**Jimma University**

**School of Graduate Studies**

**College of Natural Sciences**

**Department of Biology**

# Physico-chemical and Biological Water Quality of Fincha, Tamsa'a and Dogaja Rivers in Didessa headwaters (Blue Nile sub-catchment) South West Ethiopia

**By: Melkamu Muluneh**

**Advisers: MulugetaWakjira (PhD), Seid Tiku (PhD) and Tokuma Negisho (MSc)**

**A Thesis Submitted to the Department of Biology, College of Natural Sciences, Jimma University, in Partial Fulfilment of the Requirement for Degree of Master of Science in Biology (Ecology and Systematic Zoology)**

**June, 2019**

**Jimma, Ethiopia**

**Jimma University**

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The thesis“Physico-chemical and Biological Water Quality of Fincha, Tamsa’a and Dogaja Rivers in Didessa headwaters (Blue Nile sub-catchment) South West Ethiopia” has been approved by the Biology Department” for the partial fulfillment of the Degree of Master of Science in Biology (Ecology and Systematic Zoology)

Approved by the examining board

1. Chairperson, examination board

Name________________________ Signature ______________ Date__________

2. Advisor

Name________________________ Signature______________ Date__________

3. External Examiner

Name________________________ Signature______________ Date__________

4. Internal Examiner

Name________________________ Signature______________ Date__________

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## Acknowledgement

First I would like to express my deepest gratitude to my advisors Dr. MulugetaWakjira, Dr. SediTiku and Mr. Tokuma Negisho for their invaluable advice, comments and suggestion from the beginning to the completion of my thesis work. Finally, I would also like to extend my thanks to Ato Namara Kebede, Ato Magarsa Abera and Ato Siyoum Derib who shared me his prior experience in thesis writing.

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## Acronyms and Abbreviations

| | |
|---|---|
| ADB | Asian Development Bank |
| APHA | American Public Health Association |
| BOD | Biological Oxygen Demand |
| CSA | Central Statistics Agency |
| DO | Dissolved Oxygen |
| DR | Dogaja River |
| DTR | Dogaja Tributary River |
| FR | Fincha'a River |
| JTU | Jackson Turbidity Unit |
| MDG | Millennium Development Goal |
| $mg^{-l}$ | milligram per litter |
| MI | Macroinvertebrate |
| $NH^{-}_{4}$ | Ammonium ion |
| $NH_3$ | Ammonia |
| $NO_2^-$ | Nitrite |
| $NO_3^-$ | Nitrate |
| NTU | Nephelometric Turbidity Unit |
| PAST | Paleontological Statistics |
| pH | Power of hydrogen |

| | |
|---|---|
| $T^0$ | Temperature |
| TR | Tamsa’a River |
| TTR | Tamsa’a Tributary River |
| TSS | Total Suspended Solids |
| UN | United Nation |
| UNEP | United Nation Environmental Program |
| UNICEF | United Nations‟ International Children’s Emergency Fund |
| US EPA | United States Environmental Protection Agency |
| WASH | Water Sanitation and Hygiene |
| WHO | World Health Organization |

## Abstract

All living organisms on the earth need water for their survival and growth. Nowadays, due to anthropogenic and natural activities rivers were highly polluted with different harmful contaminants. Physico-chemical and biological water quality of Fincha, Tamsa'a and Dogaja Rivers, located in the head water of Didessa basin (Blue Nile sub-catchment) have been assessed in one wet and one dry season between October 2018-March 2019.Water pH, EC, water T and (DO) were measured in-situ using a multiprobe meter while water samples were analyzed for $BOD_5$, TSS, NO3, NH3 and PO4 in the laboratory following standard procedures. Macroinvertebrates samples were collected using kick net, preserved in 75% alcohol and identified in laboratory following standard keys. The chemical and ecological water quality was assessed at18 sampling locations using the ASPT-ETHbios, which is based on macroinvertebrate. All Significant variations in the median values of physico-chemical parameters and nutrients among the three river groups were tested using Kruskal-Wallis followed by Mann-Whitney pair wise post-hoc tests due to lack of homoscedasticity and normality of the data. Normality and homoscedasticity of the data were tested using Shapiro-Wilk and Leven statistics respectively. Benferroni p values corrected for multiple testing were used to evaluate significance of pair wise comparisons for the Mann-Whitney post-hoc tests. Spearman's correlation coefficient was used to test the possible correlations among the measured parameters. Statistical analyses were run in PAST version 3.08 and SPSS version 16.Accordinglymedian water T of the rivers varied from 19.45 $^{o}$C -24.65 °C, average DO varied from 6.60 mg/L-7.18 mg/L, average EC varied from 56.35 µS/cm-89.69 µS/cm, pH values varied from 7.56-8.37, TSS values for the rivers varied from 0.006 mg/L-0.009 mg/L and BOD5 values varied from 1.55 mg/L-2.06 mg/L. Whereas the median values of $NH_3$, $NO_3^-$ and $PO_4^{3-}$ varied from 0.08 mg/L-0.12 mg/L, 3.25 mg/L- 4.20 mg/L and 0.78 mg/L-0.93 mg/L respectively. Tamsa'a and Dogaja Rivers are relatively more polluted than Fincha River due to urbanization and disposal of wastes by the nearby communities. The community, concerned administrative and/or non governmental bodies should support by fund and by preparing suitable waste disposal areas.

**Keywords;** Dogaja, Fincha, Tamsa'a, Macroinvertebrates, Physicochemical parameters, water quality

# 1. Background

## 1.1. Introduction

Rivers are the most important freshwater resource for living organisms. Social, economic and political development has, in the past, been largely related to the availability and distribution of fresh water contained in riverine systems. Major river water uses are: sources of drinking water supply, irrigation of agricultural lands, industrial and municipal water supplies, industrial and municipal waste disposal, navigation, fishing, boating and body-contact recreation, aesthetic value (Meybeck, and Helmer, 1989). On the other hand, rivers are ecosystem of great ecological value with a rich fauna that consists of communities with a complex structure and high biological value. Unlike many other raw materials there is no substitute for water in many of its uses. The health and wellbeing of a population is directly affected by the coverage of water supply and sanitation. In general, water is the most important natural resource in the world, since life cannot exist and industry cannot operate without water. However, their special typology makes them fragile and vulnerable to environmental changes, especially those related to disturbances of anthropogenic origin, which often imply irreversible degradation of their biota (Dahl *et al*., 2004).

Currently, river water pollution has received much attention globally. Both, natural process anthropogenic activities, like hydrological features, climate change, precipitation, agricultural activities ,and wastewater discharge from industries, are the main reason for worsening of surface water quality (Ravichandran, 2003; Gantidis *et al*., 2007; Arain *et al*.,2008). Contaminated water can cause direct danger to health, so the purity and contamination of water is one of the major problems throughout the world. In order to determine whether given water is suitable or not, the job of water quality assessment is crucial based up on a set of parameters proposed by WHO or other concerned bodies. Water quality monitoring provided the practical and methodological details whereas water quality assessments give the overall strategy for assessment of the quality of the main types of water body (Chapman, 1996).

Surface water mainly rivers has different purposes in various sectors like agriculture, industry, transportation, and domestic water supply. Nonetheless, rivers have also been used for cleaning and dumping purposes. This practices more prominent in developing countries, mostly in Africa. There are numerous sources of pollutants that could deteriorate the quality of water resources (Alemayehu, 2008). On the other hand, surface water bodies become the dumping source for industrial effluent and domestic wastes. As a result, the naturally existing dynamic equilibrium among the environmental segments get affected leading to the state of polluted rivers. According to World Health Organization's (WHO) decision, water for the consumers should be free from pathogenic organisms and toxic substance. Rivers are among the main vulnerable aquatic environment to pollution because of far flow to take municipal, industrial wastes and agrochemicals through runoff (Singh *et al*., 2005). Waste water from industries, domestic sewage, and agricultural farms is discharged into rivers which lead to deteriorate surface water quality (Ravindra *et al.*, 2003).

Ethiopia is naturally endowed with abundant water resources that help to fulfill domestic requirements, irrigation and hydropower. With its current per-capita fresh water resources estimated at 1924 $m^3$, the country is one of the sub-Saharan African countries endowed with the largest surface fresh water resource. However, only 2 % of the potential is annually utilized. However, the increasing of human population, uncontrolled urbanization and inadequate sanitation infrastructure cause serious quality degradation of surface waters (Ravindra *et al.*, 2003). Now a day's water pollution from disposal of industrial waste water is becoming an environmental concern in town and its vicinity areas, where most of large and medium scale manufacturing industries are located (Arimoro and Ikomi, 2008). As a result, many rivers and streams are heavily polluted as they flow through major cities and towns (Arimoro, 2009). Pollutants can enter surface water from point sources such as single source industrial discharges and waste water treatment plants. However, most pollutants result from non-point source pollution activities including runoff from agricultural lands, urban areas, construction and industrial sites, and failed septic tanks (Osibanjo and Adie, 2007).

There are different rivers are found in south west Ethiopia. Among these rivers, Fincha, Tamsa'a and Dogaja are some examples. Fincha is found in the rural area of Chora district while Tamsa'a and Dogaja Rivers are found in Agaro town, South-west Ethiopia. Along these rivers various socio-economic activities are carried out by communities who are discharging their wastes to the river and the river receives different effluents/pollutants from different sources such as agricultural chemicals, garages, domestic wastes (from individual homes, hotels, hospital, cafes), wastes from market places such as manure of the animals (cattle) and their urines. Due to these and other similar factors these rivers are receiving such huge pollutants and pollution problems that can harm communities who are directly or indirectly dependent on these rivers for drinking, irrigation and other purposes. Therefore, the study was in conducted aiming at assessing the suitability of these rivers for drinking purpose based on he physicochemical and biological water quality parameters and give recommendation by comparing both the quantitatively and qualitatively analyzed parameters with WHO and draft Ethiopian drinking water quality standards.

## 1. 2. Statement of the Problem

The main water pollution causes in Fincha, Tamsa'a and Dogaja Rivers are, sewages, domestic wastes, municipals and rural and agricultural activities. The effect of open defecation is that fecal material would be washed into water sources during rainstorms, or transferred to the water source by wind, people or animals. Animals grazing in water catchment areas are also a cause of fecal and parasitic larvae being carried into the water source. These may cause pollution of rivers or any water bodies around these activities. Dogaja and Tamsa'a Rivers are among the rivers found in towns of Ethiopia which faces such huge pollution problems. Along these rivers various socio-economic activities are carried out by communities whom are discharging their wastes to the river and the rivers receives different pollutants from different sources such as garages, domestic wastes (from shops, houses, hotels, schools), wastes from municipality areas, effluents from market places such as manure of the animals (cattle) and their urines, cafes, hospital and restaurants in the town and many other places. But Fincha River is one the river found in the rural area. It is affected by agricultural fertilizers, pesticides, detergents used during washing, animal manure and urine from grazing field and other natural activities like flooding. Due to this and other similar factors Tamsa'a, Dogaja and Fincha Rivers facing/accepting such huge pollutants and pollution problems that can harm communities who are directly or indirectly dependent on this river for drinking, irrigation purposes and other purposes. Therefore, the study was conducted in assessing the suitability of Tamsa'a, Dogaja and Fincha Rivers for drinking purpose based on the physicochemical and macroinvertebrate parameters.

## 1.3. Objectives of the Study

### 1.3.1. General Objective

- The study aimed at assessing the physicochemical and biological water quality of Fincha, Tamsa'a and Dogaja Rivers in Didessa headwaters, southwest Ethiopia.

### 1.3.2. Specific Objectives

- To determine level of some selected physico-chemical parameters of Fincha, Dogaja and Tamsa'a Rivers.
- To identify and quantify the macroinvertebrate assemblage of Fincha, Dogaja and Tamsa'a Rivers.
- To assess the associated physical habitat characteristics of Fincha, Dogaja and Tamsa'a Rivers at the study sites.

## 1.4. Significance of the Study

Fincha, Tamsa'a and Dogaja Rivers play very important roles. They are used for human consumption, sanitation, agriculture, small industries and drinking. But through natural and human activities, these rivers are affected by different wastes and contaminants. Pollutants from different sources such as hotels, hospital, small industries, and agricultural fertilizers were likely to contaminate the rivers. Therefore, the finding of this study will provide information on the water quality status of these three rivers. The data can be used for the necessary management recommendation and decision as well as a baseline data for future appraisal of changes in the water quality status of these rivers in response to natural and anthropogenic activities.

# 2. Literature Review

## 2.1. Physico-chemical and Biological Water Quality

The health of any community fully depends on the accessibility of adequate and safe water. Hence, water is predominantly essential for life, health and for human self-respect. Therefore, in addition to community health benefits, all people have the right to safe and adequate water retrieved in equitable manner for drinking, cooking, personal, and domestic hygiene. In this case, both adequacy and safety of drinking water are equally important to reduce the incidence of water-related and water borne health problems especially diseases like diarrheal (Olijira, 2015). About 1.8 billion people around the world do not have access to save water and 2.4 billion lack accesses to adequate sanitation. Women and children spend more than 4 hours walking for water each day and more than 840,000 people die each year from water-related diseases.

WHO (1984) estimated that 80% of all sicknesses in the world arise due to poor water and sanitation and reported that greater than 3 million people, mostly children, die every year from water related diseases. In addition 1.1 billion people lack access to improved water source and 2.4 billion people lack access to basic sanitation. Only 61% of people in developing countries are estimated to have access to water supply and 36% to sanitation facilities (WHO 1998, world health report).

Ethiopia is a country having great geographic diversity. The topography varies and ranges from high peaks of 4,550m above sea level to a low depression of 110m below sea level. The predominant climate type is tropical monsoon, with temperate climate on the plateau and hot in low land areas. Usually highlands receive more and relatively stable rain fall than the lowlands. Ethiopia has great potential of both surface and ground water resources and result into giving a name to the country as the water tower of east Africa (Said, 1993). The main source of water in the country is rainfall that results into having many trans-boundary rivers, which have different water volume in different seasons. This is factually true when one considers part of the country, particularly western, south western parts and the high land areas (Seleshi, 2007).

