ASSESSMENT OF THE EFFECT OF EFFLUENT DISCHARGE FROM COFFEE PROCESSING PLANTS ON RIVER WATER QUALITY IN SOUTH WESTERN ETHIOPIA

M.Sc. THESIS

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NOVEMBER, 2012

JIMMA UNIVERSITY

ASSESSMENT OF THE EFFECT OF EFFLUENT DISCHARGE FROM COFFEE PROCESSING PLANTS ON RIVER WATER QUALITY IN SOUTH WESTERN ETHIOPIA

M.Sc. Thesis

By

Tadesse Mosissa

A Thesis Submitted to the School Of Graduate Studies, Jimma University, College of Agriculture and Veterinary Medicine

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Natural Resources Management, Specialization in Integrated Watershed Management

NOVEMBER, 2012

JIMMA UNIVERSITY

APPROVAL SHEET
School of Graduate Studies

As thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared, under my guidance, by **Tadesse Mosissa Ejeta**, entitled **"Assessment of the Effect of Effluent Discharge from Coffee Processing Plants on River Water Quality in South Western Ethiopia"**. I recommend that it be submitted as fulfilling thesis requirement.

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As member of the board of Examiners of the M.Sc. Thesis Open Defense Examination, we certify that we have read, evaluated the thesis prepared by **Tadesse Mosissa Ejeta** and examined the candidate. We recommended that the thesis could be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Natural Resources Management, Specialization in Integrated Watershed Management.

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DEDICATION

I dedicate this thesis to my beloved father, Mosissa Ejeta and my mother Jife Nagasa for nursing me with affection and love, and for their dedicated partnership in the success of my life.

ACKNOWLEDGEMENTS

First and for most I would like to thank the almighty God, who made all my way comfortable to do everything throughout my life.

I am strongly indebted to my research advisor Alemayehu Haddis (Associate Professor) for his unreserved advice and skillful contribution to this thesis and his meticulous comments I received throughout my thesis work. I would like to thank Mr. Berhanu Geneti and Mr. Dereje Bekele for his brotherly and helpful encouragement during hard times in my personal life and the selection of research thesis title for this study hitherto critical and valuable comments have been decisive on the scientific merits and shape of the thesis.

I also really indebted to Dr. Debela Hunde, Mr. Endalkachew Kissi, Mr. Alemayehu Ragasa and Mr. Tariku Mokonon for their comments at the early stage of the work and for giving me valuable suggestions at different times during this study. I do not forget Dr. Abebe Beyene and Dante R. Santiago for their keen interest and help in the laboratory work on the verification and identification of the macro- invertebrates sampled from river water. I am also indebted to JUCAVM for partially financing my study. I would like to convey my sincere thanks to Mr. Seyum Derib for his useful comments in the selection of study area and sampling sites and for his help with patience and continuously facilitating laboratory works with technical assistance and also Mr. Bayu Dume from the department of Natural Resource Management (NRM) for his unreserved help in my laboratory works. I lack words of appreciation for my brother Dereje Mosissa who has opened my eye to a world of new possibilities and opportunities. He has been a great mentor, who supported, encouraged and assisted me financially during the study and he has been a source of inspiration for me throughout my research work.

My immense thanks go to my colleagues and friends for their encouragement during my study. I owe my particular regards to Fekadu Gemechu and Temesgen Deressa for their readiness whenever I called them for help. My unforgettable memory takes me back to my friend, Merga Negassa who used to stand beside me in times of need and consternation. I would like to express my heartfelt gratitude to all people who helped and encouraged me in one way or another in connection with my thesis. If I have missed names of creditable personalities and institutions in the list, it is not intentional but failure to notice putting pen to paper. Last but not least, I am indebted to my parents for their encouragement all the time.

STATEMENT OF THE AUTHOR

First, I declare that this M.Sc thesis is my genuine work and has not been submitted to any other institution anywhere for award of any academic degree, diploma, or certificate. All sources of the materials used in this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for the award of the degree of master in Natural Resources Management (Specialization in Integrated Watershed Management) at Jimma University College of Agriculture and Veterinary Medicine, Ethiopia. A brief quotation from this thesis is allowable without special permeation provided that an accurate acknowledgment of the source is made.

