view. An installation of a buffer begins by removing the original undesirable vegetation, which otherwise are considered to be weeds against the indigenous plants. Because only the indigenous plants can easily accustom to the local conditions and function best. Buffer maintenance is an important issue to control weeds and maintain native plant diversity. Typically, 1 – 3 years are common for maintenance after buffers are established (Illinois Environmental Agency and the Northeastern Planning Commission, Lake Notes, 1996).

The buffer zone in Lake Ziway is that of prairie and vegetative wetland with 25 – 100 feet distance away from the lake. The size of polluted water collection pool is about 6.56 feet width. The main problem with this constructed buffer zone is that it is below standard. For example, the distance between the lake and the buffer zone should be at least 100 feets and above (Ministry of Urban Development and Housing Infrastructure, 2016). The shortest distance makes the water induction to the water body very fast and along that soluble and very small size pollutants may reach the water body.

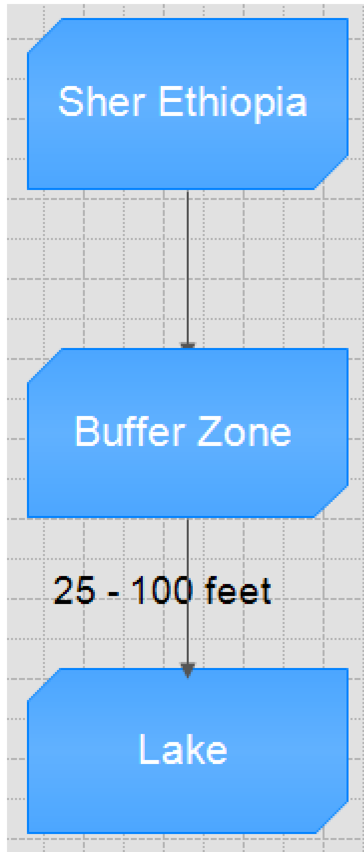


Figure 8. The location of constructed buffer by Sher Ethiopia Floriculture Farm

The other observed problem in Lake Ziway's constructed buffer zone is that intrusions should have been strictly forbidden but this is not true in Lake Ziway's Buffer zone as there are a lot of human and animal activities intervening in and around the buffer zones. Of course some parts of the buffer zones are fenced.

Advantages of Constructed Buffer Zones for Water Quality Improvement

Buffer zones give multiple advantages of surface water quality monitoring and additional environmental services. The best advantage to mention is filtering runoff ahead of entering to surface water bodies. As run off comes from nearby areas to the lake, different components in the runoff like pollutants and sediment will get filtered during the course via the buffer. Therefore, sediment and related pollutants will be removed by filtration and settling process by the plants and plant residues. Soluble pollutants, including plant nutrients, are taken up by plant roots and utilized by microorganisms in the soil. Native plants, particularly prairie vegetation have much denser, deeper root structures than conventional turf grasses which efficiently improves the infiltration of surface runoff into the ground. Based on the width and characteristics of the buffer, it can remove 70 – 95% of incoming sediment, 25 – 60% of incoming nutrients and other pollutants from the run off (Schultz, 2015; Young et al., 1993).

Along with runoff filtering, buffers specially natural buffers that extend down the water body's edge effectively prevents shoreline erosion better than conventional turf grass which is shallow rooted and intolerant of flooding. Natural riparian vegetation has dense, deep rooted systems that firmly anchor shoreline soils.

Many aquatic organisms, particularly insects, spend most portions of their life in upland environments. Buffers provide a critical transition zone between upland and aquatic/wetland habitats. Depending on their widths, buffers also can shield sensitive species, particularly birds, from potentially disruptive activities occurring in adjacent land uses.

Beyond protecting wild life uses, buffers like forested buffers can protect quality of lake recreational uses by intercepting noises from high ways and industrial operations. In the case of Lake Ziway, this helps to protect the recreational and religious uses of the monastery areas of St. Gebriel and Kidane mihret monasteries. Because these are surrounded by noisy areas in which a lot of human activities takes place.

These are related to appropriate shoreline landscaping to enhance the view of Lakes. It is important to know that buffered water body (lake) has better view than unshielded water body.

5.2 Best Management Practices (BMPs)

Best management practices are effective, practical, structural or nonstructural methods which prevent or at least minimize the movement of sediments, nutrients, pesticides and other pollutants from the land in to surface waters (State of Hawaii, department of Land and Natural resources, 1996). BMPs comprise of soil and water conservation techniques, social responsibilities for environmental protection and other management techniques (A.N. Sharpley et al, 2006).

The probability of solving pollution concerns in water and soil by only applying single BMP is low and hence combined applications of practices is very important to improve water and soil qualities. BMPs range from measures that involve a change in farming operations, like conservation tillage and crop rotation, to simple actions such as not applying manure before forecasted rainfall.

One of the best management practices known is conservation tillage. Conservation tillage is a practice of soil management with a primary goal of increasing agricultural production. But it also helps to improve water quality besides to soil management. A study on Lake Water quality improvement in USA that was carried out from 1997 to 2010 has shown the reduction of the mean concentration of total suspended solids and total phosphorus decreased by 72 and 45-56 percent respectively (Katherine Pekarek-Scott & Voit, 2011).

Conservation tillage systems range from no - till to mulch - till. No – till conservation tillage system is used by covering a crop residue on the soil surface from harvesting time to seeding time. This system is very important in sloppy areas with high degree of soil erosion. The Mulch – till on the other case comprises all types of techniques except no tillage and ridge tillage systems. Ridge till is a kind of till performed by specialized cultivars and planters by removing previous tillage residues. Strip – till is one of the mulch – till systems. It is used in less sloppy fields or places with less drainage capacity. Some parts of the field i.e narrow strips are tilled and most of the field is left untilled. Another type of mulch - till is deep-tillage in which soil is mixed with crop residues.

Social actions like afforestation and reforestation play a pivotal role for both water and soil quality management. Soil conservation or management can be the other way of water quality management. So, actions such as forest management are key to improve water quality. Forests particularly forests that are located in the upstream of water bodies are crucial to minimize soil erosion and surface runoff there by decrease sediment, pesticide and nutrient pollutants that would have been entered surface water bodies.

Other BMPs include using engineering techniques, prevention and treatment of wastes at their source, public awareness on factors that aggravate water quality deterioration and prevention strategies and others unmentioned.

One of the engineering techniques that might be of helpful to prevent pollution inlet in to Lake Ziway is construction of bypass canal in the upstream of the lake, on the way Meki and Ketari Rivers enter. This can also be constructed in any other small ways of emergency runoff that can happen during raining. This method might help a lot as one of the factors for the water quality problem of the lake is the incoming pollutants and sediments via rivers. So, bypass canals can prevent or reduce water quality problem by taking the pollutants and sediments somewhere away from the lake the lake. The effectiveness of bypass canal construction as pollution prevention strategy is already studied (Yang & Liu, 2010).

The small holder agriculturalists and companies that contribute pollution impacts to the lake have to use all methods of prevention, pollution reduction and treatment at their source. They should take the responsibilities to do so.

Public awareness regarding water quality, pollution sources of water bodies and their associate impacts in the socio - economic lives of communities is also a crucial issue. Because the biggest commitment to safeguard the natural environment should come from the public at large more than any other stake holders including the government and other nongovernmental organizations.

5.3 Strict Policies and Regulations

Having strict policies and regulations to maintain excellent water qualities solely can't solve water quality problems and their associated impacts. However, there should be strict implementation of rules and regulations. Some of the national and international binding rules that are important for protecting surface water pollution so as to have clean and healthy environment are covered in the literature review section. Abiding by these rules, regulations and standards and their implementation are ways forward for prevention and treatment options. But additional rules and regulations might come to be important and hence developing timely policies, rules and regulations is invaluable.