Up to this time, Ethiopia does not fully provide access to clean water for the society in both the rural and urban areas. The country does not reach to the optimum level of providing the access to clean water especially in the rural areas. Urban areas have relatively better access as compared to the rural part of the country. Expanding the accessibility of quality water is one of the targets of the Millennium Development Goal (MDG) in which Ethiopia is trying to fulfill. This resulted in prioritizing accessibility to improved water supply. It has been said that the chances of achieving the MDG of halving the proportion of people without access to safe water by 2015 will be seriously questioned unless levels of sustainability can be greatly improved. Unsafe industrial waste disposal causes surface water contamination in many developing countries. This is particularly true for the peri-urban shanty towns and the rural hinterland villages downstream of cities that are reliant on rivers passing through an industrialized area (Haysom, 2006).

Large percentage of waste products discharged directly into water sources without treatment especially in developing countries where sewage treatment is currently low. Only a few countries have primary treatment facilities to remove about 40-50% of the organic load (BOD) and very few use any secondary treatment process to remove more than 80% of the BOD. Many urban centers and large towns have no treatment facilities at all or ones that are antiquated or poorly maintained. Negligent discharge of raw sewage into water bodies is a common practice in developing countries; it is still practiced in a number of European countries which have power of polluting large rivers and the sea (Hoy and Belisle, 1984). In Ethiopia over 60% of the communicable diseases are related to poor environmental health conditions arising from unsafe and inadequate water supply and poor hygienic and sanitation practice. About 80% of the rural and 20% of the urban population have no access to safe water. About three fourth of the health problems of children in the country are communicable diseases arising from poor water supply and sanitation. About 46% of mortality in children of less than five years is due to diarrhea mainly related to unsafe drinking water.

This research was done to investigate and compare microbial quality of both treated and untreated water samples, which are used by most of the households as a source of water for different activities including drinking. Drinking water sources are under increasing threat from contamination, which holds widespread consequences for the health, and the economic and social development of various countries. Governments in the developing nations, as well as donor nations and organizations, should strengthen efforts to provide adequate water services for their citizens. Water policies must be redefined and be strictly implemented, and water programs should be better integrated into a country's cultures and values than they have been in the past. Water programs are not required to be large scale and financially intensive and can be simple and financially viable. Unsafe water, lack of sanitation facilities and poor hygiene are the leading causes of mortality and morbidity in developing countries because contaminated water carries various diseases such as cholera, intestinal worms, and diarrhea. It is estimated that up to half of all hospital beds in the world are occupied by victims of water contamination. Furthermore, dirty water (standing in puddles or stored) provides a perfect breeding ground for mosquitoes that go on to spread diseases such as malaria and encephalitis. Human excreta and the lack of adequate personal and domestic hygiene have been implicated in the transmission of many infectious diseases including cholera, typhoid, hepatitis, polio, cryptosporidiosis, ascariasis, and schistosomiasis. The World Health Organization (WHO) estimates that 2.2 million people die annually from diarrhoeal diseases and that 10% of the population of the developing world are severely infected with intestinal worms related to improper waste and excreta management. Achieving the sustainable development goal of universal access to water, sanitation and hygiene services (WASH) by2030 is an incredible feat, one that requires a collective understanding of the problem and its solution (Murray and Lopez, 1996).

The reason behind the absence of adequate water treatment facilities and regulations in developing countries is the lack of finances available for funding infrastructure that can regulate water pollution. This in turn reduces the amount of clean water available for human consumption, sanitation, agriculture and industrial purposes, in addition to various other ecosystem services. A decrease in the amount water available for use holds devastating environmental, health, and economic consequences that disrupt a country's social and economic growth. A possible contamination source that carries threats to drinking water quality are open field defecation, animal wastes, plants, economic activities (agricultural, industrial and businesses) and even wastes from residential areas as well as flooding situation of the area. Any water sources, especially older water supply systems, hand dug wells; pumped or gravity-fed systems (including treatment plants, reservoirs, pressure break tank, pipe networks, and delivery points) are vulnerable to such contamination. Particularly systems with casings or caps that are not watertight are most vulnerable. This is particularly true if the water sources are located close to surface runoff that might be able to enter the source. Additional way by which pollution reaches and enters a water supply system is through overflow or infiltration by floodwaters and inundation of waters commonly contain high levels of contaminants (Haylamichael *et al*., 2012). For as long as humans have lived near waterways they have also used them to wash away their wastes and pollute water bodies United Nation Environmental Program (UNEP, 2003). When water becomes polluted, it loses its value economically and aesthetically, and can become a threat to human's health, the survival of aquatic organisms and wildlife that depend on it (Deneke, 2006).

### 2.1.1. Physico-Chemical Parameters and Water Quality

Water quality guidelines provide basic scientific information about water quality parameters and ecologically relevant toxicological threshold values to protect specific water uses. Important physical and chemical parameters influencing the aquatic environment. These parameters are the limiting factors for the survival of aquatic organisms (flora and fauna). Water contains different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Some physical test should be performed for testing of its physical appearance such as temperature, pH, total suspended solids (TSS), conductivity, etc, while chemical tests should be perform for its biochemical oxygen demand (BOD), dissolved oxygen (DO), total suspended solids (TSS), nutrients and other characters(Bartram and Ballance, 1996).

#### 2.1.1.1. Dissolved Oxygen

Oxygen is essential to all forms of aquatic life, including those organisms responsible for the self-purification processes in natural water. The oxygen content of natural water varies with temperature, salinity, turbulence, the photosynthetic activity of algae and plants, and atmospheric pressure. The solubility of oxygen decreases as temperature and salinity increase. In freshwater dissolved oxygen (DO) at sea level ranges from 15 mg $L^{-1}$ at 0 °C to 8 mg $L^{-1}$ at 25 °C. Concentrations in unpolluted waters are usually close to, but less than, 10 mg $l^{-1.}$ Dissolved oxygen can also be expressed in terms of percentage saturation, and levels less than 80 percent saturation in drinking water can usually be detected by consumers as a result of poor odor and taste. Variations in DO can occur seasonally, or even over 24 hour periods, in relation to temperature and biological activity (i.e. photosynthesis and respiration). Biological respiration, including that related to decomposition processes, reduces DO concentrations. In still water, pockets of high and low concentrations of dissolved oxygen can occur depending on the rates of biological processes. Waste discharges high in organic matter and nutrients can lead to decreases in DO concentrations as a result of the increased microbial activity (respiration) occurring during the degradation of the organic matter. In severe cases of reduced oxygen concentrations (whether natural or man-made), anaerobic conditions can occur (i.e. 0 mg $L^{-1}$ of oxygen), particularly close to the sediment-water interface as a result of decaying, sedimenting material (Bartram and Ballance, 1996).

Determination of DO concentration is a fundamental part of a water quality assessment since oxygen is involved in, or influences, nearly all chemical and biological processes within water bodies. Concentrations below 5 mg $L^{-1}$ may adversely affect the functioning and survival of biological communities and below 2 mg $L^{-1}$ may lead to the death of most fish. The measurement of DO can be used to indicate the degree of pollution by organic matter, the destruction of organic substances and the level of self-purification of the water. Its determination is also used in the measurement of biochemical oxygen demand (BOD). Dissolved oxygen is of much more limited use as an indicator of pollution in groundwater, and is not useful for evaluating the use of groundwater for normal purposes. In addition, the determination of DO in groundwater requires special equipment and it has not, therefore, been widely carried out. Nevertheless, measurement of DO is critical to the scientific understanding of the potential for chemical and biochemical processes in groundwater. Water that enters groundwater systems as recharge can be expected to contain oxygen at concentrations similar to those of surface water in contact with the atmosphere. Organic matter or oxidizable minerals present in some aquifers rapidly deplete the dissolved oxygen. Therefore, in aquifers where organic materials are less plentiful, groundwater containing measurable concentrations of DO (2–5 mg $L^{-1}$) can be found (Bartram and Ballance, 1996).

#### 2.1.1.2. Water Temperature

Water temperature influences the rate of physiological processes of organisms, such as the microbial respiration which is responsible for much of the self-purification that occurs in water bodies. Higher temperatures support faster growth rates and enable some biota to attain significant populations. Under natural conditions the temperature of running water varies between 0°C and 30°C. Higher temperatures ( > 40 °C) usually only occur in volcanic waters and hot springs. In running water, the temperature normally increases gradually from the source of the river to its mouth. Cooling waters discharged to rivers, e.g. from industrial activities or from power generation, can lead to higher than normal water temperatures. These increased temperatures cause problems for sensitive organisms due to the increased oxygen demand (lowering oxygen saturation) and increased level of toxicity of harmful substances. They are sometimes also responsible for fish kills (Bartram and Ballance, 1996).

#### 2.1.1.3. pH

The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment. When measuring the effects of an effluent discharge, it can be used to help determine the extent of the effluent plume in the water body. The pH is a measure of the acid balance of a solution and is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration. The pH scale runs from 0 to 14 (i.e. very acidic to very alkaline), with pH 7representing a neutral condition. At a given temperature, pH (or the hydrogen ion activity) indicates the intensity of the acidic or basic character of a solution and is controlled by the dissolved chemical compounds and biochemical processes in the solution. In unpolluted waters, pH is principally controlled by the balance between the carbon dioxide, carbonate and bicarbonate. The natural acid-base balance of a water body can be affected by industrial effluents and atmospheric deposition of acid-forming substances. Changes in pH can indicate the presence of certain effluents, particularly when continuously measured and recorded, together with the conductivity of a water body. Variations in pH can be caused by the photosynthesis and respiration cycles of algae in eutrophic water. The pH of most natural water is between 6.0 and

8.5, although lower values can occur in dilute water high in organic content, and higher values in eutrophic water, groundwater brines and salt lakes (Bartram and Ballance, 1996).

#### 2.1.1.4. Conductivity

Navneet Kumar *et al*. (2010) suggested that the drinking water quality of study area can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas.

### 2.1.1.5. Total Suspended Solids (TSS)

Total Suspended solid is an indication of the amount of erosion that took place nearby or upstream. This parameter would be the most significant measurement as it would depict the effective and compliance of control measures e.g. riparian reserve along the water ways (Bartram and Ballance, 1996).

### 2.1.1.6. Biological Oxygen Demand (BOD)

The biochemical oxygen demand (BOD) is an approximate measure of the amount of biochemically degradable organic matter present in a water sample. It is defined by the amount of oxygen required for the aerobic micro-organisms present in the sample to oxidize the organic matter to a stable inorganic form. BOD is a measure of organic material contamination in water, specified in mg/L. Therefore, interpretation of BOD results and their implications must be done with great care and by experienced personnel. Further discussion of the BOD test, together with case history results, is given in (Velz, 1984).

### 2.1. 1.7. Nutrients and Water Quality

#### 2.1.1.7.1. Ammonia ($NH_3$) and Nitrate ($NO_3$)

Nitrogen is essential for living organisms as an important constituent of proteins, including genetic material. Plants and micro-organisms convert inorganic nitrogen to organic forms. In the environment, inorganic nitrogen occurs in a range of oxidation states as nitrate ($NO_3^-$) and nitrite ($NO_2^-$), the ammonium ion ($NH_4^+$) and molecular nitrogen ($N_2$). Organic nitrogen consists mainly of protein substances (e.g. amino acids, nucleic acids and urine) and the product of their biochemical transformations (e.g. humic acids and fulvic acids). Organic nitrogen is naturally subject to the seasonal fluctuations of the biological community because it is mainly formed in water by phytoplankton and bacteria, and cycled within the food chain. Increased concentrations of organic nitrogen could indicate pollution of water body. Organic nitrogen is usually determined using the Kjeldahl method which gives total ammonia nitrogen plus total organic nitrogen (Kjeldahl N). Ammonia occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of the nitrogen gas in water by micro-organisms and from gas exchange with the atmosphere. It is also discharged into water bodies by some industrial processes (e.g. ammonia-based pulp and paper production) and also as a component of municipal or community waste. At certain pH levels, high concentrations of ammonia ($NH_3$) are toxic to aquatic life and, therefore, detrimental to the ecological balance of water bodies. Unpolluted waters contain small amounts of ammonia and ammonia compounds, usually < 0.1 mg $L^{-1}$ as nitrogen. Ammonia is, therefore, a useful indicator of organic pollution. Natural seasonal fluctuations also occur as a result of the death and decay of aquatic organisms, particularly phytoplankton and bacteria in nutritionally rich waters. Urban wastewaters and some industrial wastes are major sources of nitrate and nitrite. However, in regions with intensive agriculture, the use of nitrogen fertilizers and discharge of waste-waters from the intensive indoor rearing of livestock can be the most significant sources. Heavy rain falling on exposed soil can cause substantial leaching of nitrate, some of which goes directly into rivers, but most of which percolates into the groundwater from where it may eventually reach the rivers if no natural de-nitrification occurs. Nitrate concentrations in some rivers of western Europe are approaching the World Health Organization (WHO) drinking water guideline value of 50 mg $L^{-1}$ $NO_3$ (Meybeck and Helmer, 1989).

### 2.1.1.7..2. Orthophosphate ($PO_4$)

Phosphorus occurs widely in nature in plants, in micro-organisms, in animal wastes and so on. From various forms of phosphorus for the growth of algae orthophosphate is the most readily used form. Phosphorus may be in true solution, in colloidal suspension or adsorbed onto particulate matter, and it is very difficult to differentiate between the various fractions by separation (e.g. filtration) or analysis. A useful parameter is orthophosphate (strictly, total filterable and non-filterable orthophosphate) which is the phosphate responding to the analytical procedure without any pre-treatment such as hydrolysis or oxidative digestion. However, the determination of orthophosphate as specified is of great use in highlighting the presence of one of the most important nutrients and the results are of special interest in waters receiving sewage discharges (Meybeck, 1982).