Name: Tadesse Mosissa Ejeta Signature: ___________________________

Place: JUCAVM, Jimma, Ethiopia Date of Submission: ___________________

BIOGRAPHICAL SKETCH

The author, Tadesse Mosissa Ejeta, was born in Gida Ayana District, East wollega zone, Ethiopia on August 5, 1988 from his father Mosissa Ejeta and his mother Jife Nagasa. He attended and completed grade 1 to 8 at Gida Ayana Elementary School (1994-2001) and grade 9 to 12 at Gidda Ayana Senior Secondary School (2001-2005), in East Wollega, Ethiopia. He joined Haramaya University, Agricultural faculty in September 2005, and graduated with a B.Sc degree in Soil and Water Engineering and Management in July 2008. The author was employed by Oromia Agriculture and Rural Development Bureau, September 2009 and served for the organization as an expert of soil and water conservation and leader of integrated watershed management, Limmu District in Rural Development and Agricultural Office of East Wollega Zone, for two years. In September 2010, he joined the school of graduate studies at Jimma University, College of Agriculture and Veterinary Medicine to pursue his graduate study in Natural Resource Management (Specialization in Integrated Watershed Management).

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LIST OF ABBREVIATIONS

AF	Accumulation Factor
AMT	Ambient Temperature
ANOVA	Analysis of Variances
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CRD	Complete randomized design
CV	Coefficient of variation
D	Simpson's diversity index
DO	Dissolved Oxygen
DS_1	Downstream sites one
DS_2	Downstream sites two
DS	Downstream sites
E	Equitability or Evenness index
EC	Electric conductivity
EFF	Effluent discharge site (Effluent)
ENP	Entry point
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Trichoptera Index
F	Total number family in the sample
GLM	General Linear Model
H’	Shannon-Wiener Diversity Index
INF	Influent
Max	Maximum
Min	Minimum
MSD	Minimum significance difference
Org-N	Organic nitrogen
Orth- P	Orthophosphate
RBPs	Rapid-Bioassessment Protocols
RRC	River Recovery Capacity
S	Specious richness taxa

SS	Settleable solid
SEM	Standard error mean
SW	South Western
TDS	Total dissolved solid
TFS	Total fixed Solid
TN	Total nitrogen
TSS	Total Suspended Solid
TS	Total solids
TVS	Total volatile solid
TURB	Turbidity
UPS	Upstream sites
WT	Water temperature
WHO	World Health Organization

ABSTRACT

South Western Ethiopia is a major coffee growing region with coffee refineries located along rivers water. With intensification of wet coffee processing and rampant waste discharge, an increased pressure on fauna and flora of river water bodies becomes evident. This study was conducted to find out the effects and extent of effluents generated from coffee refineries on river water quality based on the physico-chemical and nutrient parameters and macro-invertebrate assemblages as biological indicators. The experiment was done using CRD with 3 replications and composite. Sampling sites were selected to represent different ecological and environmental variations within each river, in order to understand the influences of effluent discharge by coffee refineries induced stress on physical, chemical, nutrient and biological attributes of the river water quality. A total of 72 water samples were collected at 6 sampling sites (INF, EFF, UPS, ENP, DS_1 and DS_2) in 4 rivers. The physic-chemical and nutrient parameters and biological indicators sampling was done immediately during the peak time of coffee refineries. The results were subjected to different statistical analyses to analysis of variance (ANOVA) using SAS. Results of physico-chemical and nutrient parameters and biological indicators analysis revealed that highly significant difference interaction effect among 4 rivers and sites at ($p<0.01$). This study indicated that mean value of river water parameters analysis exceed the maximum permissible limit set by WHO at DS_2. It was observed during the study that coffee refineries discharge their rampant waste into ambient and in rivers water bodies. These effects were observed to have serious impact on the Limu Kosa District of river water and ecosystem. The mean average abundance of UPS of all river water were dominated by pollution sensitive taxa (Ephemeroptera, Hemispheres, Trichoptera, Plecoptera and Coleoptera) while DS were dominated by pollution tolerant families (Simulidae, Chironomidae, leeches). The UPS and DS river water quality was distinctly different when described by physico-chemical and nutrient parameters and biological assemblages (species richness, diversity and abundance) indicators. From these results, it can be revealed that river water quality of DS of Limu Kosa District were adversely affected and impaired by effluents discharged from the coffee refineries as compared to UPS. The alteration in river water quality parameters were more pronounced immediately during the peak time of coffee refineries. The high AF and RRC of BOD, COD and NH_3-N at DS might be a pointer to the efficiency of the river's no aeration mechanism which was no free flow of river water. All physico-chemical and nutrient parameters were negatively and significantly correlated among all biological indicators, while DO and pH were positively significantly correlated at ($p<0.05$). This study shows that only tolerant taxa inhabit the impacted sites, especially over the peak time of coffee refineries. It was also observed at some private sites influences of effluent discharge by coffee refineries wastes dumped in river water making conditions worse than government site. Therefore, thus concluded that the investigated area of Ketalenca river water, almost all the measured physico-chemical and nutrient parameters analysis showed an increasing trend from UPS to DS it has not yet been so polluted and might not causes any health effects on aquatic ecosystem as compared to that of the Kebena and Awetu river water. The result of the present study is used as a basis for further research needs to be conducted on the effects and extent of effluents generated from coffee refineries. Further in depth study and technology assessment is highly recommended.