6. Conclusion and Recommendation

6.1 Conclusion

This study shows that the water quality parameters' vary both with time and space. But the variation of the parameters at each site with respect to time may not be enough for conclusion as the study has been conducted with only three months period. The spatial variations of the water and sediment parameters has provided clues about the pollution sources of the lake. Unlike to the pollution source identification, there was no full information from the study to know the exact pollution pathways. But the laboratory data revealed that the edges of Lake Ziway near to the floriculture farms seem to receive the pesticide and fertilizer wastes from the farms. Moreover, it can be concluded that sites that has human interventions have direct or indirect impacts on water quality deterioration of Lake Ziway.

The results were compared with international water quality guidelines to check if the water the water quality of Lake Ziway complies with the standard ranges. In this study the water quality parameters for some parameters at southern shoreline, floriculture outlet, Sher Ethiopia buffer zone, Meki River and specific sampling sites were found to be above the ranges of the WHO guideline values. But, with this study, the water quality of Lake Ziway can be generally acceptable for irrigation with the current condition. However, this doesn't mean it is possible for drinking and hence if pollution prevention methods are not taken on the Lake, the water quality of the Lake may seriously deteriorate and aquatic life of the lake and human life would be endangered.

The descriptive analysis shows that there is no extremely large variations between the means and the WHO water quality guidelines. The interpretation from the ANOVA table also shows there are significant variations of water quality parameters' values between sampling sites except the BOD and COD. The correlations also indicates that there are significant correlated variables and hence determination of the one variable can be used to interpret the other correlated variable.

Based on the similarity of water quality parameters, two significant clusters were found 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 has similarly two clusters; cluster one consists of sites two, three and five and cluster two consists of sites five and six.

Generally, the results show that the major sources of water quality deterioration emanate from the activities in the upstream of the lake. These include inflow of effluents from the floriculture industries, domestics, small and large scale agricultural practices and saline seeps in to the lake at sites one, two, three, four and five. The other causes of pollution are from people's activities in boats and islands, run off, silt, waste effluents and etc. as shown in cluster one, formed by sites six and eight.

Therefore, waste water control and treatment of the point sources are important. Commercial floriculture farms, small and large scale agricultural practices need to develop the use of pest management systems. The concerned authorities should also regularly assess the waste management of the farms and other industries around the lake.

6.2 Recommendation

The recommendations from this study focuses on two dimensions. One is on the further researches and the other is in prevention and treatment options.

Further comprehensive researches on Lake Ziway are recommended for having sufficient data about the lake. This helps to have appropriate pollution prevention and restoration techniques. The association of high quality habitat to deeper lake areas as well as wetland areas should be studied by taking more samples from respective areas. Furthermore, the indigenous vegetation types for the areas of Lake Ziway should be identified for selecting best species of vegetation or plants for buffer construction and other BMPs. Identification of organic pollutants in the lake is also recommended so as to assess the introduction of banned chemical products that threatens human, animal and aquatic lives. In addition, an environmental impact assessment of the floriculture development and other interventions should be carried out ahead of their execution.

As a prevention options, increasing vegetation cover, promoting afforestation and reforestation, decreasing overgrazing, implementing rules and regulations like water resource use and management law (No. 197/2000), pollution prevention law (No. 300/2005) and land use law (No.456/2005) are recommended. Besides, Limiting arable agriculture near vulnerable areas like Lake Ziway is a recommended option.

Promoting public awareness regarding the health and safety of agrochemicals to humans, animals and ecology should be given prior concern. The farm owners are also responsible for establishing toilets, clean drinking water and health care facilities inside their farms. Providing workers' protective wears is another responsibility vested on the farm owners.

Lake Ziway water quality could be improved using waste water treatment methods or Best Management Practices. Wastewater treatment and Recycling are important point source pollution reduction methods. Floriculture industries particularly have to recycle waste water before treatment. Constructing buffer zones are also useful at a safe distance away from the pollution sources. Vegetation buffer is specially recommended to be used in the upstream of the lake where pollutions are taught to emanate. This is one possible way to reduce the pollution impacts because there will not be discharged waste that reaches the lake. Advising ordinary farmers to plant trees and vegetation in their farm yard as a buffer zone to minimize any environmental risks from their fertilizer and pesticide usage is also crucial. Alongside, integrated pest management practices are invaluable to decrease the social and environmental impacts of chemicals. Additionally, the government is recommended to incentivize floriculture and horticulture farm owners for the use of environmental friendly agro-chemicals.

Finally, no wastewater or solid waste of floriculture industries or else should be allowed for disposal before treatment or pollution reduction at proper disposal sites. Solid wastes like chemical containers and cartoons are recommended to get into proper land fill or incinerator inside the floriculture compound.

7. References

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8. Appendices

Appendix A: tests of Normality Table

	Time	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	df	Sig.
pH	February	.148	7	.200*	.966	7	.868
	March	.193	7	.200*	.955	7	.776
	April	.200	7	.200*	.943	7	.666
EC	February	.254	7	.190	.870	7	.184
	March	.216	7	.200*	.934	7	.582
	April	.160	7	.200*	.956	7	.783
TDS	February	.422	7	.000	.557	7	.000
	March	.394	7	.002	.578	7	.000
	April	.351	7	.009	.640	7	.001
Turbidity	February	.286	7	.086	.832	7	.083
	March	.162	7	.200*	.946	7	.697
	April	.177	7	.200*	.923	7	.494
Ammoinia	February	.213	7	.200*	.956	7	.782
	March	.250	7	.200*	.786	7	.029
	April	.218	7	.200*	.894	7	.298
T.Hardness	February	.275	7	.117	.830	7	.080
	March	.243	7	.200*	.835	7	.090
	April	.156	7	.200*	.946	7	.694
Sodium	February	.243	7	.200*	.906	7	.372
	March	.231	7	.200*	.883	7	.242
	April	.184	7	.200*	.929	7	.547

Potassium	February	.245	7	.200*	.917	7	.444
	March	.295	7	.067	.829	7	.079
	April	.220	7	.200*	.931	7	.563
T.Iron	February	.290	7	.078	.895	7	.302
	March	.169	7	.200*	.935	7	.593
	April	.168	7	.200*	.942	7	.657
Manganese	February	.276	7	.115	.743	7	.011
	March	.282	7	.098	.845	7	.110
	April	.215	7	.200*	.870	7	.187
Calcium	February	.158	7	.200*	.954	7	.766
	March	.161	7	.200*	.971	7	.906
	April	.120	7	.200*	.978	7	.949
Magnesium	February	.209	7	.200*	.901	7	.338
	March	.266	7	.144*	.800	7	.041
	April	.191	7	.200	.909	7	.387
Alkalinity	February	.342	7	.013*	.780	7	.026
	March	.203	7	.200*	.843	7	.107
	April	.155	7	.200	.953	7	.759
Bicarbonate	February	.374	7	.004	.752	7	.013
	March	.183	7	.200	.907	7	.378
	April	.259	7	.170	.875	7	.207
Chloride	February	.262	7	.159*	.818	7	.061
	March	.258	7	.176*	.769	7	.020
	April	.328	7	.022*	.722	7	.006
Sulphate	February	.371	7	.004*	.689	7	.003
	March	.397	7	.001*	.699	7	.004