### 2.1.2. Macroinvertebrates and Water Quality

Rivers and streams are home for many small animals called macroinvertebrate. These animals generally include insects, crustaceans, molluscs, arachnids and annelids. The term macroinvertebrate describes those animals that have no backbone and can be seen with the naked eye. Some aquatic macroinvertebrate can be quite large, such as freshwater crayfish. However, most are very small. Invertebrates that are retained on a 0.25 mm mesh net are generally termed macroinvertebrate. These animals live in the water for all or part of their lives, so their survival is related to the water quality. They are significant within the food chain as larger animals such as fish and birds rely on them as a food source. Macroinvertebrates are sensitive to different chemical and physical conditions. If there is a change in the water quality, perhaps because of a pollutant entering the water, or a change in the flow downstream of a dam, then the macroinvertebrate community may also change. Therefore, the richness of macroinvertebrate community composition in a water body can be used to provide an estimate of water body health. Macroinvertebrate communities vary across the State and different water bodies often have their own characteristic communities. Most have a phase within their life cycle to escape extreme conditions (Ambelu *et al*., 2010).

# 3. Materials and Methods

## 3.1. Description of Study Area and Sampling Sites

The study was conducted on three rivers namely Fincha, Dogaja and Tamsa’a all located in Didesa River headwaters (Blue Nile sub-catchment) in Chora District (Buno-Bedele Zone) and Agaro town (Jimma Zone), southwest Ethiopia. Each river was sampled at six sites (Table 1; Fig. 1). Chora lies at latitude and longitude of $36^0$1460 E, $8^0$ $19^1$ 60 N and an estimated population of about 100,506 (CSA, 2013). Chora is bordered on the south by the Jimma zone, on the west by Yoyo, on the northwest by Supena Sodo, on the north by Dega and east by Bedele. The major town in Chora is Kumbabe..Fincha River is located in the north-east of Kumbabe town. Fincha River flows from west to eastern direction. Agaro Town is 397.4 km from the Capital Addis Ababa. It lies at latitude and longitude of 7°51' N, 36°35' E, and an elevation of 1560 meters above sea level. It has an estimated population of about 35, 659 (CSA, 2013). It has an estimated annual rainfall of 659mm. The annual mean temperature ranges between 19.21 $^o$C-11.14 °C. Tamsa’a and Dogaja Rivers are located in the vicinity of the town. Tamsa’a River flows from south to north on the east of the town while Dogaja River flows in the same direction but on the western side of the town. Both rivers receive untreated waste from the town and two rivers meet after small distance from the town in Gomma district then flows to North-West direction.

**Table 1**.Altitude and locations of sampling sites of the rivers studied; TTR = Tamsa’a Tributary river; DTR = Dogaja tributary river.

| Site | Alt (m) | N (° ') | E (° ') | Site | Alt (m) | N (° ') | E (° ') |
|---|---|---|---|---|---|---|---|
| FinchaR1 | 1902 | 8 23.926 | 36 7.481 | TamsR4 | 1627 | 7 51.272 | 36 35.578 |
| FinchaR2 | 1902 | 8 23.756 | 36 7.606 | TTR | 1622 | 7 51.279 | 36 35.577 |
| FinchaR3 | 1902 | 8 23.684 | 36 7.707 | TamsR5 | 1605 | 7 51.553 | 36 35.765 |
| FinchaR4 | 1899 | 8 23.588 | 36 7.786 | DogajaR1 | 1627 | 7 51.747 | 36 35.176 |
| FinchaR5 | 1887 | 8 23.546 | 36 7.941 | DogajaR2 | 1597 | 7 51.884 | 36 34.271 |
| FinchaR6 | 1883 | 8 23.518 | 36 8.099 | DogajaR3 | 1596 | 7 51.911 | 36 35.357 |
| Tamsa’aR1 | 1661 | 7 50.460 | 36 35.727 | DogajaR4 | 1585 | 7 51.954 | 36 34.455 |
| Tamsa’aR2 | 1655 | 7 50.699 | 36 35.779 | DTR | 1601 | 7 51.773 | 36 34.606 |
| Tamsa’aR3 | 1643 | 7 51.172 | 36 35.740 | DogajaR5 | 1576 | 7 51.979 | 36 34.518 |

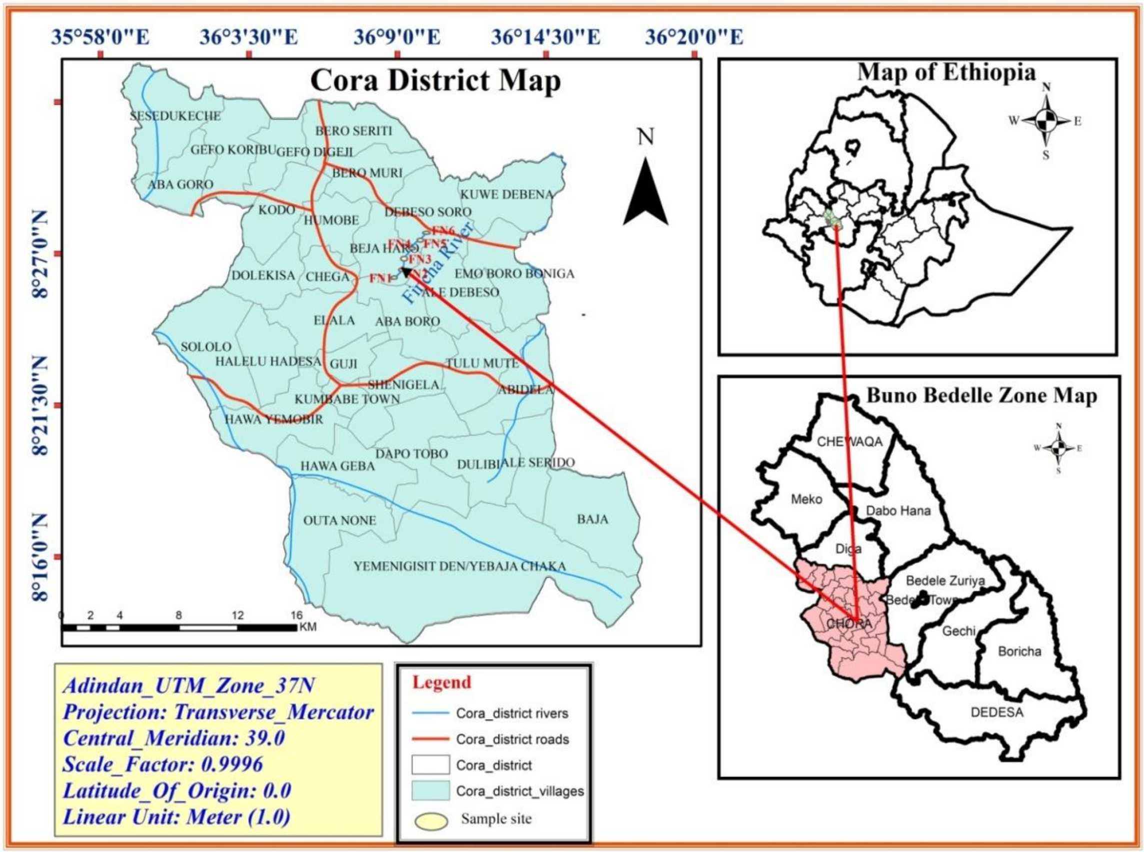


**Fig. 1.** Map of the study river of Fincha and sampling sites

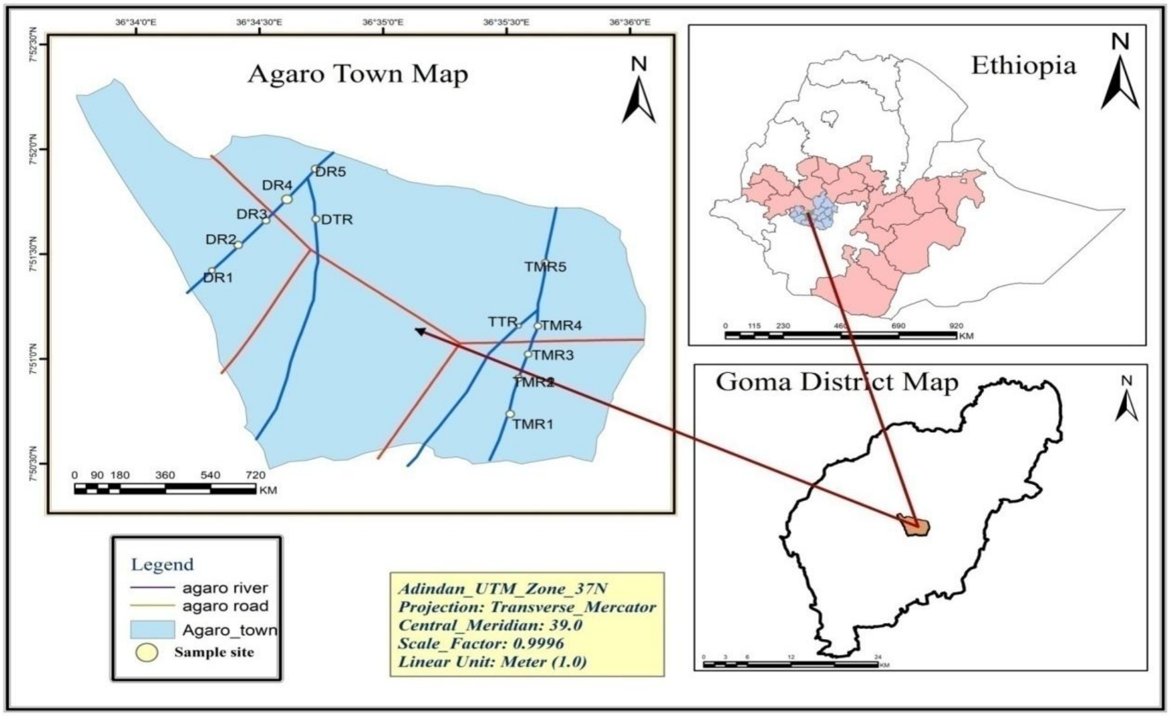


**Fig. 2.** Map of the study river of Tamsa'a, Dogaja and sampling sites

## 3.2 Field Work.

The selection of these sampling points were based on or by taking into consideration the activities done around the river such ashuman interferences such as area where domestic wastes are discharged to the river i.e. from the town (municipal wastes), from market place (may be manure and urine of the animals in the market that is discharged into the river which is immediate pollutant of the river) and at downstream wastewater from small coffee industries, hospitals, hotels, individual houses and also agricultural activities at downstream.

**Physico-chemical Parameters**

Water samples were collected two times from each sampling points selected by using bucket and plastic bottles. With 2 liters sterilized plastic bucket for the analysis of physicochemical and 2 liters for chemical parameters from the six sampling points each three rivers. The containers were rinsed thoroughly with de-ionized water after being washed in detergents. During the collection of the river waters, the containers were rinsed several times with the river water. For Fincha River (Finch $R_1$-Finch $R_6$) in October 15-16, 2018 and March 17, 2019, for Tamsa'a River (Tam $R_1$-Tam $R_5$) and its Tributary River (TTR) while in the case of Dogaja River (Dog $R_1$-Dog $R_5$) and its tributary river (DTR) in October 21, 2018 and March 17, 2019 in wet and dry season respectively. All samples were labeled properly. Some parameters like temperature, conductivity, pH and dissolved oxygen were measured on site. Water samples were analyzed by standard methods (Trivedi and Goel, 1986). Dissolved oxygen (DO), Temperature, pH and Conductivity (EC) were measured using a Multi probe parameter (Model HQ 40d) (Appendix 5). The remaining 2 liters water was transported to the laboratory for chemical analysis water. Water samples from each of six sampling points were collected by direct immersion of bottles into the river.

**Macroinvertebrates**

Macroinvertebrate samples were collected for nearly 5 min with the kick sampling method as described by Gabriels *et al.* (2010) using a D-frame net of mesh size of 250μm diameter. The MI samples were collected from each sampling station within a range of 10 m (which we have considered a sampling reach) (Ambelu *et al*., 2010) and then cleaned of detritus and sediment debris on the plastic tray. MIs were then sorted alive onsite by using forceps and preserved in 70

% ethanol for further identification process (Appendix 5). MI sample collection at a site was just once in each sampling season (October and March). Average values of the two sampling dates were used for analysis and interpretation. Standard operating procedures for macroinvertebrate sampling and processing were adopted (U.S.EPA, 2003).Habitat characteristics for each river were assessed criteria modified from Harding *et al*. (2009) as applicable to the rivers studied (Appendix 1).

## 3.3. Sample Analysis

Total Suspended Solids (TSS) was analyzed using filtration techniques and ($BOD_5$) was determined using Winkler's method following (APHA, 1999). All other measurements were carried out within 24 hours after sampling. Water quality parameters that required immediate analysis; Orthophosphate, Ammonia and Nitrate were measured with a Spectrophotometer (Model DR/5000 Hach Lange) using appropriate reagents. For Ammonia ($ZnSO_4$.7H2O, $HgI_2$, KI, NaOH, Rochelle salt solution). For Nitrate (Phenol disulphonic acid and KOH) and for Orthophosphate (Ammonium molbidate and Stannous chloride) all Model-Sigma Aldrich products at the Jimma University Environmental and Technology Laboratory (Appendix 6). Samples were preserved in an airtight ice chest at room temperature (~20 °C) before being transported to the laboratory.

### 3.3.1. Biological Oxygen Demand (BOD)

Biochemical Oxygen Demand was tested as water samples was collected in sample bottles for BOD that was analyzed and measured using the 5-day incubation period ($BOD_5$) as the standard test following the detailed protocols and procedures. For BOD analysis 300 ml of unfiltered water was added in the bottom round flask (BOD bottles) and incubated at 20 $^oC$. After the five day incubation the final DO was again remeasured. Finally the overall $BOD_5$after the five days was taken as difference of initial DO and final DO.