Key words: Biological indicators, Correlation, DS, DS_1, DS_2, EFF, ENP, INF, Physico-Chemical and nutrient parameter, Pollution tolerant taxa, UPS and Water bodies

1. INTRODUCTION

1.1. Background

Water is the most important component among the natural resource. The availability of adequate water in terms of quality and quantity is essential to all the forms of life: from very small creature to very complex systems of animals and human being existence. In the past, people only recognized the importance of water from a quantity view point rather than quality (Adewoye, 2010; Walakira, 2011; Walakira and James, 2011).

South-western Ethiopia is a major coffee growing region with coffee processing plants located along river water banks for easy availability of water, high dependency on water amount and also enormous volumes disposal of these wastes into ambient environment and water bodies. With intensification of wet coffee processing and rampant waste discharge, an increased pressure on fauna and flora of river water bodies becomes evident. Currently coffee generates more than 35 percent of the total export earnings from Ethiopia. According to (Jimma Zone Agricultural and Rural Development Office, 2012) coffee production in Jimma Zone covers more than 20 percent of the total coffee export share of Ethiopia. According to the same source, an estimated 35-50 percent of the population in Jimma Zone is directly or indirectly engaged in coffee production, processing and marketing. The Jimma Zone produces more than $32x10^6$ kg of processed coffee per year (Jimma Agricultural Research Center data, 2012) and other studies have calculated that pulping alone can consume 80–93L of water per 1 Kg of parchment coffee (Selvamurugan *et al*.,2010a; Selvamurugan *et al*., 2010b).

One of the most critical problems of developing countries is the ever increasing population and the progressive adoption of an industry processing based lifestyle that has led to an increasing anthropogenic impact on the ambient environment and river water bodies. In SW Ethiopia, water bodies are the primary dump sites for disposal of wastes, especially the effluents from coffee processing plants containing wide varieties of synthetic and organic wastes that are near them (Alemayehu Haddis and Devi, 2008; Abebe Beyene *et al*., 2011). More challenging is unsafe disposal of these wastes into the ambient environment and river water bodies. Water bodies especially freshwater (river) reservoirs are the most affected. Water pollution is an acute problem in all the water bodies and major river water quality is the gloomy setback for development in coffee producing Zone, especially in SW Ethiopia (Asamudo *et al*., 2005; Kanu *et al*., 2011; Ewa, 2011).

The actual volume of water used for coffee processing it depending on the conventional or advanced wet coffee processing plants. That means a lot of water is required in wet coffee processing plant and typically river water is used to remove the coffee pulp (Tsigereda Kebede, 2011; Walakira and James, 2011). These are generating approximately millions of liter of effluent per day at peaked time coffee of processing plants. The effluent from 1000kg of parchment coffee processed following by wet-processing method often generate comparable to the human waste that can be generated by 3000-5600 people per day. To produce 1 Kg of parchment coffee, by generating water for washing and pulping causes pollution equivalent to 5-6 people per day (Sarah, 2011). This river water bodies end up with contaminated organic matter comprises inorganic matter. Larger amount of water is drawn out than what is actually required due to careless and excessive used, a major bulk of water is drained out in an impure state as waste (Alemayehu Haddis and Devi, 2008; Abebe Beyene *et al*., 2011).