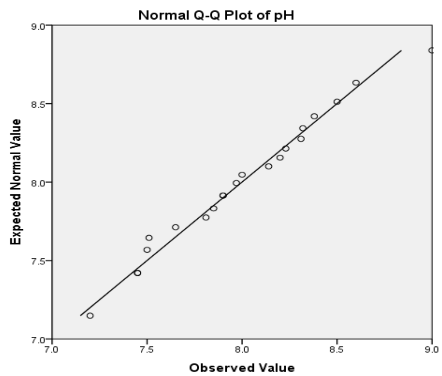
	April	.388	7	.002	.691	7	.003
Nitrate	February	.395	7	.001*	.585	7	.000
	March	.428	7	.000*	.565	7	.000
	April	.416	7	.001*	.575	7	.000
Nitrite	February	.148	7	.200*	.966	7	.871
	March	.138	7	.200*	.938	7	.619
	April	.354	7	.008*	.804	7	.044
Floride	February	.186	7	.200	.924	7	.499
	March	.207	7	.200*	.935	7	.597
	April	.193	7	.200	.971	7	.906
phosphate	February	.220	7	.200*	.882	7	.237
	March	.313	7	.037*	.785	7	.029
	April	.224	7	.200	.798	7	.039
DO	February	.232	7	.200	.899	7	.326
	March	.183	7	.200*	.963	7	.841
	April	.198	7	.200*	.898	7	.319
	February	.168	7	.200*	.981	7	.965
	March	.232	7	.200*	.921	7	.479
BOD	April	.305	7	.048*	.847	7	.115
COD	February	.149	7	.200*	.984	7	.978
	March	.180	7	.200	.969	7	.890
	April	.170	7	.200*	.937	7	.614

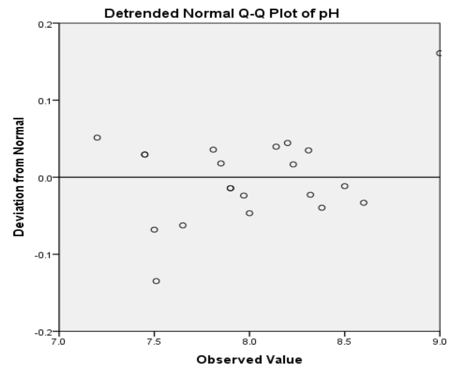
*. This is a lower bound of the true significance.

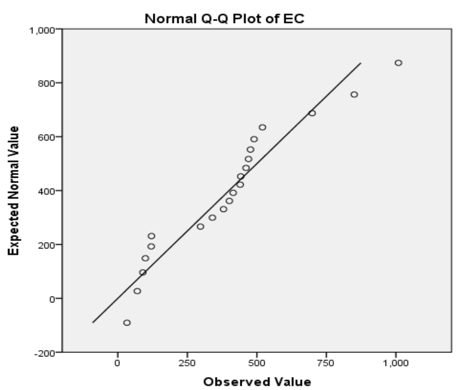
a. Lilliefors Significance Correction

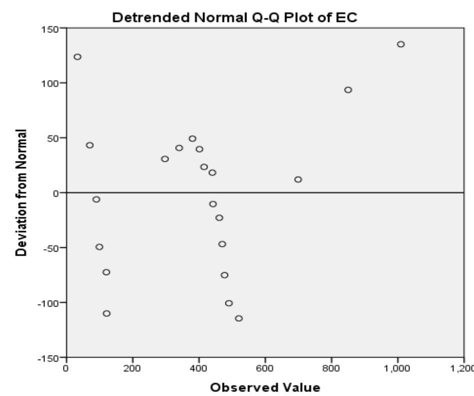
Appendix B: The Normal and Detrended Normal Q-Q Plots

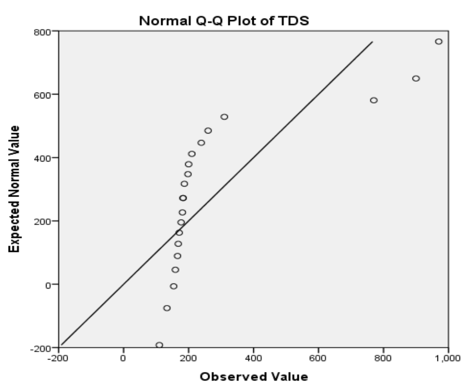
Water quality normal and detrended normal q-q plots