### 3.3.2. Total Suspended Solids (TSS)

Total suspended solids (TSS) correspond to non-filterable residue. To determine TSS 100ml of sample water was taken from each sample and filtered into the pre-weighted filter paper (Model-Whatman /diameter 90µm, pore size 12µm) which measured by analytical balance. The filtered residue paper dried in the oven at 105°C for one hour then cooled in desiccator. After that the dried paper with residue taken from the oven and weighted by analytical balance. Then calculated the initial weight from the final. The remaining weight was the weight of the residue (TSS).

### 3.3.3. Nitrate ($NO_3$)

As significant sources of nitrate are chemical fertilizers from farming lands as well as domestic and some industrial water, the water samples was also sampled for the $NO_3^{-.}$ Persulfate digestion method was used for the oxidative digestion of nitrogen compounds followed by Phenol disulphonic acid method to determine the amount of $NO_3^-$. For this method, 25 ml of sample water filtered from each sample in to each cup and boiled on hot plate. The water evaporated and $NO_3$ extracted from the sample then added 2 ml of phenol disulphonic acid into each cup and rubbed the remaining nitrate in the cups and added some distilled water then transfer in to test tube. Finally, added 7 ml of concentrated NaOH to each test tube to neutralize the acid. Covered the test tube and shake thoroughly, then determined through spectrophotometer. Measured the absorbance at a wave length was 410 nm against a blank prepared from the same volumes of reagents was used for the samples. Constructed a calibration curve in the range 0-2 mg/L $NO_3$ by adding 0, 0.2, 0.5, 1.0, 3.0, 5.0, and 10 mL of standard nitrate solution to separate evaporating dishes and treating them in the same way as the sample. Determined the μg of $NO_3$ in the sample by reference to the calibration curve.

### 3.3.4. Ammonia ($NH_3$)

Direct Nesslerization Method was used to measure the $NH3^-$ concentrations (Clesceri *et al*., 1999). For this method, 100 ml of sample water was taken (unfiltered water). Added 1ml of $ZnSO_4$ and 0.5 ml (5N) of NaOH, used to make sediments (increase turbidity). Then, 50 ml of water was taken in the test tube from the first sample and added 1ml of Nessler reagents to each prepared test tube by using pipette. Finally, added 0.1 ml of Rochelle salt to each test tube. The result was determined by using spectrophotometer. Allow the yellow or brownish color to develop for at least 10 minutes Read the absorbance at 425 nm with a spectrophotometer. Determined the microgram $NH_3$ from the calibration curve.

### 3.3.5. Orthophosphate ($PO_4^{-3}$)

Orthophosphate was determined by Stannous Chloride method (Clesceri *et al*., 1999). For Orthophosphate analysis 50 ml of filtered water was measured from each sample and added 2 ml of Ammonium Molbidate. Then, added 6 drops of Stenos Chloride. After 10 minutes, but before 12 minutes, measured the color photo metrically at 690 nm using distilled water as blank. Construct a calibration curve using the standards and determined the amount of phosphate in μg present in the sample.

**Macroinvertebrate**

The macroinvertebrate were identified up to their family level by using Petridis, forceps, dissecting microscope and hand lens. This was carried out at the Jimma University Department of Biology in Zoology laboratory by using standard systematic keys (Subramanian, and Sivaramakrishnan, 2004)**.** Even the damaged MIs were identified by examining closely both head and tail (Appendix 7).

## 3.4. Data Analysis

### 3.4.1. Physico-chemical and Nutrients

Significant variations in the mean values of physico-chemical parameters and nutrients among the three rivers groups were tested using Kruskal-Wallis followed by Mann-Whitney pair wise post-hoc tests due to lack of homoscedasticity and normality in the data. Normality and homoscedasticity of the data were tested using Shapiro-Wilk and Leven statistics respectively. Benferroni p values corrected for multiple testing were used to evaluate significance of pairwise comparisons for the Mann-Whitney post-hoc tests. Spearman's correlation coefficient was used to test the possible correlations among the measured parameters. Statistical analyses were run in PAST version 3.08 and SPSS version 16.

### 3.4.2. Macroinvertebrates

The Ethiopian Average Biotic Score per Taxon (ASPT-ETHbios) was computed according to Aschalew and Moog (2015) in order to complement assessment of the ecological conditions of the rivers using the Physic-chemical parameters.

Calculation of biotic score (ETHbios)

ETHbios was calculated as the sum of sensitivity score of each Taxon present in a sample as follows:

$$\text{ETHbios} = \sum_{i=1}^{n} score_i$$

The Average Score Per Taxon (ASPT) was calculated as ETHbios divided by total number of taxa considered in the calculation.

$$\text{ASPT} = \frac{\sum_{i=1}^{n} \text{score}_i}{n}$$

where Scorei is the score of Taxon i and n is the number of taxa considered in the calculation.

# 4. Result

## 4.1. Variations of Physico-chemical Parameters and Nutrients

A summary of the measured environmental variables for all the three rivers is presented in Appendix 2. Table 2summarizes statistical tests of these variables compared among the three rivers.  The analysis showed that average values of four variables namely water temperature, pH, electric conductivity and ammonia varied significantly among the three rivers while dissolved oxygen, biochemical oxygen demand, total suspended solids, nitrate and orthophosphate were not varied.

**Table 2**. Summary of the non-parametric tests of mean differences of the physico-chemical parameters and nutrients among the rivers; Med = Median; Statistical significance was evaluated at 5%; significant p-values are indicated with asterisk (*).

| | | **Water T** | | **DO** | | **pH** | | **EC** | | **TSS** | | **$NH_3$** | | **$NO_3$** | | **$PO_3$** | | **$BOD_5$** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River | N | Med | Mean Rank | Med | Mean Rank | Mead | Mean Rank | Med | Mean Rank | Med | Mean Rank | Med | Mean Rank | Med | Mean Rank | Med | Mean Rank | Med | Mean Rank |
| Fincha | 12 | 24.65 | 27.04 | 6.60 | 15.42 | 7.56 | 8.14 | 56.35 | 11.5 | 0.006 | 14.75 | 0.08 | 15.17 | 3.25 | 16.75 | 0.88 | 18.62 | 1.55 | 17.75 |
| Tamsa'a | 12 | 19.45 | 12.42 | 6.77 | 16.04 | 8.10 | 20.12 | 75.8 | 22.12 | 0.007 | 17.25 | 0.12 | 25.75 | 4.20 | 21.00 | 0.93 | 22.83 | 2.06 | 20.42 |
| Dogaja | 12 | 21.55 | 16.04 | 7.18 | 24.04 | 8.37 | 24.92 | 89.69 | 21.88 | 0.009 | 23.5 | 0.09 | 14.58 | 3.32 | 17.75 | 0.78 | 14.04 | 1.80 | 17.33 |
| **Kruskal-Walis test** | | | | | | | | | | | | | | | | | | | |
| Chi-Square | | 12.55 | | 5.00 | | 16.19 | | 7.95 | | 4.39 | | 8.54 | | 1.07 | | 4.19 | | 0.61 | |
| Degree of freedom | | 2 | | 2 | | 2 | | 2 | | 2 | | 2 | | 2 | | 2 | | 2 | |
| p | | **0.00*** | | 0.08 | | **0.00*** | | **0.02*** | | 0.11 | | **0.01*** | | 0.59 | | 0.12 | | 0.74 | |

The Mann-Whitney pair wise post-hoc tests for each variable that returned statistically significant variations using Kruskal-Walis test are summarized in Table 3.

**Table 3** Summary of the Mann-Whitney pair wise post-hoc tests for the variables that demonstrated significant variations using Kruskal-Wallis test; Statistical significance was evaluated at 5%; significant p-values are indicated using asterisk (*); Finch = Fincha River, Tams = Tamsa'a River, Dog = Dogaja River.

| | Water Temp-Finch | Water Temp-Tams | | pH-Finch | pH-Tams | | EC-Finch | EC-Tams | | NH3-Finch | $NH_3$-Tams |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Water Temp-Finch | | | pH-Finch | | | EC-Finch | | | $NH_3$-Finch | | |
| Water Temp-Tams | **0.03*** | | pH-Tams | **0.01*** | | EC-Tams | **0.05*** | | $NH_3$-Tams | **0.03*** | |
| Water Temp-Dog | **0.00*** | 0.38 | pH-Dog | **0.00*** | 0.61 | EC-Dog | **0.05*** | 1.00 | NH3-Dog | 1 | **0.05*** |

Analysis of linear correlation among selected variables using Spearman's rho coefficient is presented in Table 4.

**Table 4**. Summary of linear correlation among selected variables using Spearman's rho coefficient (r); N= 36 for each variable; *Correlation is significant at 0.05 level (2-tailed).

| | | Water temp | DO |
|---|---|---|---|
| DO | r | **-0.35*** | |
| | p | 0.04 | |
| BOD5 | r | **0.34*** | **-0.52*** |
| | p | 0.04 | 0.00 |

In the above Table 4 the temperature was negative correlation with dissolved oxygen. The DO and BOD5 had also negative correlation. Their correlation was significant at 0.05levels.

## 4.2. Results of Physico-chemical Parameters of Fincha, Tamsa'a and Dogaja Rivers

The variations in water temperature among the rivers are statistically significant with the Fincha and Tamsa'a rivers having the highest and the least median values respectively ($p = 0.00$; Table 2). Pairwise comparisons showed that water temperature for Fincha River varied significantly from those of Tamsa'a and Dogaja rivers ($P < 0.05$; Table 3)while there is no significant variation between water temperature values of the latter two.

The results of physicochemical parameters of Fincha Tamsa'a and Dogaja Rivers were shown in Table 1. During the study period, the median value of water temperature of Fincha, Tamsa' a and Dogaja Rivers were ranged from 19.45 $^{o}$C to 24.65 $^{o}$C at Tamsa'a and Fincha Rivers respectively. The highest value was recorded at Fincha River 24.65 $^{o}$C (Table 2Fig. 3).

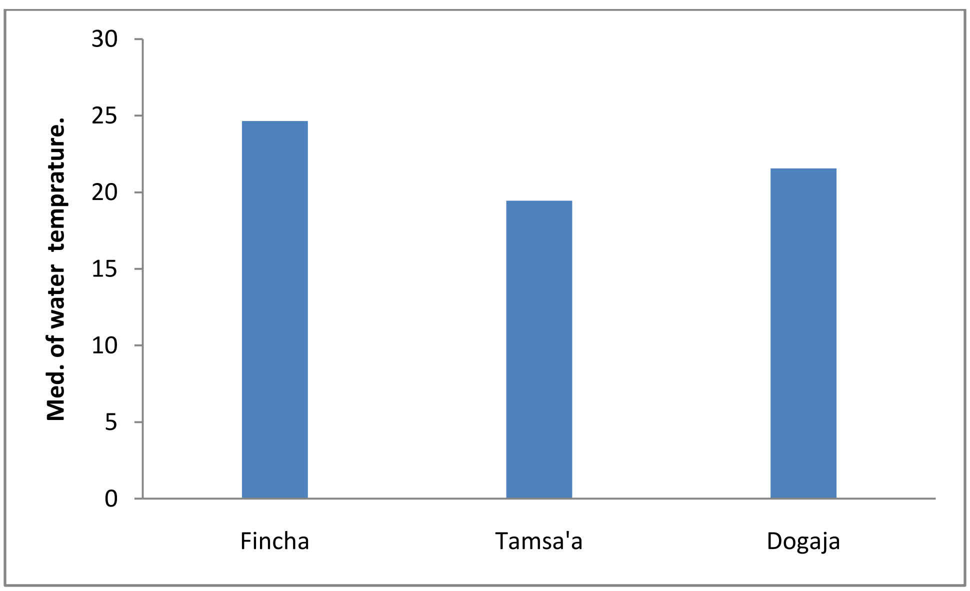


**Fig.3.** The median value of water temperature of Fincha, Tamsa'a and Dogaja Rivers

The average values of dissolved oxygen varied from 6.60 mg/L (Fincha) to 7.18 mg/L (Dogaja). However, the variations in the low dissolved oxygen among all the three rivers were not statistically significant ($P = 0.08$; Table 2). Nevertheless, the lowest amount of dissolved oxygen in Fincha River could relate to the highest water temperature of the river as compared to the other two rivers. The correlation between the two variables is negative and statistically significant (r = -0.35; p = 0.04; Table 4). Similarly, the highest dissolved oxygen value for Dogaja River could be related to biochemical oxygen demand ($BOD_5$) that was relatively lower than the value for Tamsa'a River. DO and $BOD_5$ are related negatively and the relationship is statistically significant (r = -0.52; p = 0.00; Table 4). Moreover, Dogaja and Tamsa'a Rivers have comparable water temperature that was lower than that of Fincha River. The variations in the biochemical oxygen demand ($BOD_5$) among the three rivers were statistically not significant (p = 0.74; Table 2).

An average median value of the concentration of dissolved oxygen in Fincha, Tamsa'a and Dogaja Rivers were ranged from 6.60 mg/L to 7.18 mg/L at Fincha and Dogaja Rivers respectively. The highest median value of dissolved oxygen 7.18mg/L was recorded at Dogaja River (Table 2 Fig. 4).