Alarmingly increasing rampant wet coffee processing plants are contributing to dwindling surface water quality in Southwestern Ethiopia to a greater extent. However, alarmingly and worrisome (exacerbate**)** increased wastewaters from the coffee processing plants tend to carry a huge load of organic and inorganic pollutants (Ewa, 2011; Ram S. Lokhande *et al*., 2011*)*. According to (Alemayehu Haddis and Devi, 2008; Yared Kassahun *et al*., 2010; Abebe Beyene *et al*., 2011) water quality dwindling in Limu Kosa District has become a main threat to human health, especially for those living downstream sites areas and along the main river water draining through the community. Green coffee bean production in the coffee processing plants involves main steps to removing the coffee pulp, washing the green coffee beans and fermentation. The byproducts (e.g. de-mucilage, pulping) during the wet processing generates vast volumes of waste material to river water near the area, especially during the peak time of coffee processing plants season. In addition, plant cleaning, sorting and grading, soaking and floating and floor produces high quantities of polluted river water (Tsigereda Kebede, 2011; Walakira, 2011).

Coffee processing effluents, having both chemical (with very high organic content) and microbial contaminant, results in a rather chaotic layout of utilities such as water supply, domestic and Agricultural. The decline in utilization of the river water for water supply, domestic and Agricultural purposes causes serious soil fertility, as noticed by a few people exploiting the available free land space around the coffee processing for intensive farming. As a consequence, there is a risk to human health from intake of pollutants through consumption of such crops and drinking of river (Alemayehu Haddis and Devi, 2008).

Nowadays, the Kebena, Awetu, Bonke and Ketalenca river water of Limu Kosa District are faced with increasing problems of being a receptacle for untreated and rampant coffee processing plants effluent. This has often gradually rendered the Kebena, Awetu, Bonke and Ketalenca river water of Limu Kosa District river water unsuitable for various beneficial purposes and to maintain and restore the wholesomeness of river water in terms of its ecological sustainability is the logical necessity of today (Kanu *et al*., 2011; Nitin, 2011; Ewa, 2011). These effluents from coffee processing plants have a great toxic influence that causes pollution of the river water body.

By examining patterns in the responses of benthic micro invertebrates to potential stressors, especially nutrients and suspended material, associated with coffee wastes discharges, it may be possible to assess the extent and effect to which pollution alters the physico-chemical and nutrient characteristics and assemblages of benthic macro-invertebrates in river water and eco-systems. Benthic macro-invertebrates assemblage composition and distribution within and among water quality are interrelated and excellent indicators of water quality and easy to respond to organic and inorganic pollution load from human interferences. Most of coffee processing plants in Limu Kosa District are lack efficient effluent treatment plants (Henry, 2008). Well treated wastewater from these processing plants could be used for water supply, domestic and irrigation purposes.

Depending on previous studies recommendation, wet coffee processing plants is practiced in some parts of Jimma zone in order to produce wastewater that has effect on the ambient environment and water bodies. However; no studies have been detail conducted regarding the evaluation to represent different ecological and environmental variations within each river water sites, in order to understand the influences of effluent discharge by coffee processing plants inconsistence in the variation of physico-chemical, nutrient and biological attributes of the river water quality among river water courses. Previous studies have been conducted simply to assess the pollution load of the effluent from coffee processing plant. However, this study deals with the extent of both the degree of contamination as a result of effluent discharge by coffee processing plant inputs was estimated by the accumulation factor (AF) and river water pollution of recovery in percent by the river recovery capacity (RRC) values at downstream sites two as compared to the reference point upstream sites.

Therefore, the current research was initiated to study focused on two rivers within the same ecoregion, one in wet coffee processing plants in private sector and the other two in government sector, with the aim of assemblages of benthic macro invertebrate diversity, taxa richness and evenness in relation to water quality and nutrient parameters to assess the effects and extent of the four wet coffee processing plants practices on water quality along the river water courses and overall ecosystem integrity in Limu Kosa District.

General objective

The general objective of the study was to determine the effects and extent of effluents generated from coffee processing plants on river water quality based on the physic-chemical parameters and benthic macro-invertebrate assemblages as biological indicators of river water quality in Limu Kosa District.

Specific Objectives

The specific objectives were:

1. To determine the effects and extent of effluent generated from coffee processing plants on the river water quality based on physico-chemical parameters.
2. To determine the effects of wastes generated from coffee processing plants on river water quality based on benthic macro-invertebrate assemblages as biological indicators.