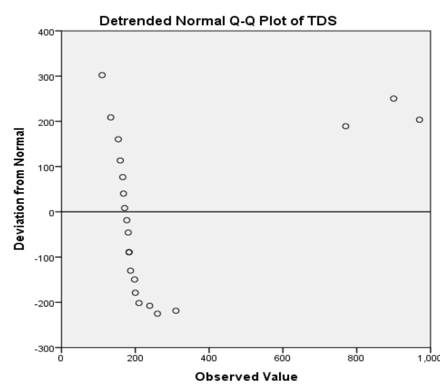


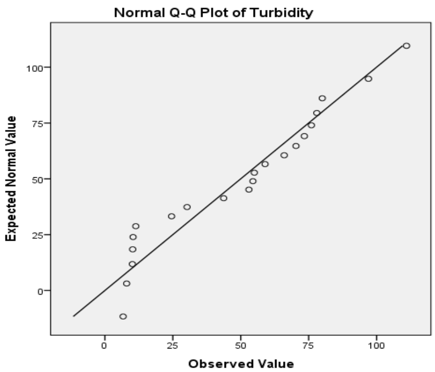


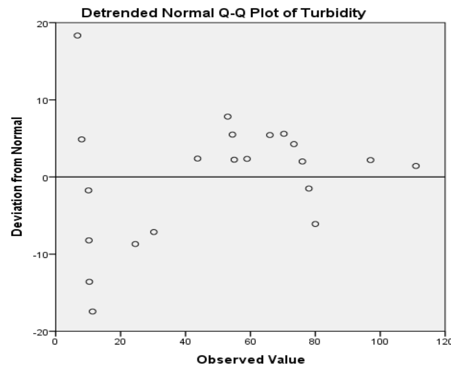


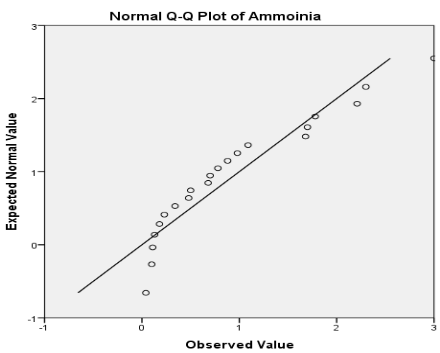


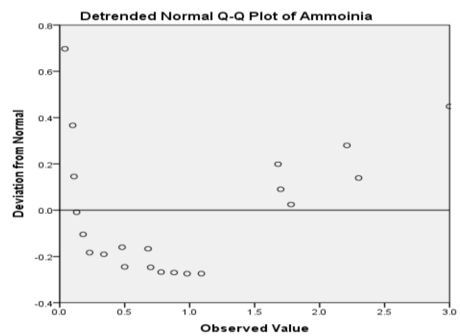


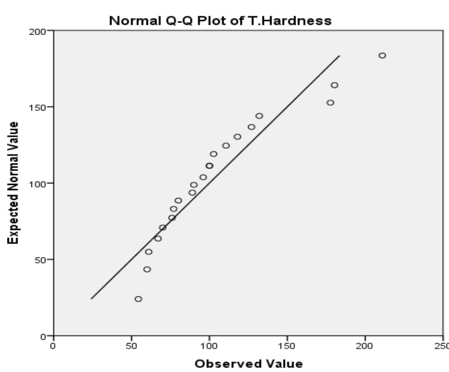


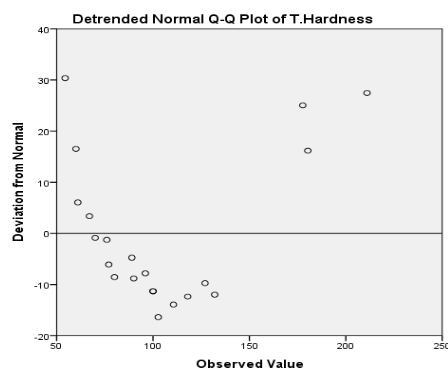

Normal Q-Q Plot of Turbidity
Expected Normal Value
Observed Value

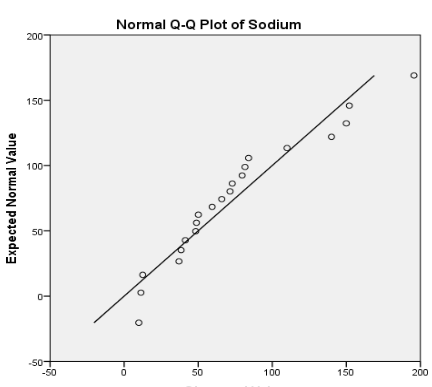

Detrended Normal Q-Q Plot of Turbidity
Deviation from Normal
Observed Value

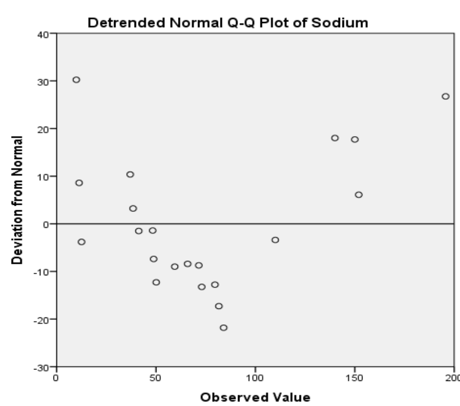

Normal Q-Q Plot of Ammoinia
Expected Normal Value
Observed Value

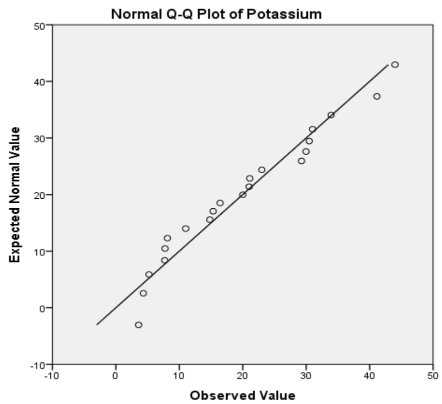

Detrended Normal Q-Q Plot of Ammoinia
Deviation from Normal
Observed Value

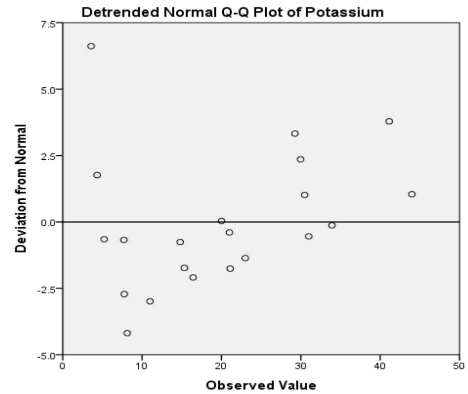

Normal Q-Q Plot of T.Hardness
Expected Normal Value
Observed Value

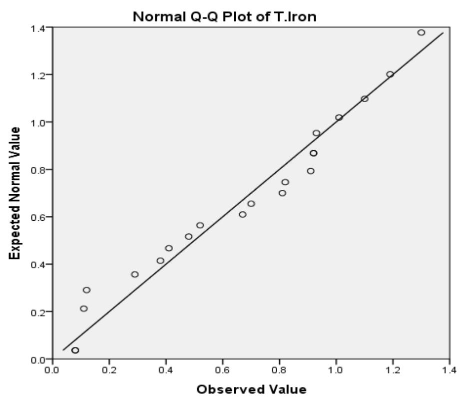

Detrended Normal Q-Q Plot of T.Hardness
Deviation from Normal
Observed Value

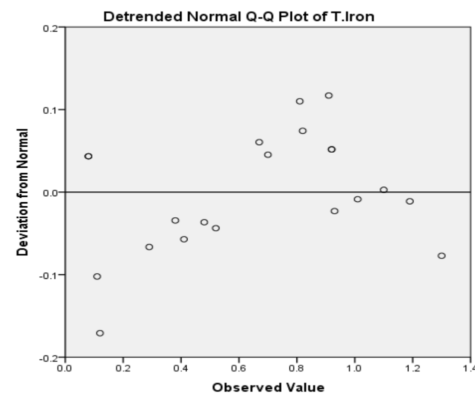

Normal Q-Q Plot of Sodium
Expected Normal Value
Observed Value

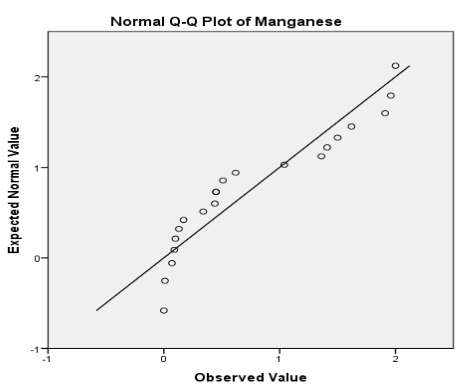

Detrended Normal Q-Q Plot of Sodium
Deviation from Normal
Observed Value

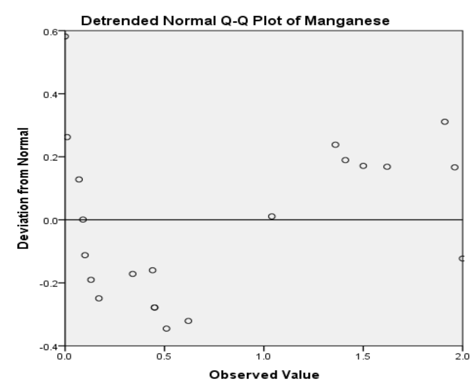

Normal Q-Q Plot of Potassium
Expected Normal Value
Observed Value

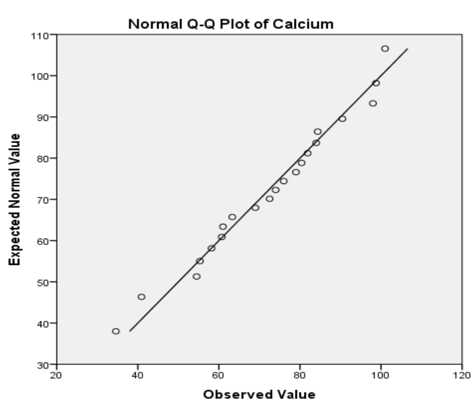

Detrended Normal Q-Q Plot of Potassium
Deviation from Normal
Observed Value

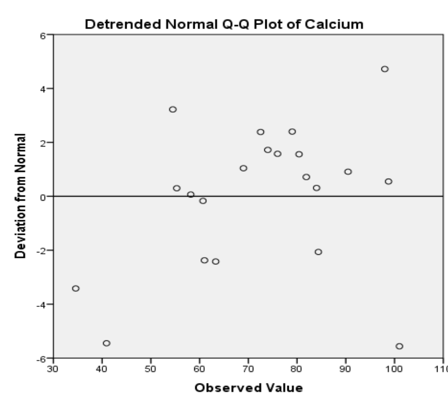

Normal Q-Q Plot of T.Iron
Expected Normal Value
Observed Value

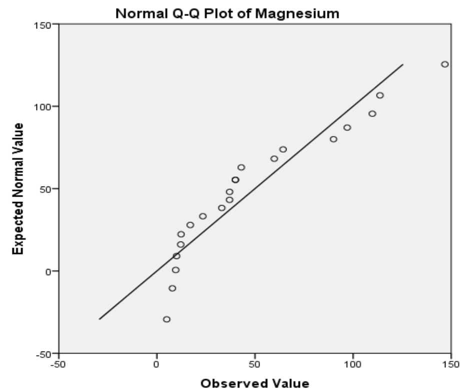

Detrended Normal Q-Q Plot of T.Iron
Deviation from Normal
Observed Value