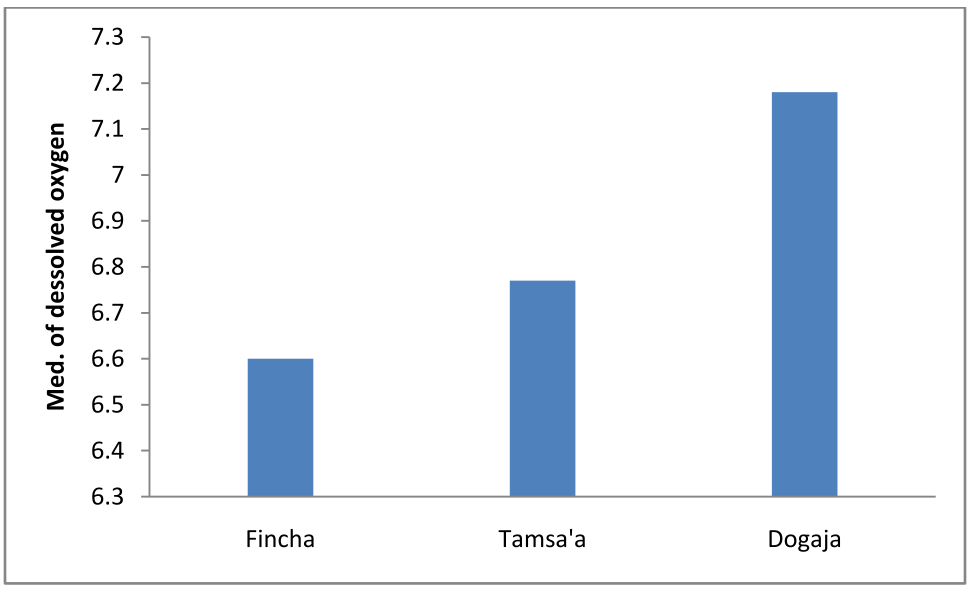


**Fig.4**. The median value of dissolved oxygen of Fincha, Tamsa'a and Dogaja Rivers

Median pH values at in three rivers were ranged between 7.56to8 37 at Fincha and Dogaja Rivers respectively. The highest pH value recorded at Dogaja River 8.37 (Table 2.Fig. 5).

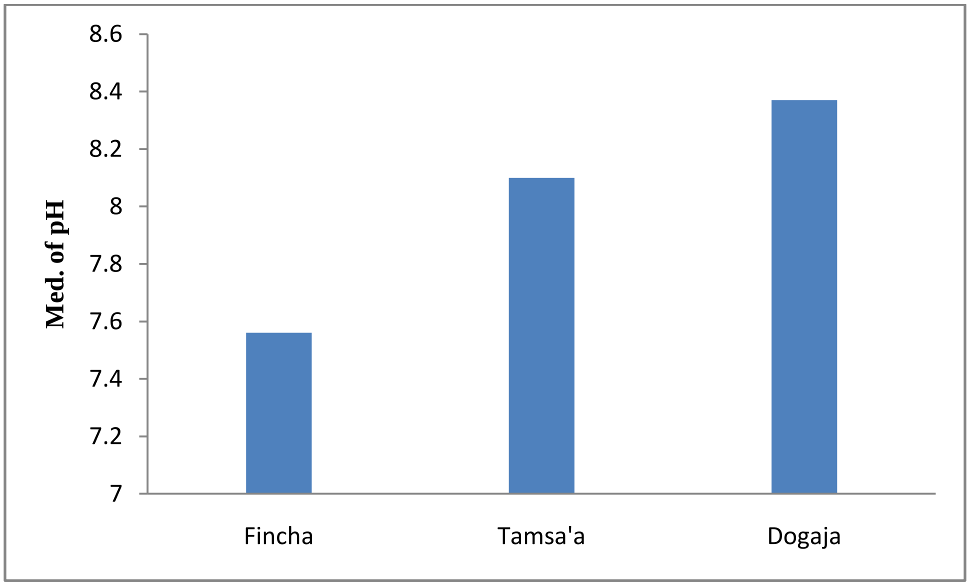


**Fig.5**. The median value of pH of Fincha, Tamsa'a, and Dogaja Rivers

The median value of electric conductivity of Fincha, Tamsa'a and Dogaja Rivers were ranged between 56.35 µS/cm and 89.69 µS/cm at Fincha and Dogaja Rivers respectively. The highest median value recorded at Dogaja River 89.69 µS/cm (Table 2 Fig.6), the variation was statistically significant ($p = 0.02$; Table 2).The lower EC value for Fincha River varied significantly from those of Tamsa'a and Dogaja rivers ($p = 0.05$; Table 3) that had comparable values. Although EC of the rivers tended to increase with water temperature, the relationship was statistically not significant in this study ($p > 0.05$).

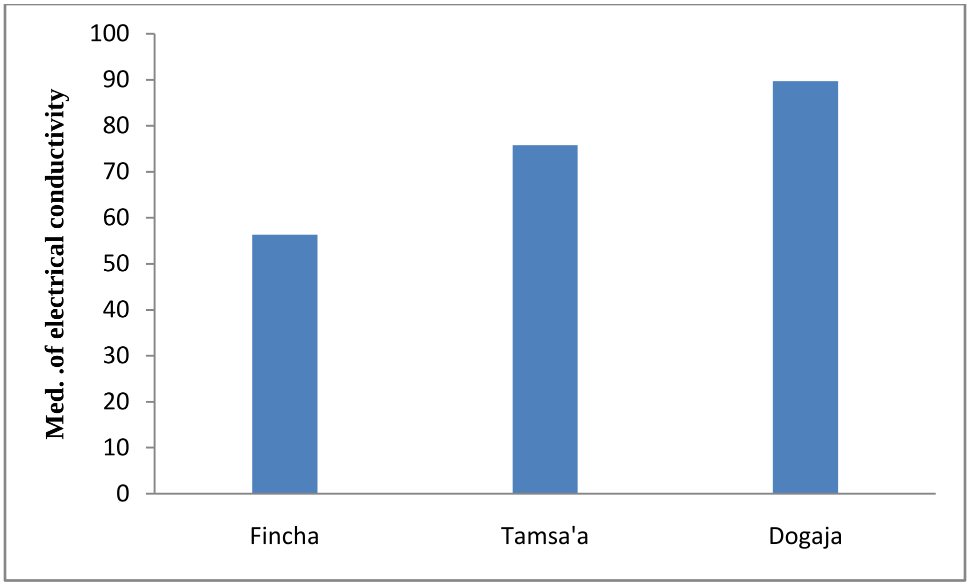


**Fig.6.** The median value of electric conductivity of Fincha, Tamsa'a and Dogaja Rivers

The median value of total suspended solids (TSS) of the three rivers at Fincha and Dogaja Rivers were 0.006 mg/L to 0.009 mg/L respectively. The highest 0.009 mg/L were recorded at Dogaja River (Table 2 Fig.7).

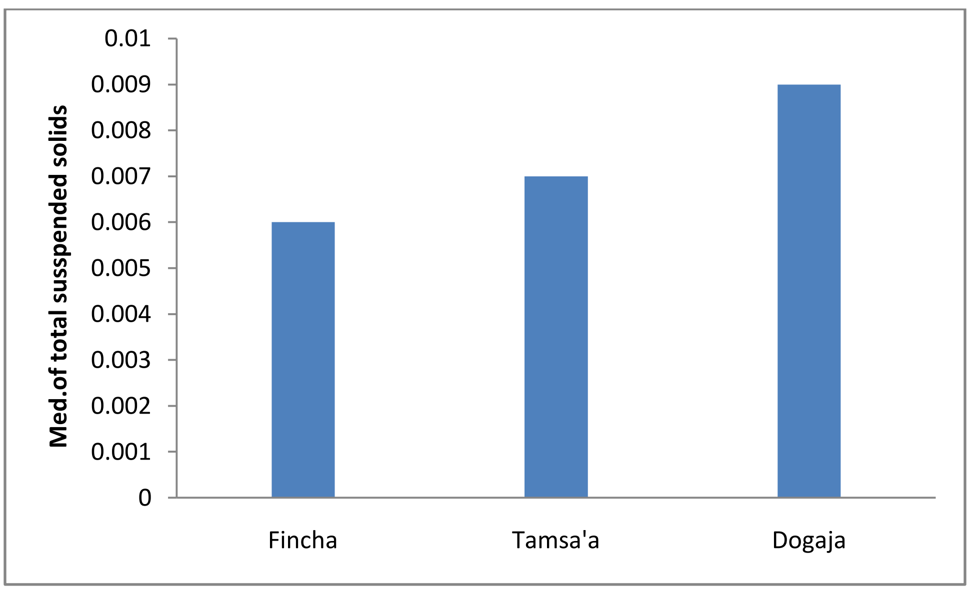


**Fig.7**. The median value of total suspended solids of Fincha, Tamsa'a and Dogaja Rivers

At present investigation the median value of the ammonia concentration of the three rivers were ranged from 0.08 mg/L to 0.12 mg/L at Fincha and Tamsa'a Rivers. The median value of the highest concentration of ammonia was 0.12 mg/L recorded at Tamsa'a Rivers (Table 2 Fig.8). However, only the concentrations of $NH_3$ varied significantly among the rivers ($p = 0.01$; Table 2). The median value of $NH_3$ at Tamsa'a River varied significantly from the values measured at both Dogaja and Fincha Rivers ($p < 0.05$; Table 3) while the values for the latter two did not vary significantly.

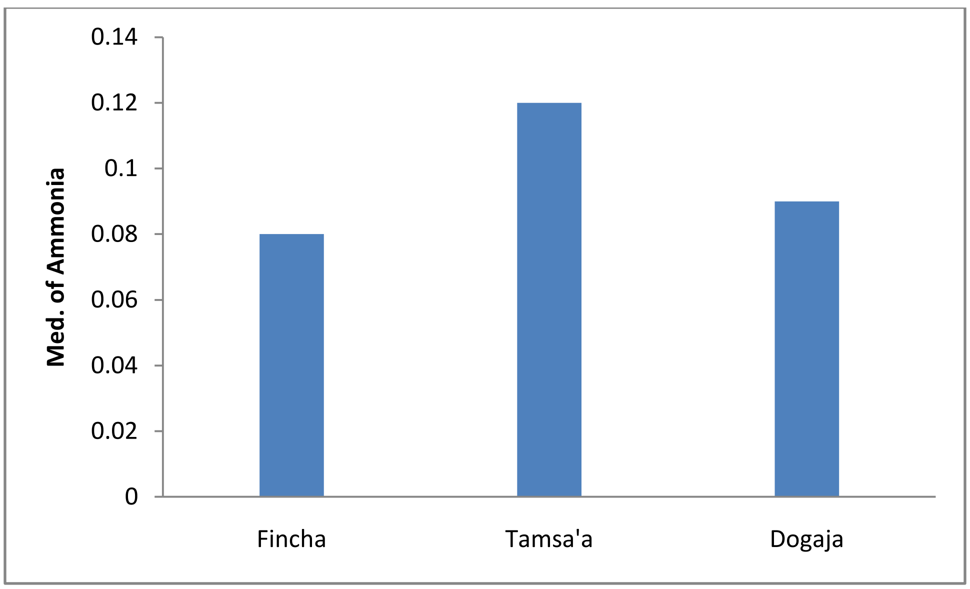


**Fig.8**. The median value of the concentration of ammonia at Fincha, Tamsa'a and Dogaja Rivers

The concentration of nitrate were ranged from 3.25 mg/L to 4.20 mg/L at Fincha and Tamsa'a Rivers respectively while the highest concentration recorded 4.20 mg/L at Tamsa'a River (Table 2 Fig. 9).

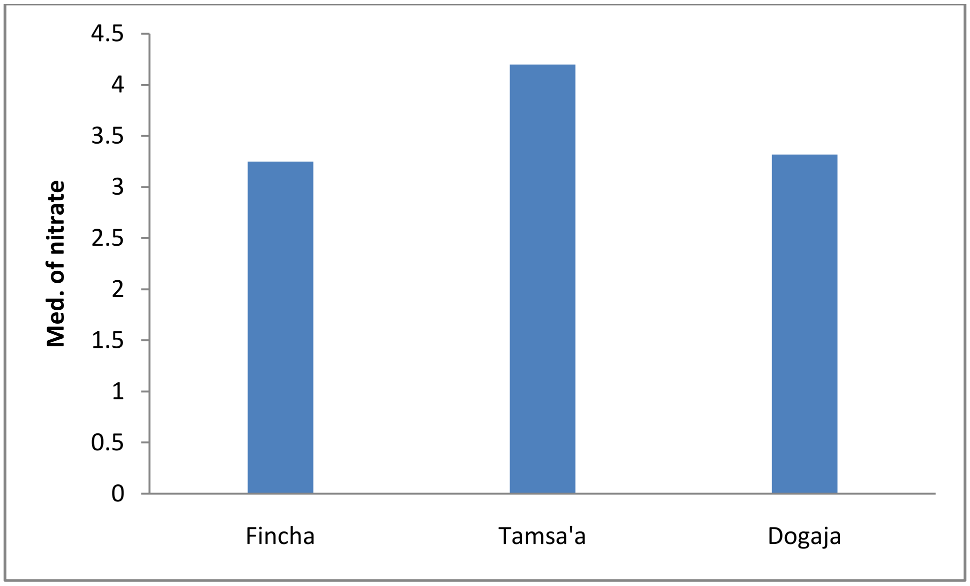


**Fig.9**. The median value of nitrate concentration of Fincha, Tamsa'a and Dogaja Rivers

The median value of phosphate concentration of the three rivers was ranged from 0.78 mg/L to 0.93 mg/L at Dogaja and Tamsa'a Rivers respectively. The highest value was recorded at Tamsa'a River (Table 2 Fig; 10).