2. LITERATURE REVIEW

2.1. General Concept of Coffee Refineries on Water Qualities

In the Jimma Zone effluent generated from coffee processing plants is designate to dump in to river water. The mucilages (fermentation), pulp process and waste washing from green coffee bean has been causing serious water quality problems at the local level not only due to the consumption of large water, but more due to the discharge of effluents with large volumes of organic waste to the stream, river course and vicinity. This site is also used for specific industrial, hazardous wastes. This effluent is being directly discharged to the nearby ambient of water bodies and in water bodies, thus causing many severe health problems like spinning sensation, eye, ear and skin irritation, stomach pain, nausea and breathing problem among the residents of nearby areas and bad odor in the surrounding areas. It is breeding site of disease vectors, when dumped around the coffee processing plants and pollution of surface water and ground water bodies through run-offs and leaching respectively. These consequences can cause serious water pollution (surface and underground water) by adding vast concentration of toxic elements in soils, which results in decreased land productivity and increased use of chemicals for its solution. Coffee effluents and solid wastes are organic and acetic acidic from the fermentation of the coffee that make the wastewater very acidic (with pH as low as 2.9), and has a high content of suspended and dissolved organic matter. However, other toxic substances (chemicals) found in coffee wastewater like tannins, alkaloids (caffeine) and polyphenolics make the river water for biological degradation of organic material in the wastewater more difficult (Chanakya and De Alwis, 2004; Alemayehu Haddis and Devi, 2008).

Thus, the decomposition of this organic and inorganic waste matter in the Agricultural land, rivers, stream and lakes makes the water unsuitable for various uses and damages the aquatic ecosystem (including all the associated biota), because of the level to which the self-purification mechanism of the river was able to refresh water in the presence of pollutants was very low. Especially, the communities residing in the downstream river sites that use the water for different purposes are affected by the water pollution and breeding of disease vectors and deterioration of water quality in the most downstream sites (Yared Kassahun *et al*., 2010). However, the lack of the hitherto enforcement of river water area assessment before issuing the permit to the newly established processing stations and failure of monitoring and evaluation activities of the existing processing stations have resulted in the generation of huge amounts of processing byproducts around major river catchments used for coffee processing in Ethiopia. The utilization of the processing wastes is also another potential option for pollution control (Yared Kassahun *et al*., 2010; Rizal *et al*., 2012).

Use of well-designed treatment technologies for coffee waste treatment as the poorly designed and constructed lagoons do not curb pollution of water bodies and are resulting in longer-term threat to irrigation, aquatic life, human health and wildlife. Although high concentration of waste from coffee processing is a valuable resource to make biogas, compost or bio char and nutrient-rich animal food, it is usually dumped into nearby water courses (Yared Kassahun *et al*., 2010; Abebe Beyene *et al*., 2011). Thus, treatment of wastewater is essential in order to reduce the spread of communicable diseases caused by the pathogenic organisms and to prevent the pollution of surface and ground water. Also Recycling of used water is strongly advised for both fully washed and semi-washed coffee. Characterization in terms of its physical, chemical, and biological composition of wastes is essential for an effective and economic waste management program (Chanakya and De Alwis, 2004; Bhatia, 2005).

As part of the solution to address the problem, it is necessary to identify the source and characterize the wastewater from coffee processing plants, which are dumped into river water. Understanding how the wastewater is produced is as important as knowing what contaminants are present (Irene Liu, 1999). Thus, a review of coffee processing plants provides the knowledge base needed to evaluate the best place to reduce, recover, or treat individual waste River. According to Irene Liu (1999) the important points to characterize the wastewater should include the following:

1. All refineries activities within the facility i.e. raw materials used and processing records.
2. Detailed drawings of the plant showing the locations of processing units, their water distribution and wastewater dumped and collection systems.
3. The quantity, analysis, frequency, and flow rate of the waste water quality discharge from each unit process.
4. The frequency, extent, and type of monitoring and sampling used in accordance with the nature and variability of each waste water quality.
5. The flow measurement and location of sample collection points within the facility indicating the type of monitoring stations (permanent or temporary) used.

2.2. The Use of Water Bodies as Receiving for Industrial Effluents

Population explosion, haphazardous rapid urbanization, industrial and technological expansion, energy utilization and wastes generation from domestic and industrial sources have rendered many water resources unwholesome and hazardous to human being and other living resources (Nubi *et al*.,2008; Kanu *et al*., 2011). Water pollution is now a significant gloomy setback for development in coffee producing countries and this also appears to be the case in Ethiopia (Alemayehu Haddis and Devi, 2008; Abebe Beyene *et al*., 2011). Coffee processing plants effluents are a main source of direct and often continuous input of pollutants into aquatic ecosystems with long-term implications on ecosystem functioning including difficult for self purification of water bodies and an extreme threat to the self-regulating capacity of the biosphere combination of very high acidity and physico-chemical parameters widely exceeds self purification capacity of river water quality and does not allow aquatic life and complex effects on flowing waters (Fakayode, 2005).