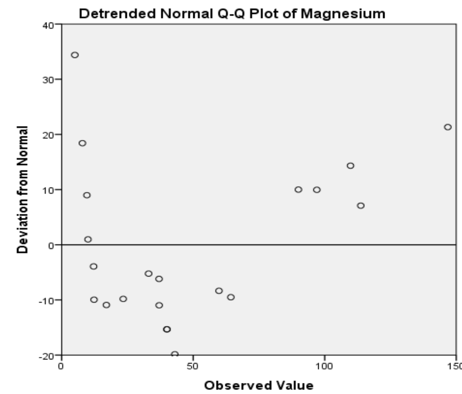

Normal Q-Q Plot of Manganese
Expected Normal Value
Observed Value

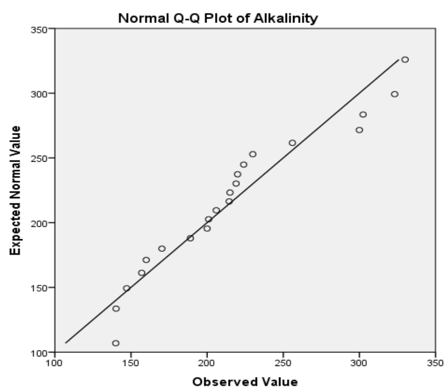

Detrended Normal Q-Q Plot of Manganese
Deviation from Normal
Observed Value

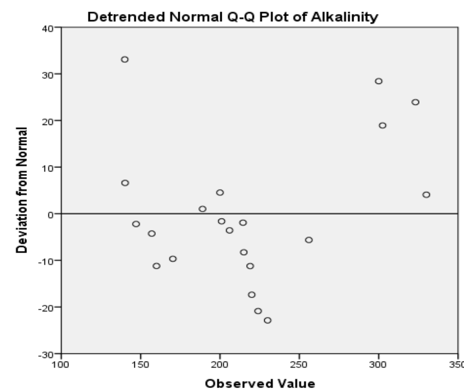

Normal Q-Q Plot of Calcium
Expected Normal Value
Observed Value

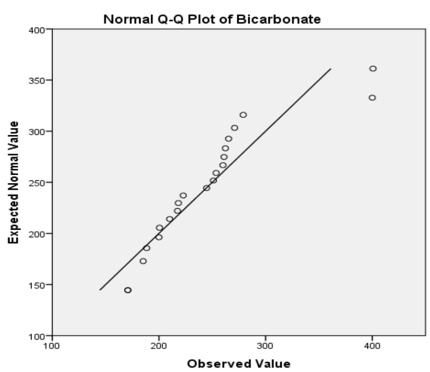

Detrended Normal Q-Q Plot of Calcium
Deviation from Normal
Observed Value

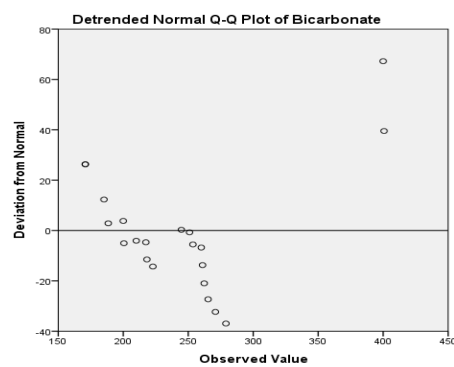

Normal Q-Q Plot of Magnesium
Expected Normal Value
Observed Value
150
100
50
0
-50
-50
0
50
100
150


Detrended Normal Q-Q Plot of Magnesium
Deviation from Normal
Observed Value
40
30
20
10
0
-10
-20
0
50
100
150


Normal Q-Q Plot of Alkalinity
Expected Normal Value
Observed Value
350
300
250
200
150
100
100
150
200
250
300
350


Detrended Normal Q-Q Plot of Alkalinity
Deviation from Normal
Observed Value
40
30
20
10
0
-10
-20
-30
100
150
200
250
300
350


Normal Q-Q Plot of Bicarbonate
Expected Normal Value
Observed Value
400
350
300
250
200
150
100
100
200
300
400


Detrended Normal Q-Q Plot of Bicarbonate
Deviation from Normal
Observed Value
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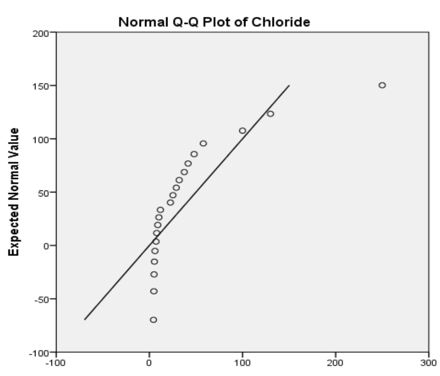
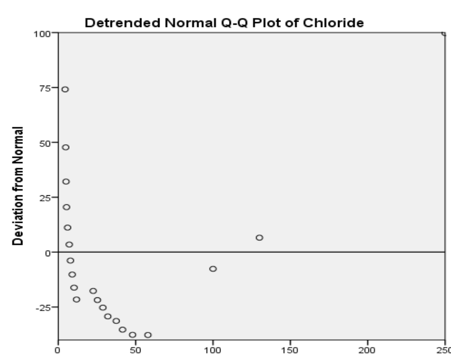
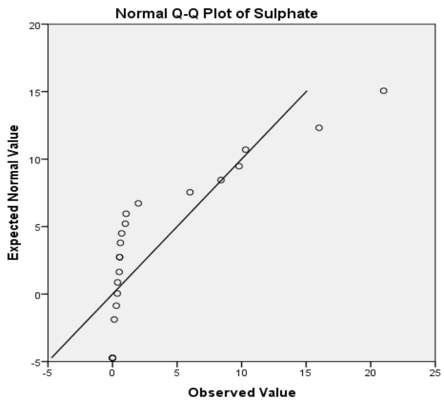
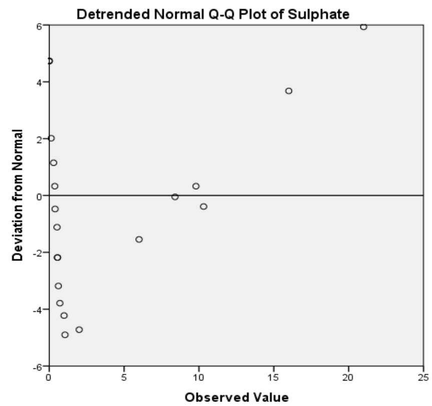
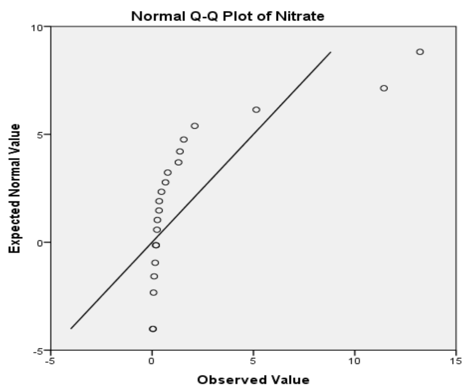
60
40
20
0
-20
-40
150
200
250
300
350
400
450

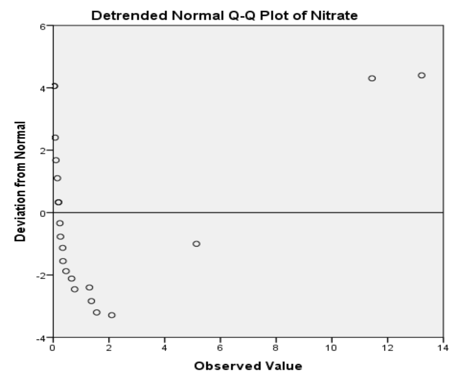

Normal Q-Q Plot of Chloride
Expected Normal Value
Observed Value
200
150
100
50
0
-50
-100
-100
0
100
200
300