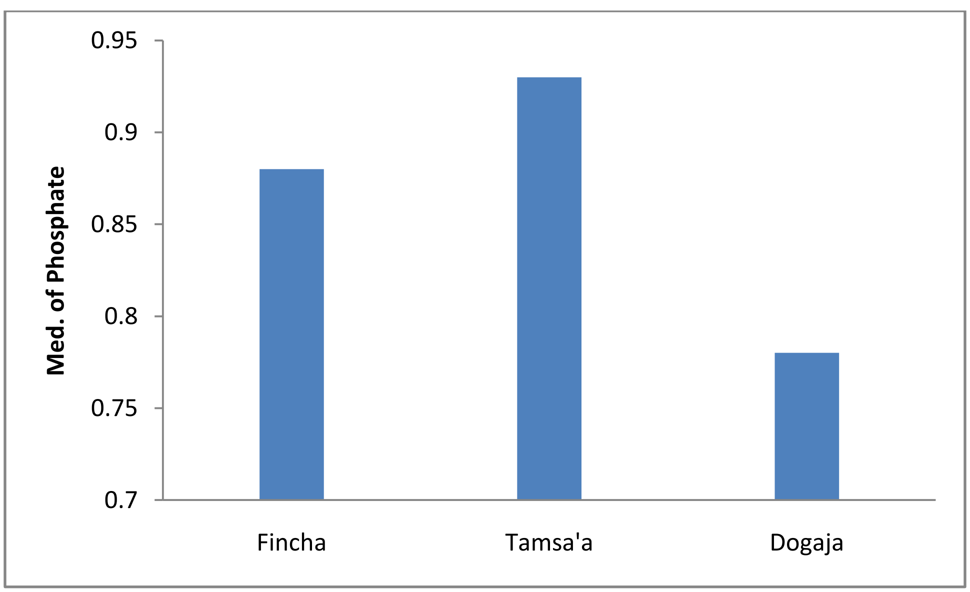

**Fig.10**. The median value of phosphate concentration of Fincha, Tamsa'a and Dogaja Rivers

The average median value of the concentration of biological oxygen demand was ranged from 1.55 to 2.06 mg/L to 20.42 mg/L at Dogaja and Tamsa'a Rivers respectively. The highest concentration 20.42 mg/L was recorded at Tamsa'a River (Table 2 Fig.11).

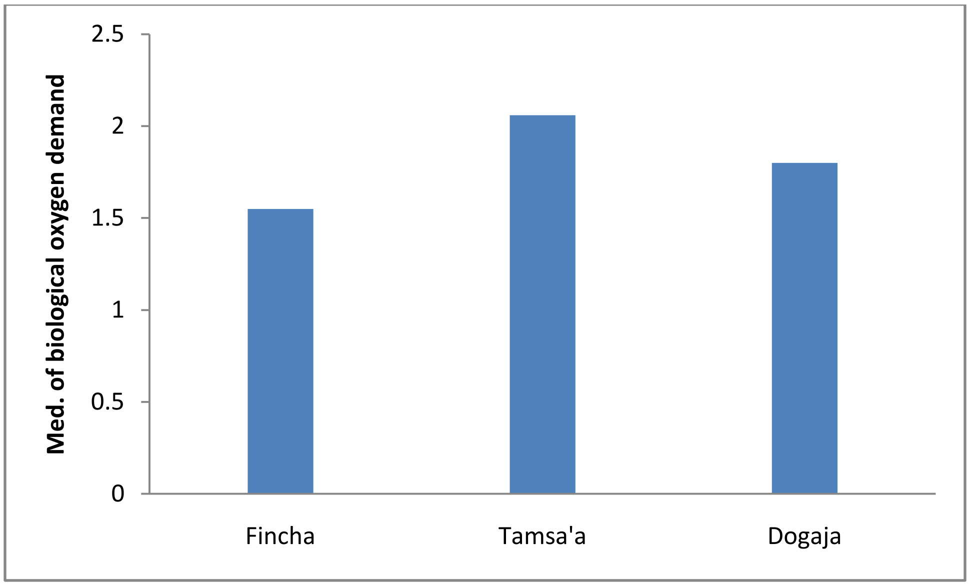


**Fig.11**. The concentration of biological oxygen demand of Fincha, Tamsa'a and Dogaja Rivers

## 4.3. Macroinvertebrates

Summary of the macroinvertebrate diversity identified from the three rivers during the study period is provided in Appendix 3. The ETHbios-ASPT scores of the Macroinvertebrates evaluated according to Aschalew and Moog (2015) are provided in Table 5.

**Table 5**. The ETHbios-ASPT score of the macroinvertebrate for the three rivers studied

| **River** | **ETHbios-ASPT** | **River water quality class (**according to Aschalew and Moog, 2015) |
|---|---|---|
| Fincha | 4.85 | Moderate water quality; significant ecological disturbance |
| Tamsa'a | 3.58 | Poor water quality; major degradation |

| | | |
|---|---|---|
| Dogaja | 3.50 | Poor water quality; major degradation |

## 4.4. Habitat characteristics

**Table 6**. Summary of the most relevant habitat characteristics of the three studied rivers

| River site | Streambed substrate | Shading | Flow type | Stock access | Stock damage | Adjacent land use | Catchment land use |
|---|---|---|---|---|---|---|---|
| FinchaR1 | Mud | Open | Run | Yes | Moderate | Short grazed | Farming |
| FinchaR2 | Gravel | Open | Run | Yes | Minor | Short grazed | Farming, Native forest |
| FinchaR3 | Gravel, pebble | Partial | Riffle | Yes | Moderate | Short grazed | Farming, Native forest |
| FinchaR4 | Boulder | Partial | Run | No | No | Coffee forest | Natural forest |
| FinchaR5 | Boulder | Partial | Run | Yes | Minor | Coffee forest | Farming, Forest |
| FinchaR6 | Pebble | Heavy | Run | No | No | Coffee forest | Coffee forest |
| Tams’aR1 | Cobble, Boulder | Open | Riffle | Yes | Minor | Plantation (eucalyptus) | Coffee forest, Grazing |
| Tamsa’aR2 | Cobble, Boulder | Open | Run | Yes | No | Plantation (eucalyptus) | Coffee forest, Grazing |
| Tamsa’aR3 | Sand, Mud | Open | Riffle | Yes | Minor | Plantation (Sugar cane) | Plantation (Sugar cane), Urban |
| Tamsa’aR4 | Boulder, Bedrock | Open | Riffle | Yes | Minor | Bush, Construction | Urban |
| TTR | Bedrock | Open | Riffle | No | No | Bush, Coffee | Natural forest, Plantation, Urban |
| Tamsa’aR5 | Bedrock | Open | Riffle | Yes | Minor | Shrub/Bush | Coffee |
| DogajaR1 | Muddy | Open | Run | No | No | Coffee | Coffee, Plantation (eucalyptus) |
| DogajaR2 | Boulder | Partial | Riffle | No | No | Natural vegetation, Plantation (eucalyptus) | Natural vegetation, Plantation (eucalyptus) |
| DogajaR3 | Bedrock | Open | Run | Yes | Minor | Road, Bridge | Urban |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Doga jaR4 | Mud, Clay | Ope n | Riffl e | No | No | Coffee, Plantation (eucalyptus) | Coffee, Plantation (eucalyptus) |
| DTR | Bedrock | Ope n | Riffl e | Yes | Minor | Bush, Houses | Urban |
| Doga jaR5 | Boulder | Ope n | Riffl e | Yes | Minor | Cattle watering | Stone extraction, Coffee mill |

Majority of Fincha River sites have muddy, silty, or sandy bottoms and slow moving. Most of the areas were open field and short grazed. The distinctive land use feature was farming characterizing Majority of Tamsa'a and Dogaja River sites have coble to bedrock, streambed and riffle. The distinctive land use feature of Tamsa'a and Dogaja Rivers were urban land characterizing. The most adjacent land use was plantation.

## 5. Discussion

Water temperature is very important physicochemical parameters. It affects ecological features, the behaviour of organisms, and solubility of gases and content of salts in water. In addition water temperature exerts a strong influence on many physical and chemical characteristics of water including the, chemical reaction and toxicity. The fluctuation of temperature usually depends on the season, geographic location; sampling time and content of effluents enter with the industrial area. Water temperature also controls the characteristics of organisms and salts in water usually depends on the season, geographic location, sampling of effluents entering the stream (Dallas and Day, 2004).

The concentration of physicochemical parameters in Fincha, Tamsa'a and Dogaja Rivers were shown in Table 2.During the study period, the lower median value of water temperature at Tamsa'a River was 19.45 $^{o}$C and the higher median value of water temperature was 24.65 $^{o}$C recorded at Fincha River.

The median water temperature value (24.65 °C) in the present study was higher than the average value (16.7 °C) in Tinishu Akaki River, Ethiopia, reported by Samuel *et al.*(2007), but it was substantially lower than the mean water temperature value (25.65 °C) in Upper Awash River, Ethiopia (Fasil *et al.*, 2013).

Possible factor may be that Fincha River is located in open space at most of the sites sampled while the latter two rivers have relatively better vegetation cover at most of their sampling sites. Materials that cause water to be turbid include: clay, silt, finely divided organic and inorganic matter, soluble, colored organic compounds, plankton and microscopic organisms may be higher in Fincha River than the two rivers. Such particles absorb heat in the sunlight, thus raising water temperature, which in turn lowers dissolved oxygen levels. In addition the head water of Fincha River was in open field, for this cause the temperature may be higher than the two rivers. Most samples of Tamsa'a and Dogaja Rivers were taken at the morning it may reduce the water temperature. The level of turbidity of the two rivers at the time of sampling may be lower than Fincha River. The mouths of the two rivers were better shaded than Fincha River.

Dissolved oxygen is probably the most important parameter in natural surface water systems for determining the health of aquatic ecosystems (Yang *et al., 2007*). In the case of dissolve oxygen(DO), the tolerance limit for inland surface waters used as raw water and bathing is 3 mg/L, for sustaining aquatic life is 4 mg/L whereas for drinking purposes is 6 mg/L. The median DO value for Fincha, Tamsa'a and Dogaja Rivers waters were between 6.60 mg/L to 7.18 mg/L at Fincha and Dogaja Rivers respectively (Table 2). At all places water has higher DO value than the limit prescribed (WHO, 1993).

In the present investigation, Fincha River has low dissolved oxygen content while it may be due to high temperature. Mineral wastes and agricultural runoff results to get lower DO levels (Srivastava *et al.*, 2011; Addo *et al.,* 2013). On the other hand, Tamsa'a and Dogaja Rivers have coble to bedrock streambed. When the water flows it may be increase aeration. In addition, the concentration of BOD and COD may be decreases the levels the dissolved oxygen content in the river water (Ubwa *et al.*, 2013). This may be the cause of Fincha River. Fincha River also has substrates of mud to pebble. This mud may be covered plants living in water; it may be the cause of lower concentration because plants are sources of oxygen. However, in the case of biochemical oxygen demand (BOD5), no variation at three rivers.

All the three rivers have pH values slightly higher than the neutral value ranging from 7.56 (Fincha) to 8.39 (Dogaja) Rivers. Dogaja and Tamsa'a Rivers tended to have comparable and relatively higher pH that varied significantly from that of Fincha River ($P < 0.05$; Table 3). While pH of the rivers tended to decrease with water temperature, the relationship was statistically not significant ($p > 0.05$).

The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment (APHA, 1995).In present investigation, the median values of the three (Fincha, Tamsa'a and Dogaja) Rivers were varied from neutral to slightly alkaline. The lowest value was 7.56 at Fincha River and the highest median value was 8.37 at Dogaja River (Table 2), which lies within the WHO maximum allowable drinking water quality ranges and the draft Ethiopian drinking water guide lines.

The pH values of most natural water in the range of 6.5-8.5 (Chapman, 1996). The highest value of pH is associated with water that receives wastes from human activities. The median value of Fincha, Tamsa'a and Dogaja Rivers slightly higher than the average pH values in most rivers in Addis Ababa was 7.39 which was 6.06 in Kebena River and 7.5 in little Akaki River (Tamiru, *et al.*,2005). The pH values of river increases with industrial and domestic waste discharged to the system increase the pH of the water (Tekelhaimanot, 2003). The pH of waters gets drastic change with time due to exposure to biological activity and temperature. The higher pH values observed in Tamsa'a and Dogaja suggests that carbon dioxide, carbonate-bicarbonate equilibrium was affected more may be due to change in physicochemical condition (Tiwari *et al*., 2009).

The specific conductivity of water is a solution in its capacity to conduct electric current and depends on the nature and concentration of ionized salts. Electrical conductivity showed variations between rivers. The result obtained from the laboratory analysis of electrical conductivity of the Fincha, Tamsa'a and Dogaja Rivers throughout the study period were average values ranging from 56.35 µs/cm to 89.69 µs/cm at Fincha and Dogaja Rivers respectively (Table 2). The lower value was at Fincha river i.e. 56.35 µs/cm indicated that the human and industrial activities (Agricultural chemicals) near this sample point was considerably less. Fincha River is far from the town and hence the anthropogenic interferences are expected to be minimal. The high EC value at Tamsa'a (75.8 µs/cm and Dogaja River (89.69 µs/cm) indicated that the effect of domestic wastes discharge into the rivers.

Tamsa'a and Dogaja Rivers are located in the town .and wastes from small industries disposed in to Tamsa'a and Dogaja Rivers. It might be responsible for the increasing values of the EC. There were an increasing trend in EC values starting from the rural area towards the urban since, more anthropogenic and other activities increase the electrical conductivity. The pattern of EC is quite similar to that of TDS which reflects the status of surface water pollution.

The variations might be observed in Fincha and Tamsa'a-Dogaja Rivers may be due to different factors such as salinity, dissolved solids, the concentration of free ions; and high level of industrial waste and temperature. Similar results are reported by (Boyd, 1981). In Fincha River may be due to low amount of ionized salts with high temperature when compared with the other two rivers. However, Tamsa'a and Dogaja Rivers contain high electrical conductivity values were may be due to with predominant sodium and chloride ions, whereas it was related to TDS content and its value becomes higher with the increase of the degree of pollution.