This was a result of high accumulation rates coupled with diffuse cases of removing the coffee hull and washing the green coffee beans leakage from the Coffee processing. These wastes are usually discharged into water bodies and the cumulative hazardous effects it has on the environment have received much attention. The industrial discharge, therefore contribute a larger portion of the flow of the river during the dry season, with the result that the water quality of the river is further deteriorated. Uses, for which the river is employed involving body contact, expose serious hazards to users due to the bacterial situation. Many bodies of water in Ethiopia experience seasonal fluctuations, leading to a higher concentration of pollutants during the dry season when effluents are least diluted (Nubi *et al*, 2008; Kanu *et al*, 2011).

2.3. The Importance of Benthic Macroinvertebrates for Bio Monitoring

Bio-monitoring is monitoring the state of the environment through the performance of living organisms. It depicts the impacts of pollution on organisms, and can potentially detect the long-term exposure of a site to environmentally harmful chemicals. In addition, they provide an overall picture of the impact of environmental factors that often cannot be detected by physiochemical variables (Barbour *et al*., 1996; Phillip *et al*., 2009). They developed the idea of saprobity (the degree of pollution) in rivers as a measure of the degree of contamination by organic matter and the resulting decrease in dissolved oxygen. Since then, benthic macro-invertebrates as bio indicators have been used in many bio monitoring and Bioassessment programs (Bode and Novak, 1995; Barbour *et al*., 1996; Fore *et al*., 1996). Benthic macroinvertebrates are river-inhabiting organisms, easily viewed with the naked eye. They spend (use) at least part of their lives, in or on the stream bottom and are retained by mesh sizes 200 to 500µm. The name benthic macroinvertebrates is derived from the fact that they are bottom dwelling (benthic), large enough to be seen (macro), and small organisms without backbones (invertebrates) (Rosenberg and Resh, 1993).

Different groups of macroinvertebrates have different pollution tolerance level, which means they can serve as useful indicators of water quality. They may live from several weeks to many years and directly depend on adequate habitat and water quality for survival. As a result, macro-invertebrates can indicate pollution impacts from various, cumulative or multiple sources. Since the invertebrates inhabit the stream bottom, any modification of the streambed by pollutants, deposited sediment and water shade degradation, will most likely have a profound effect upon the benthic community. These make macroinvertebrates attractive water quality study subjects, with advantages over other community members (Birenesh Abay, 2007).

Bio-assessment is a monitoring technique intended to characterize the overall health of a water body. A health water body's determined by gathering multiple measures of biological data, converting the data into a single numeric index, then comparing the index with an index developed for a reference condition. Reference conditions are established by characterizing the biology and water quality of reference sites with unimpacted water bodies (Baye Sitotaw, 2006).

The rapid-Bioassessment protocols (RBPs) advocate an integrated assessment, comparing habitat (e.g., physical structure, flow regime), water quality and biological measures with empirically defined reference conditions (via actual reference sites, historical data, and/or modeling or extrapolation). Reference conditions are best established through systematic monitoring of actual sites that represent the natural range of variation in "minimally" disturbed water chemistry, habitat, and biological conditions (Gibson *et al*., 1996). Of these 3 components of ecological integrity, ambient water chemistry may be the most difficult to characterize because of the complex array of possible constituents (natural and otherwise) that affect it. The implementation framework is enhanced by the development of an empirical relationship between habitat quality and biological condition that is refined for a given region. As additional information is obtained from systematic monitoring of potentially impacted and site-specific control sites, the predictive power of the empirical relationship is enhanced.

Once the relationship between habitat and biological potential is understood, water quality impacts can be objectively discriminated from habitat effects, and control and rehabilitation efforts can be focused on the most important source of impairment (Solomon Akalu, 2006; Birenesh Abay, 2007).

2.3. 1. Measurements of diversity indices

The basic macroinvertebrates metric selection was done based on representing richness, composition and tolerance/intolerance measures were considered for the index development. To be used in the final index, a given metric needed to satisfy the following criteria: (1) show potential for change associated with habitat degradation, (2) provide unique information (i.e. not be linearly correlated with another metric or metrics) and (3) have measurably different values in known reference sites versus known impaired sites (Royer *et al.*, 2001).