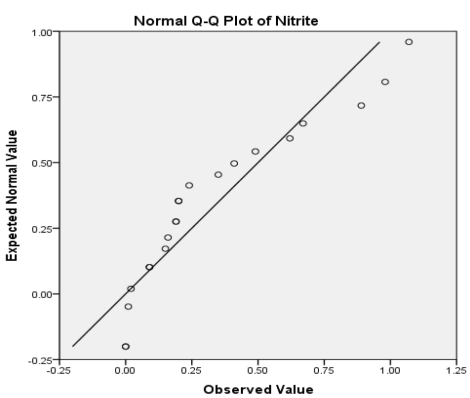

Detrended Normal Q-Q Plot of Chloride
Deviation from Normal
Observed Value
100
75
50
25
0
-25
0
50
100
150
200
250

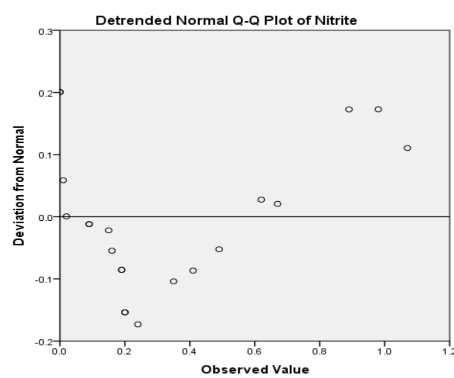

Normal Q-Q Plot of Sulphate
Expected Normal Value
Observed Value
20
15
10
5
0
-5
-5
0
5
10
15
20
25

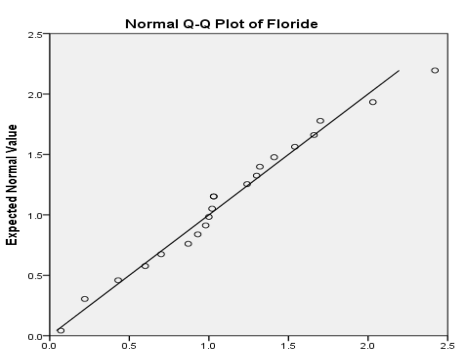

Detrended Normal Q-Q Plot of Sulphate
Deviation from Normal
Observed Value
6
4
2
0
-2
-4
-6
0
5
10
15
20
25

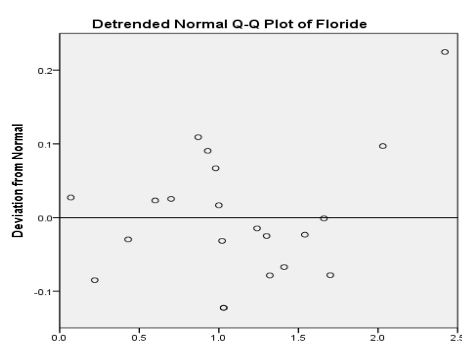

Normal Q-Q Plot of Nitrate
Expected Normal Value
Observed Value
10
5
0
-5
-5
0
5
10
15

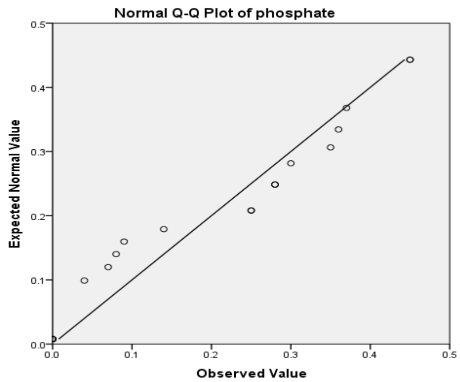

Detrended Normal Q-Q Plot of Nitrate
Deviation from Normal
Observed Value
6
4
2
0
-2
-4
0
2
4
6
8
10
12
14

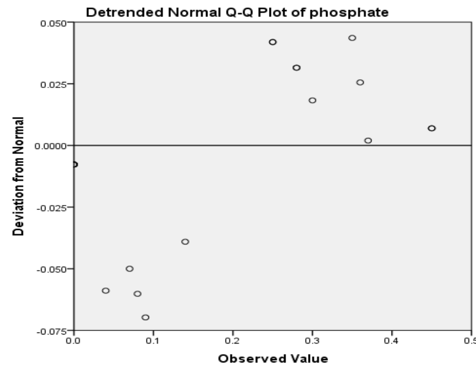

Normal Q-Q Plot of Nitrite
Expected Normal Value
Observed Value
1.00
0.75
0.50
0.25
0.00
-0.25
-0.25
0.00
0.25
0.50
0.75
1.00
1.25

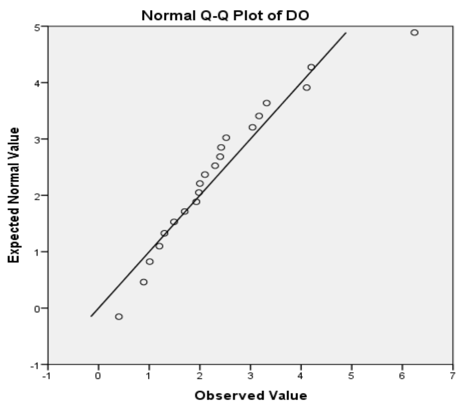

Detrended Normal Q-Q Plot of Nitrite
Deviation from Normal
Observed Value
0.3
0.2
0.1
0.0
-0.1
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2

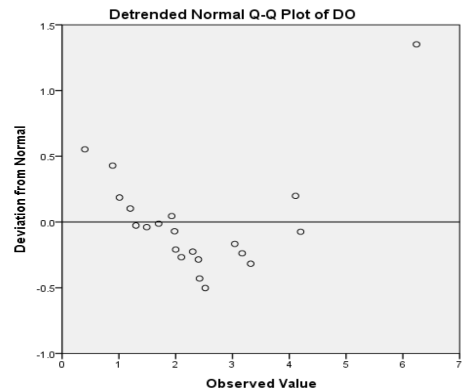

Normal Q-Q Plot of Floride
Expected Normal Value
Observed Value
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5

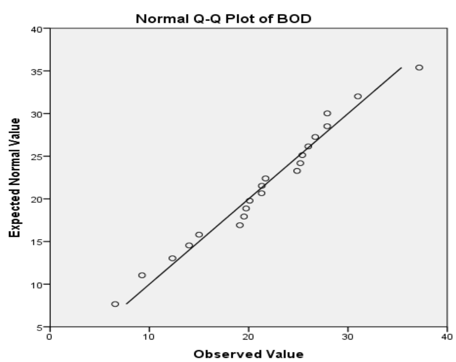

Detrended Normal Q-Q Plot of Floride
Deviation from Normal
Observed Value
0.2
0.1
0.0
-0.1
0.0
0.5
1.0
1.5
2.0
2.5