The average TSS values for the rivers varied from 0.006 mg/L (Fincha) to 0.009 mg/L (Dogaja). The TSS result that has been obtained from three rivers indicated that Dogaja has the maximum median value of 0.009 mg/L and Fincha has the minimum 0.006 mg/L median value (Table 2). The total suspended solid concentration is more pronounced at Dogaja River located near coffee industry, domestic wastes from the town and at stone extraction industry which discharge effluents, soil and dust might contribute to the load of total suspended solids. Pollution of the rivers by suspended particulate matter with increment in concentration at Dogaja-Tamsa'a Rivers and reduction at Fincha River was observed with respect to drinking water suitability. The median values of all three rivers water were below the maximum allowable limits of the WHO and draft Ethiopia drinking water standards of 1000mg/L and 1176mg/L respectively.

Tamsa'a River has the highest concentrations of $NH_3$, $NO_3^-$ and $PO_4^{3-}$. From the results obtained from the laboratory analysis, the average value of ammonia for Fincha, Tamsa'a and Dogaja Rivers were below WHO (1993) and draft Ethiopian drinking water allowable concentration of 1.5 mg/L and 3 mg/L respectively.

The result of ammonia concentration obtained from the two rivers water in the town was shown in (Table 2). The average median value of Dogaja River was (0.09 mg/L) and (0.12 mg/L) at Tamsa'a River. It was less than the maximum concentration of WHO and draft Ethiopian drinking water standard. In unpolluted water the level of ammonia is below 1.5 mg/L (Chapman, 1996).

Domestic wastes from hotels, individual homes and hospital might discharge ammonia and ammonium containing substances which could be one of the reasons for the high level of ammonia than Fincha River. This might be due to the accumulation of solid wastes and sanitary near these rivers. The accumulation of ammonia in water is an indicator of possible bacteria, sewage and animal wastes (WHO, 2004) is exhibited in these sampling points which increase rate the of decomposition of nitrogen containing substances and rate of nitrification process for increasing ammonia and ammonium level.

The median value of nitrate concentration at Fincha, Dogaja and Tamsa'a Rivers were below 45mg/L, which was below the limit of WHO standards. The results obtained from the analysis of the three rivers water were by far very low and ranges between 3.25 mg/L to 4.20 mg/L. It was an indication that less of oxidation that can convert ammonia into nitrite due to less/absence of nitrogen fixing bacteria. The phosphate analysis of the median value (Table 2), indicated that the value of three rivers were not more than 0.93 mg/L. The values range from 0.78 mg/L to 0.93 mg/L. This indicated that the level of phosphate contamination at three Rivers water were relatively insignificant. This indicating that disposal of phosphate from domestic and industrial sewage as a washing powder, intensive rearing of livestock and the use of phosphate containing fertilizer is very less while these are the major phosphatecontaminations in rivers of Addis Ababa (Tamiru *et al*., 2005). Thus the rivers were fulfil the WHO drinking water quality standards and draft Ethiopia drinking water quality standards. These rivers were possibly safe from nitrate and phosphate contamination which currently indicated the limited agricultural activities around the river basin and the river currently may not face associated eutrophication problem. With respect to drinking water suitability the median values of all three rivers water were below the maximum allowable limits of the WHO and draft Ethiopia drinking water standards.

In present investigation, the physico-chemical parameters and habitat characteristics affected on the ecological water qualities of rivers. Degraded habitat features and moderate water quality at Fincha River were associated with watershed agriculture and the consequent shift and removal of riparian vegetation. Agricultural activities in the watershed of Fincha River shifted the riparian vegetation from heterogeneous natural condition to few annual domestic crops and grass. Removing vegetation from the catchment affects on water temperature and decrease the concentration of oxygen. In moderate (low) polluted water, the balance between carbon dioxide, carbonate and bicarbonate ions as well as other natural compounds controls the pH, this may be for Fincha River (Dodds, 2002). Lower bank stability may be affecting the water temperature by increasing silts. Silts and other sediments may be increase water temperature by absorbing light energy from the sun and releasing to the water. Trees and shrubs which indirectly contribute to the instream habitat integrity by fencing floods and trapping sediments (Allan, 2004; Belsky *et al.,* 1999; Sweeney *et al*., 2004; USEPA, 2000) are only limited to a narrower distance from the river bank. Low amount of nutrients in the river indicated the area was less affected by domestic wastes, sewages, industrial fertilizers and other organic and inorganic compounds.

Better habitat integrity scores were recorded at the upstream of Tamsa'a and Dogaja Rivers with less human impact. Increased degradation and removal of riparian vegetation in the downstream with increased human influence were the causes for the very poor habitat integrity. Habitat qualities such as bank stability, sediment deposition, pool substrate characterization and flow regime were adversely affected at those sites. The effects of industrial and household waste discharge, manure of grazing domestic animals near the river bank and human faeces defecations in the riparian vegetation altering habitat qualities such as water appearance all contributed to the lower habitat integrity at the downstream of rivers (Braccia and Voshell, 2006).

On the other hand, in Tamsa'a and Dogaja Rivers the temperature was lower than Fincha River this was may be due to some of the area was covered with different plants and most samples taken in the morning. Animal fecal materials and agricultural wastes entered and the increased $NH_3$ level might be due to decomposition of these organic wastes. However, according to Beasley and Kneale (2003), increasing urbanization and industrialization generates different non-point sources of contamination, causing impairment of water quality of rivers. This environmental impact can be seen in the town of Agaro and its surroundings. High anthropogenic pressure on aquatic ecosystems in this region is a consequence of the ever-increasing population and establishment of small industries, fuel station and hotels especially on the banks of rivers (Benetti and Garrido, 2010).

The structure of macroinvertebrate assemblages is influenced by factors such as the hydrological regime, substrate stability, type and abundance of trophic resources, or land use in the river basin (Dessaix *et al.*, 1995; Quinn *et al.*, 1997; Zamora-Muñoz & Alba-Tercedor, 1996). In this study, both natural characteristics (geology, substrate, water flow) and those artificially created by the impact of fuel station, livestock market, and road and bridge infrastructures may determine the structure of the macroinvertebrate assemblages. Tamsa'a and Dogaja Rivers contain more pH, EC and TSS than Fincha River. This may be due to the cause of low temperature, high amount of total dissolved solids, silt, industrial chemicals from farm lands, sewages and animal faeces from the town, while lower water quality than Fincha River. Habitats and diversity of macroinvertebrate were greatly affected in Tamsa'a and Dogaja Rivers greatly affected on their habitat and diversity of macroinvertebrate when compared with Fincha River.

Majority of Tamsa'a and Dogaja rivers sites have coble to bedrock streamed. These rivers are defined as those with bottoms made up of gravel, cobbles, and boulders in any combination and usually have definite riffle areas (Table 6). Riffle areas are fairly well oxygenated and therefore, the prime habitats for macroinvertebrates. When the river flows through rocks the air simply enter in to the water from the atmosphere. Increasing the concentration of pH may be due to water temperature and the low flow (riffle) of the rivers while domestic and industrial wastes exposed to the river, stored and increase the concentration of pH in two rivers. Many populations in the town exposed huge amount of domestic wastes from different sources. Many people use the rock for washing, bathing and the riparian vegetation uses as defecation. Detergents from bathing, washing and latrine may be increase the concentration of electric conductivity. The concentration of nutrients like ammonia and nitrate concentration were higher may be due to high decomposition organic matter and inorganic compounds released in to the rivers. Solid and liquid pollutants flow to the river through artificial drainage from the catchment area of the river (from the town). The increasing of silts in rivers may be due to the flooding of soil particles from the catchment area.

Fincha River has muddy, silty, or sandy bottoms and lack riffle. Most of the area of Fincha River was open field (Table 6). From farming and grazing fields soil and animal manure flow to the river. Higher water temperature may be attributed to temperature of sample taken. The temperature affect on the concentration of oxygen whereas the concentration of dissolved oxygen lower at Fincha River. On the other hand, the absence of rocks in most area of the river may become lower the aeration of the water. The concentration of  pH, conductivity and nutrients lower at Fincha River, these may be at sampling time, domestic wastes, industrial wastes (Agricultural chemicals) low in the river. This is may be due to lack (reduced) in the river catchment or dissolved in high volume of water.

# 6. Conclusion

Water is an essential and life-sustaining natural resource and is critical for the survival of all living organisms, food production and economic development. Surface water is most exposed to pollution due to their easy accessibility for disposal of wastewater. The result of physicochemical and macroinvertebrate analysis of the three rivers from different sampling stations indicated that the higher level of pH, EC, TSS, BOD, occur at the vicinity where much of the agricultural practices and waste disposal have been underway. This correlates with higher values of pollution indicating nutrient ($NH_3$, $PO4^{-3}$ and $NO_3^-$). This study shows that Tamsa'a and Dogaja Rivers are relatively more polluted than Fincha River due to urbanization and disposal of wastes by the nearby communities. The waste discharge from the town has directly caused the considerable effect on macroinvertebrate habitats and diversity. In general, the direct and indirect effects of agricultural land use, liquid and solid waste disposal, cattle-raising, and other anthropogenic pressures have deteriorated the biodiversity and water quality of these three Rivers.

## 7. Recommendations

Fincha, Tamsa’a and Dogaja Rivers were found to be under high impact and impaired. On the other hand, these rivers water are used for a variety of purposes such as irrigation, drinking and domestic purposes without prior treatment. At the moment, preserving the rivers from the anthropogenic threats is one of the key concerns. This can be achieved by creating awareness among the people by applying appropriate communication strategy about the importance of river and the suitable waste disposal. The community and concerned body should take the controlling mechanism such as treating wastewater discharged from different sources into the river and controlling municipal wastes discharged from the town into water body. For sustainable management of this water resource, environmental protection agencies at different levels and other concerned administrative and/or nongovernmental bodies should support by fund and by preparing suitable waste disposal areas.

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**Appendix 1**: River Site characterization (only slightly modified from (Harding et al., 2009).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Site** | **Site code** | | **Site name** | | **Site Alt.** m | **GPS** | **N-** |
| | **Assessor** | | **Date** | | | | **E-** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **In-stream information** | **1. Streambed substrate, mm** | Clay/silt/ sand/mud (≤2) | Gravel (>2-16) | Pebble (>16-64) | Cobble (>64-256) | Boulder (>256-4000) | Bedrock (>4000) | **Additional notes** |
| | **2. Bed stability** | Highly stable | Moderately stable | Highly unstable | **3. Mean water depth** | ___m | |
| | **4.Macrophytes** | Submergent | Marginal | Emergent | Floating | None | |
| | **5. Moss** | Absent | Sparse | Common | Abundant | Dominating | |
| | **6. Periphyton** | None visible | Sparse | Common | Abundant | Dominating | |
| | **7. Wood** | | Sparse | Common | Abundant | Dominating | |
| | **8. Leaves** | Absent | Sparse | Common | Abundant | Dominating | |
| | **9. Shading** | Open | Partial | Heavily shaded | **10. Overhanging vegetation** | Yes/No | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Channel and bank information** | **1. Channel (wetted) width** | ____m | **2. Channel (bankfull) width** | ___m | **3. Vegetated bank width** | ___ m | **4. Site (reach )** | ___m | **Additional notes** |
| | **5. Channel shape** | Artificially channelized | Straight | Weakly sinuous | Strongly sinuous | | | | |
| | **6. Flow conditions** | Low flow | Base flow | High flow | | | | | |
| | **7. Flow types** | Riffle/rapid | Run | Pool | Other | **Flow rate** | _____m/s | | |
| | **8. Lower bank (Channel) height** | Left __m | Right __m | **Mean Lower chan. height** ___m | **Upper bank (channel) height** | Left ___ m | Right ___ m | **Mean upper chan. height** ___m | |
| | **9. Bank stability** | Stable | Mostly stable | Highly unstable | **Bank under cut** | Yes/No | | | |
| | **10. Bank cover** | Soil | Stony | Grass | Tussock | Bush | Trees | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Riparian and catchment information** | **1. Riparian cover** | Soil | Rock/ | Grass | Tussock | Wetland | Ferns | Shrubs | Native trees | **Additional notes** |
| | | Deciduous Exotic | Conifers | Others | **2. Riparian** | L- ____m | R- ___m | | | |
| | **3. Proble** | Yes/No | Photo taken – Yes/No | Type(s): | | | | | | |
| | **4. Stock** | L – Yes/No | R – Yes/No | **Stock damag** | None | Minor | Moderate | High | | |
| | **5. Adjacent** | Conservative/ reserve | Short graz | Long ungrazed | Production forest | Others | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Crops | Horticulture | Road | | Bridge | Urban | Other | |
| | **6. Catchment** | Native forest | Plantation forest | | Farming | Urban | Industry | Mining | Road | Others |

**Appendix 2:** Summary of Environmental parameters measured during the study period

| | Ambient T (°C ) | | | Water temp (°C) | | | DO (mg/L) | | | pH | | | EC (μS/cm) | | | TSS (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sites | Wet | Dry | Mean | Wet | Dry | Mean | Wet | Dry | Mean | Wet | Dry | Mean | Wet | Dry | Mean | Wet | Dry | Mean |
| Fincha R1 | 29 | 31 | 30 | 23.9 | 28.6 | 26.25 | 7.28 | 3.65 | 5.47 | 7.52 | 7.24 | 7.38 | 42.7 | 69.7 | 56.2 | 0.006 | 0.002 | 0.004 |
| Fincha R2 | 25 | 33 | 29 | 24.4 | 29.5 | 26.95 | 7.89 | 3.83 | 5.86 | | 7.23 | 7.23 | 41.8 | 68.6 | 55.2 | 0.006 | 0.011 | 0.008 |
| Fincha R3 | 21.5 | 28.5 | 25 | 22 | 27.3 | 24.65 | 7.11 | 5.8 | 6.46 | 7.65 | 7.54 | 7.595 | 44.1 | 70.7 | 57.4 | 0.003 | 0.006 | 0.005 |
| Fincha R4 | 24 | 28 | 26 | 23.7 | 26.6 | 25.15 | 7.04 | 5.38 | 6.21 | 7.69 | 7.56 | 7.625 | 40.8 | 70.3 | 55.55 | 0.005 | 0.007 | 0.006 |
| Fincha R5 | 24 | 29 | 26.5 | 22.5 | 25.1 | 23.8 | 6.97 | 5.62 | 6.30 | 7.79 | 7.28 | 7.535 | 39.9 | 69.2 | 54.55 | 0.015 | 0.005 | 0.010 |
| Fincha R6 | 23 | 27.5 | 25.25 | 22.2 | 24.9 | 23.55 | 7.12 | 6.23 | 6.68 | 7.75 | 8 | 7.875 | 40.1 | 68.6 | 54.35 | 0.015 | 0.007 | 0.011 |
| Tams R1 | 19 | 30 | 24.5 | 18.2 | 27.2 | 22.7 | 6.86 | 7.05 | 6.96 | 8.06 | 8.42 | 8.24 | 48.4 | 75.5 | 61.95 | 0.009 | 0.005 | 0.007 |
| Tamsa'a R2 | 18 | 30.5 | 24.25 | 17.9 | 26.7 | 22.3 | 6.88 | 6.75 | 6.82 | 8.03 | 8.3 | 8.165 | 50.1 | 76.1 | 63.1 | 0.011 | 0.007 | 0.009 |
| Tamsa'a R3 | | 23 | 23 | 18.2 | 19.8 | 19 | 7.04 | 5.74 | 6.39 | 7.83 | 7.7 | 7.765 | 51.5 | 83.4 | 67.45 | 0.014 | 0.006 | 0.010 |
| Tamsa'a R4 | 22 | 19.5 | 20.75 | 19.1 | 19.1 | 19.1 | 6.78 | 7.41 | 7.10 | 8.32 | 7.52 | 7.92 | 52.7 | 86.2 | 69.45 | 0.015 | 0.005 | 0.010 |
| TTR | 26 | 19.5 | 22.75 | 21.3 | 18.5 | 19.9 | 6.6 | 6.58 | 6.59 | 8.52 | 7.54 | 8.03 | 160.7 | 162 | 161.35 | 0.018 | 0.003 | 0.011 |
| Tamsa'a R5 | 24 | 29.4 | 26.7 | 21.3 | 26.3 | 23.8 | 6.53 | 6.5 | 6.52 | 8.51 | 8.13 | 8.32 | 62.6 | 97.9 | 80.25 | 0.002 | 0.007 | 0.005 |
| DogajaR1 | 27 | 27 | 27 | 22.4 | 21.2 | 21.8 | 7.24 | 7.3 | 7.27 | 8.28 | 7.75 | 8.015 | 48.3 | 96.9 | 72.6 | 0.004 | 0.007 | 0.005 |
| DogajaR2 | 25 | 27.5. | 25 | 21 | 21.5 | 21.25 | 6.89 | 7.4 | 7.15 | 8.37 | 7.72 | 8.045 | 48.7 | 96.2 | 72.45 | 0.010 | 0.006 | 0.008 |
| Do | 25 | 28. | 26. | 20 | 21 | 21. | 7. | 7. | 7.3 | 8. | 8.5 | 8.4 | 49.8 | 97.9 | 73.8 | 0.01 | 0.00 | 0.01 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| gajaR3 | | 5 | 75 | .8 | .6 | 2 | 11 | 62 | 7 | 38 | 1 | 45 | | | 5 | 6 | 8 | 2 |
| DogajaR4 | 26 | 30 | 28 | 21.1 | 22.5 | 21.8 | 7.17 | 7.38 | 7.28 | 8.37 | 8.46 | 8.415 | 50.6 | 100.5 | 75.55 | 0.019 | 0.051 | 0.035 |
| DTR | 25.5 | 29 | 27.25 | 21.9 | 26 | 23.95 | 6.5 | 4.68 | 5.59 | 8.17 | 8.21 | 8.19 | 83.17 | 134.8 | 108.99 | 0.017 | 0.006 | 0.011 |
| DogajaR5 | 24 | 30 | 27 | 21.3 | 23.6 | 22.45 | 7.19 | 6.88 | 7.04 | 8.45 | 8.44 | 8.445 | 50.4 | 106.5 | 78.45 | 0.015 | 0.010 | 0.012 |

Table 2 (Continued)

| | **$NH_3$ (mg/L)** | | | **$NO_3^-$ (mg/L)** | | | **$PO_4^{3-}$ (mg/L)** | | | **Tot. $PO_4$3- (mg/L)** | | | **$BOD_5$ (mg/L)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sites** | **Wet** | **Dry** | **Mean** | **Wet** | **Dry** | **Mean** | **Wet** | **Dry** | **Mean** | **Wet** | **Dry** | **Mean** | **Wet** | **Dry** | **Mean** |
| FinchaR1 | 0.07 | 0.07 | 0.07 | 2.89 | 3.65 | 3.27 | 1.77 | 1.11 | 1.4385 | 1.623 | 0.12 | 0.87 | 1.19 | 3.9 | 2.55 |
| FinchaR2 | 0.17 | 0.10 | 0.14 | 3.12 | 3.24 | 3.18 | 0.77 | 0.78 | 0.777 | 1.803 | 1.11 | 1.46 | 1.58 | 3.66 | 2.62 |
| FinchaR3 | 0.04 | 0.11 | 0.07 | 0.32 | 3.47 | 1.89 | 1.33 | 1.11 | 1.221 | 2.016 | 1.29 | 1.65 | 0.9 | 4.69 | 2.80 |
| FinchaR4 | 0.06 | 0.11 | 0.09 | 2.98 | 3.35 | 3.17 | 1.00 | 0.84 | 0.9195 | 1.974 | 0.93 | 1.45 | 0.51 | 2.69 | 1.60 |
| FinchaR5 | 0.13 | 0.09 | 0.11 | 1.74 | 3.82 | 2.78 | 0.92 | 0.84 | 0.879 | 2.196 | 1.23 | 1.71 | 1.11 | 4.66 | 2.89 |
| FinchaR6 | 0.05 | 0.01 | 0.03 | 3.25 | 5.52 | 4.39 | 0.61 | 0.69 | 0.6495 | 1.995 | 2.43 | 2.21 | 0.87 | 1.52 | 1.20 |
| TamsR1 | 0.13 | 0.09 | 0.11 | 4.80 | 1.88 | 3.34 | 2.14 | 0.84 | 1.488 | 2.37 | 3.42 | 2.90 | 1.34 | 2.63 | 1.99 |
| Tamsa’aR2 | 0.20 | 0.11 | 0.15 | 5.35 | 2.70 | 4.02 | 1.82 | 0.81 | 1.3125 | 2.49 | 3.72 | 3.11 | 2.23 | 1.36 | 1.80 |
| Tamsa’aR3 | 0.22 | 0.08 | 0.15 | 5.30 | 2.79 | 4.05 | 1.99 | 0.93 | 1.458 | 2.34 | 3.93 | 3.14 | 0.84 | 4.59 | 2.72 |
| Tamsa’aR4 | 0.30 | 0.10 | 0.20 | 6.10 | 2.62 | 4.36 | 1.62 | 0.93 | 1.2735 | 2.517 | 1.77 | 2.14 | 1.88 | 1.86 | 1.87 |
| TTR | 0.27 | 0.10 | 0.19 | 5.10 | 3.60 | 4.35 | 1.47 | 0.93 | 1.2 | 2.913 | 1.14 | 2.03 | 3.69 | 3.36 | 3.53 |
| Tamsa’aR5 | 0.17 | 0.11 | 0.14 | 5.14 | 2.52 | 3.83 | 0.68 | 0.75 | 0.714 | 2.043 | 4.2 | 3.12 | 1.83 | 2.45 | 2.14 |
| DogajaR1 | 0.02 | 0.09 | 0.05 | 5.32 | 2.15 | 3.74 | 2.29 | 0.69 | 1.488 | 2.187 | 1.05 | 1.62 | 2.16 | 1.79 | 1.98 |
| DogajaR2 | 0.02 | 0.09 | 0.06 | 4.69 | 2.01 | 3.35 | 0.88 | 0.42 | 0.651 | 2.874 | 0.96 | 1.92 | 1.37 | 1.81 | 1.59 |
| DogajaR | 0.0 | 0.1 | 0.0 | 4.0 | 1. | 2.72 | 0.1 | 0.3 | 0.21 | 2.8 | 0.7 | 1.8 | 1.0 | 2.4 | 1.74 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 4 | 1 | 7 | 6 | 37 | | 3 | 0 | 3 | 98 | 8 | 4 | 3 | 5 | |
| DogajaR | 0.0 | 0.1 | 0.1 | 4.9 | 2. | | 1.5 | 0.8 | 1.19 | 2.8 | 0.8 | 1.8 | 1.0 | 2.6 | |
| 4 | 8 | 7 | 3 | 6 | 11 | 3.54 | 8 | 1 | 25 | 59 | 4 | 5 | 1 | 4 | 1.83 |
| DTR | 0.0 | 0.1 | 0.0 | 5.6 | 2. | | 0.8 | 0.7 | 0.78 | 2.1 | 0.8 | 1.5 | 1.3 | 4.7 | |
| | 1 | 4 | 7 | 5 | 58 | 4.11 | 2 | 5 | 6 | 96 | 7 | 3 | 6 | 5 | 3.06 |
| DogajaR | 0.0 | 0.1 | 0.0 | 5.6 | 1. | | 1.2 | 0.6 | 0.95 | 2.6 | 0.7 | 1.6 | 1.0 | 2.5 | |
| 5 | 3 | 5 | 9 | 7 | 84 | 3.75 | 5 | 6 | 25 | 07 | 2 | 6 | 8 | 8 | 1.83 |

**Appendix 3:** Summary of the macroinvertebrate diversity of the studied rivers based on identification keys(Subramanian and Sivaramakrishnan, 2004) to FFG = functional feeding group; CG = collector-gatherer; FC = Filterer-collector; P = Predator

| | | | Abundance | | |
|---|---|---|---|---|---|
| **Order** | **Family** | **FFG** | **Fincha** | **Tamsa** | **Dogaja** |
| Ephemeroptera (Mayflies) | Baetidae | CG, Scrappers | 47 | 210 | 263 |
| Hemiptera (Water bugs) | Belostomatidae | Predator | 23 | 16 | 22 |
| Ephemeroptera (Mayflies) | Caenidae | GC | 0 | 42 | 0 |
| Odonata (damselflies) | Calopterygidae | Predator | 4 | 9 | 7 |
| Diptera (Flies) | Ceratopogonidae | Predator | 1 | 83 | 55 |
| Diptera (Flies) | Chironomidae | CG (Sc, FC, P) | 0 | 38 | 106 |
| Odonata (damselflies) | Coenagrionidae | Predator | 45 | 25 | 27 |
| Hemiptera (Water bugs) | Corixidae | CG | 11 | 0 | 0 |
| Megaloptera | Corydalidae | Predator | 1 | 0 | 0 |
| Diptera (Flies) | Culicidae | CF, CG | 8 | 0 | 0 |
| Coleoptera (water beetles) | Dytiscidae (Predaceous diving beetles) | Predators | 0 | 1 | 0 |
| Trichoptera (Caddisflies) | Ecnomidae | Predators | 11 | 88 | 38 |
| Hemiptera (Water bugs) | Gerridae | Predator | 28 | 59 | 20 |
| Coleoptera (water beetles) | Gyrinidae | Predator | 116 | 0 | 7 |
| Ephemeroptera (Mayflies) | Heptageniidae | CG | 39 | 55 | 45 |
| Annelida (Arhynchobdellida) | Hirudinidae (Leeche) | Parasite | 0 | 25 | 21 |
| Coleoptera (water beetles) | Hydraenidae | Scrappers (Adults), Predator (larvae) | 0 | 0 | 1 |
| Hemiptera (Water bugs) | Hydrometridae | Predator | 8 | 0 | 0 |
| Coleoptera (water beetles) | Hydrophilidae | Predator (Larvae), CG (Adults) | 5 | 0 | 2 |
| Trichoptera (Caddisflies) | Hydropsychidae | CF | 23 | 0 | 0 |
| Coleoptera (water beetles) | Hydroscaphidae | Scraper | 3 | 1 | 4 |
| Odonata (dragonflies) | Libellulidae | Predator | 42 | 45 | 18 |
| Trichoptera (Caddisflies) | Lepidostomatidae | Shredder | 10 | 0 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| Ephemeroptera (Mayflies) | Leptophlebiidae | CG | 7 | 0 | 0 |
| Odonata (damselflies) | Lestidae | Predator | 32 | 104 | 42 |
| Mollusc (Gastropoda) | Lymnaeidae (feshwater snails) | Scraper | 0 | 12 | 0 |
| Hemiptera (Water bugs) | Nepidae | Predator | 2 | 4 | 4 |
| Plecoptera (Stoneflies) | Perlidae | Predator | 15 | 0 | 0 |
| Crustacea (Decapoda) | Potamonidae (freshwater crab) | Predator (Omnivore) | 6 | 1 | 0 |
| Coleoptera (water beetles) | Psephenidae | Scraper | 0 | 1 | 0 |
| Trichoptera (Caddisflies) | Rhyacophilidae | Predator | 2 | 0 | 0 |
| Mollusc (Veneroida [Bivalvia]) | Sphaeriidae (freshwater clams) | CF | 0 | 46 | 35 |
| Diptera (Flies) | Syrphidae (hover flies) | CG | 0 | 7 | 0 |
| Diptera (Flies) | Tipulidae Crane flies) | Shredders (P, CG) | 5 | 5 | 4 |

**Appendix 4 :** The threerelative studied rivers

Dogaja River

Tamsa'a River

Fincha River

**Appendix 5:** When physico-chemical parameters were measured and macroinvertebrates were sorted on sites

**Appendix 6:** During the samples were analyzed in Jimma University Environmental Science and Technology Laboratory

**Appendix 7:** Macroinvertebrates were identified into their familes in Jimma University Department of Biology in Zoology Laboratory