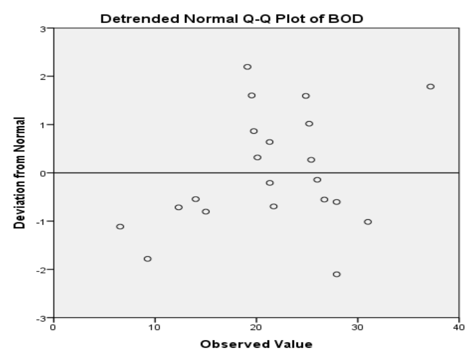

Normal Q-Q Plot of phosphate
Expected Normal Value
Observed Value

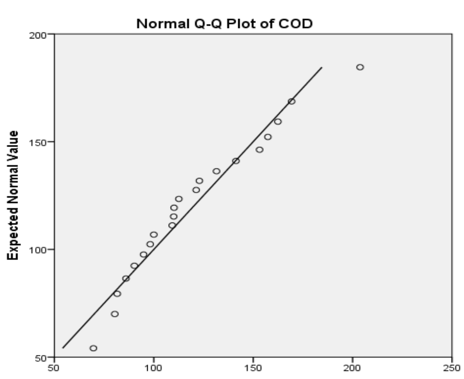

Detrended Normal Q-Q Plot of phosphate
Deviation from Normal
Observed Value

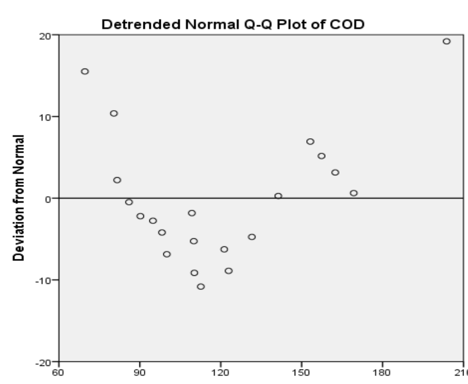

Normal Q-Q Plot of DO
Expected Normal Value
Observed Value


Detrended Normal Q-Q Plot of DO
Deviation from Normal
Observed Value

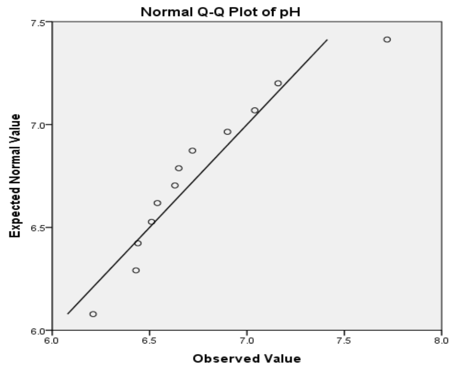

Normal Q-Q Plot of BOD
Expected Normal Value
Observed Value

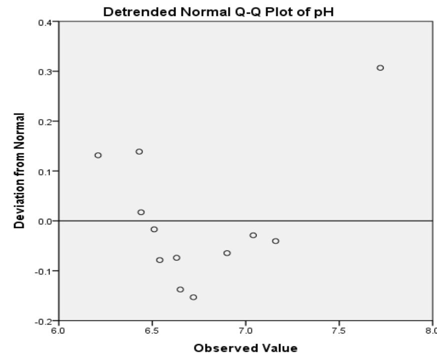

Detrended Normal Q-Q Plot of BOD
Deviation from Normal
Observed Value

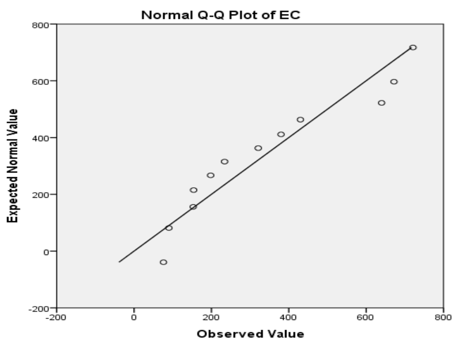

Normal Q-Q Plot of COD
Expected Normal Value
Observed Value

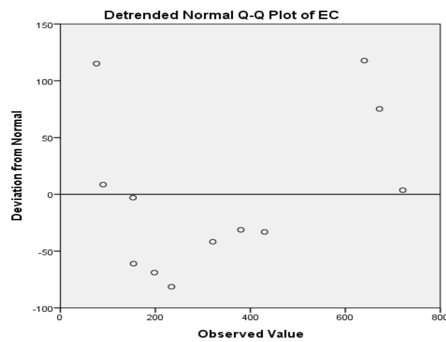

Detrended Normal Q-Q Plot of COD
Deviation from Normal
Observed Value

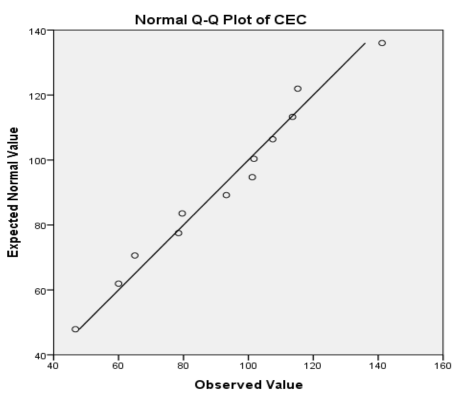
Sediment normal and detrended normal q-q plots

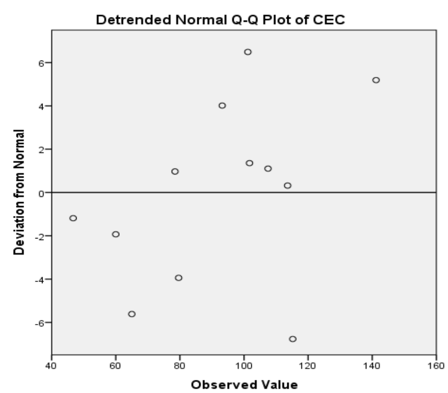


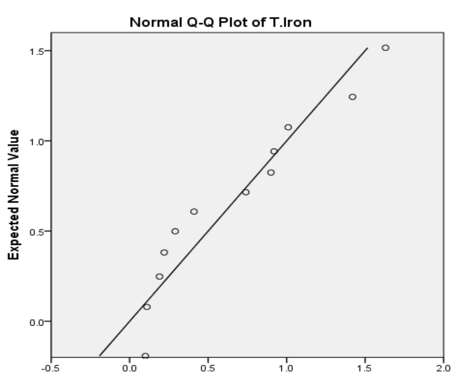


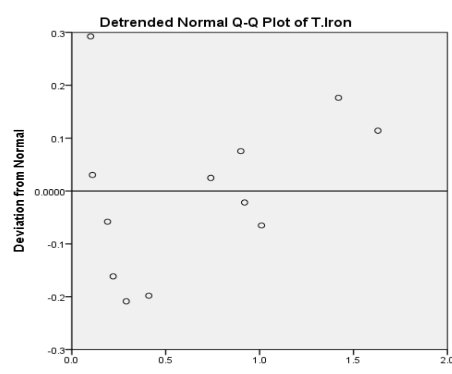


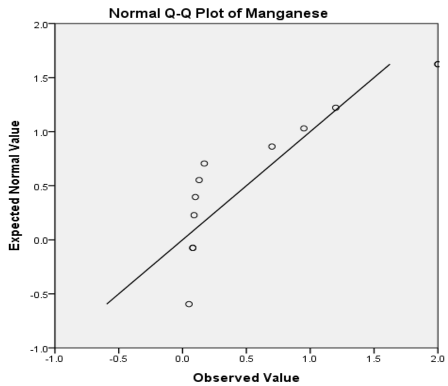


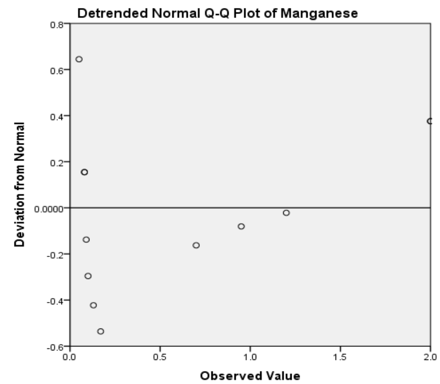


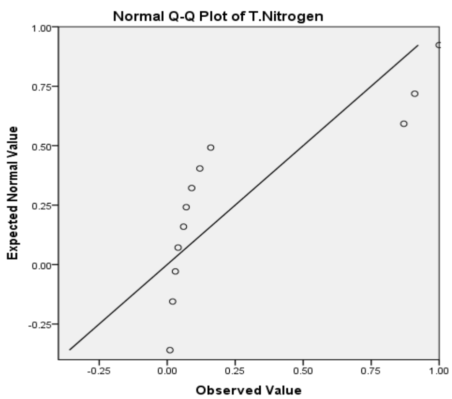


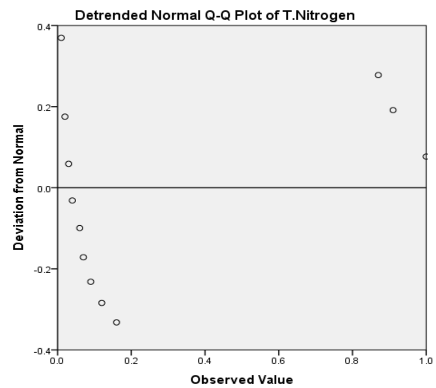


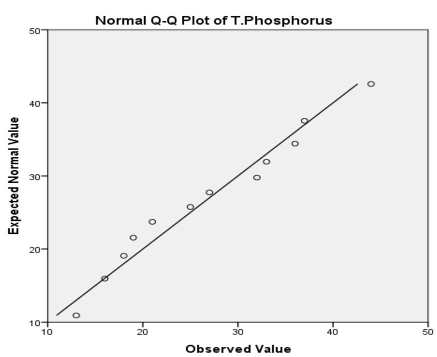


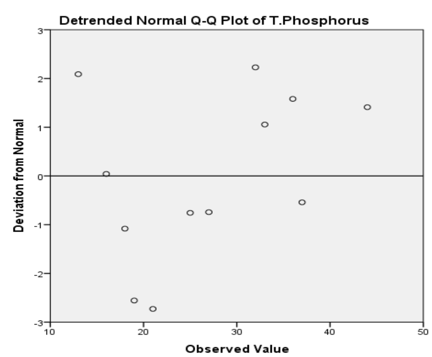

Normal Q-Q Plot of Manganese
Expected Normal Value
Observed Value


Detrended Normal Q-Q Plot of Manganese
Deviation from Normal
Observed Value


Normal Q-Q Plot of T.Nitrogen
Expected Normal Value
Observed Value


Detrended Normal Q-Q Plot of T.Nitrogen
Deviation from Normal
Observed Value


Normal Q-Q Plot of T.Phosphorus
Expected Normal Value
Observed Value


Detrended Normal Q-Q Plot of T.Phosphorus
Deviation from Normal
Observed Value

Appendix C: Questionnaire for Convenient Interviews

1. Do you know what Water pollution is?

   [] Yes [] No

2. Do you know the impacts of Water pollution in the environment, aquatic lives, and human life?

   [] Yes [] No

   If yes, explain

3. Are you aware of water pollution in Ziway area?

   [] Yes [] No

4. Where is the drinking water source of Ziway Town?
5. Are you aware that water resources in the world are finite and diminishing with the passage of time?

   [] Yes [] No

6. Are you aware of that living in a clean and healthy environment is the 'Right to Life'?

   [] Yes [] No

7. What are the reasons for water pollution in Lake Ziway rea?

   [] Agriculture [] Urbanization [] Industrial effluents [] Floriculture Farms [] others

8. Are you aware of if there are any regional or federal government awareness for the prevention and control of pollution in Lake Ziway?

   [] Yes [] No

   If yes, what measures did they take? If yes, explain

9. Have you ever made or seen any complaint to any authority against any individual/group for polluting the Lake Ziway water?

   [] Yes [] No

10. Has any individual/government officer/ NGO made any effort to prevent and control Lake Ziway's water pollution?

    [] Yes [] No

    If yes, what measures have been taken?

11. Has any individual/government officer/ NGO made any effort to make you aware about water pollution and how you could contribute to minimize the incidences?

    [] Yes [] No

    If yes, explain

Appendix D: Palintest photometer procedures

S/N	Parameter	Reagents and Equipment used	Sample amount (in ml)	Response time (in minutes)
1	Alkalinity (mg/l $CaCO_3$)	- 1 Palintest Alkaphot Tablet - Palintest Photometer (7100) - Round Test Tubes - 10 ml glass	10	1
2	Ammonia	- Palintest Ammonia No 1 - Tablets Palintest - Ammonia No 2 Tablets - Palintest Photometer (7100) - Round Test Tubes - 10 ml glass	10	10
3	Bicarbonate	Alkalinity*1.22	-	-
4	Calcium	- Palintest Calcicol No 1 Tablets - Palintest Calcicol No 2 Tablets - Palintest Photometer - Round Test Tubes - 10 ml glass	10	2
5	Carbonate			
6	Chloride	- Palintest Acidifying CD Tablets	10 (9 ml deionized water and 1ml)	2

		- Palintest Chloridol Tablets - Palintest Photometer - Round Test Tubes - 10 ml glass - Measuring Syringe, 1 ml - Sample Container, 100/50/10 ml plastic		
7	Floride	- Palintest Fluoride No 1 Tablets - Palintest Fluoride No 2 Tablets - Palintest Photometer (7100) - Round Test Tubes - 10 ml glass	10	5
8	Magnesium	- Palintest Magnecol Tablets - Palintest Photometer (7100) - Round Test Tubes - 10 ml glass - Measuring Syringe, 1 ml	10 (9 ml deionized water and 1ml sample water under test)	5
9	Manganese	- Palintest Manganese No 1 Tablets - Palintest Manganese No 2 Tablets - Palintest Photometer (7100)	10	20

		- Round Test Tubes - 10 ml glass		
10	Nitrate	- Palintest Nitratest Powder (Spoon Pack) - Palintest Nitratest Tablets - Palintest Nitricol Tablets - Palintest Nitratest Tube, 20 ml - Palintest Photometer - Round Test Tubes - 10 ml glass	10	10
11	Nitrite	- Palintest Nitricol Tablets - Palintest Photometer - Round Test Tubes - 10 ml glass	10	10
12	Phosphate	- Palintest Phosphate HR Tablets - Palintest Phosphate SR Tablets - Palintest Photometer - Round Test Tubes - 10 ml glass	10	10
13	potassium	- Palintest Potassium K Tablets - Palintest Photometer - Round Test Tubes - 10 ml glass	10	5

14	Sodium	- Palintest Potassium Na Tablets - Palintest Photometer - Round Test Tubes - 10 ml glass	10	10
15	Sulphate	- Palintest Sulphate Turb Tablets - Palintest Photometer - Round Test Tubes - 10 ml glass	10	5
16	Total hardness	- Palintest Hardicol No 1 Tablets - Palintest Hardicol No 2 Tablets - Palintest Photometer (7100) - Round Test Tubes - 10 ml glass	10	2
17	Total iron	- Palintest Iron HR Tablets - Palintest Photometer - Round Test Tubes - 10 ml glass	10	10

Appendix E: Chain of Custody (Form) and measurement units

Water Quality testing Parameters

S/N	Water Quality testing Parameters	Units of Measurement
1.	pH	pH
2.	EC	
3.	Total dissolved solids	mg/l
4.	Turbidity	NTU
5.	Ammonia	mg/l

6.	Total hardness	mg/l $CaCO_3$
7.	Sodium	mg/l
8.	Potassium	mg/l
9.	Total Iron	mg/l
10.	Manganese	mg/l
11.	Calcium	mg/l
12.	Magnesium	mg/l
13.	Alkalinity	mg/l
14.	Carbonate	mmol/L
15.	Bicarbonate	mmol/L
16.	Chloride	mg/l
17.	Sulphate	mg/l
18.	Nitrate	mg/l
19.	Nitrite	mg/l
20.	Fluoride	mg/l
21.	Phosphate	mg/l
22.	Dissolved oxygen	mg/l O_2
23.	Biochemical oxygen demand	mg/l O_2
24.	Chemical oxygen demand	mg/l O_2
	Sediment/sludge quality testing parameters	**Units of Measurement**
25.	pH	pH
26.	Electrical Conductivity	µs/cm
27.	Cationic exchange capacity	cmol/kg
28.	Total Nitrogen	mg/l
29.	Total Phophorus	mg/l
30.	Total Iron	mg/l
31.	Manganese	mg/l