The Shannon-wiener diversity indices (H') is a diversity index that combines taxa richness and community balance (evenness) to characterize species diversity in a community. The H' requires a count of the total number of individuals and a total count of each of the taxa. This index is an index applied to biological systems by derived from a mathematical formula used in communication area by (Shannon, 1948 and Mandaville, 2002). It's the most preferred index among the other diversity indices. The index values are between 0.0 – 5.0. Results are generally up to 1.5 – 3.5 and it exceeds 4.5 very rarely. A high H' suggests good benthic habitat and non-impacted water quality. The values above 3.0 indicate that the structure of habitat is stable and balanced; the values under 1.0 indicate that there are pollution and degradation of habitat structure (Gencer and Nilgün, 2010).

Diversity within the benthic macroinvertebrates community was described using the Simpson's diversity index (D); its values range from 0, indicating a low level of diversity, to a maximum of 1, while a value closer to 1 is good water quality. The D value which is standing for the dominance index is used in pollution monitoring studies. As D increases, diversity decreases. That way it is effectively used in Environmental Impact Assessment to identify perturbation (Hayal Desta Yimer and Seyoum Mengistou, 2009).

The Equitability or Evenness (E) diversity indices is a measure of macroinvertebrates which represents the relative abundance with which each family is presented in the area. Evenness index is also an important component of the diversity indices. This expresses how evenly the individuals are distributed among the different species. The values are between 0 – 1. When the value is getting closer to 1, it means that the individuals are distributed equally. Evenness near 0 is poor, while a value closer to 1 is good water quality ambient (Pielou, 1966; Muhammad, 2009).

2.3.2. Measurements of biotic indices

This metric is a biotic index that is calculated by multiplying the number of individuals of each family by an assigned tolerance value, summing these products, and dividing by the total number of individuals. Assigned tolerance values range from 0 to 10 for families, and increase as water quality decreases (Hilsenhoff, 1988). Although the H-FBI may before toxic pollutants, it is based on organism tolerance to low dissolved oxygen levels and has only been evaluated for organic pollutants. On a 0-10 scale, tolerance values range from intolerant (0) to tolerant (10) (Bode *et al*, 1996).High H-FBI values are indicative of organic pollution, while low values are indicative of clean-water conditions. A family level biotic index was calculated for each sample. Samples with H-FBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 polluted (Kobingi *et al.*, 2009).

These metric tallies the proportion of individuals of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddis flies) found in a sample. These orders are considered to be mostly clean-water organisms, and their presence generally is correlated with good water quality. However, habitat specific conditions (e.g. substrate, water temperature, flow velocity) and time of year during which sampling takes place can influence the relative abundance of EPT taxa and may result in low EPT richness values even if water quality is non-impacted (Rosenberg and Resh,1993; Kobingi *et al.*, 2009).

2.4. Water quality

A water quality standard refers to “the physical, chemical or biological characteristics in reference to a particular use”. For example, water quality standards for irrigation are not necessarily acceptable for drinking water or certain changes in water quality due to watershed use can be acceptable for fisheries, irrigation and not for drinking. Each component of the hydrologic cycle (precipitation, surface water runoff, surface water and groundwater storage, evaporation) changes the quality of a water body. All humans generate waste trough the consumption of resources and the rapidly growing world population is contributing to the deterioration of the water quality. Water is considered to be polluted if it is unusable for a particular purpose (Sarah, 2011). Each freshwater body has an individual pattern of physical and chemical characteristics which are determined largely by the climatic, geo morphological and geochemical conditions prevailing in the drainage basin and the underlying aquifer. The selection of variables for any water quality assessment programmed depends upon the objectives of the programmed (Sarah, 2011).

2.5. The Effect of Agricultural Activities on Water Pollution

Pollution of environment and its component may occur because of different activities. Coffee processing plants are one of the major agro-based industries which are responsible for water pollution. Agricultural wastes are typically high in nutrients (phosphorus and nitrogen), biodegradable organic matter, suspended solids and the like (Marquita, 2010). Nutrients, mainly nitrogen and phosphorus, can promote accelerated eutrophication, or the rapid biological “aging” of lakes, streams, river and estuaries (Narayanan, 2007). Phosphorus adheres to inorganic sediments and transported with sediments in storm runoff. Nitrogen tends to move with organic matter or is leached from soils and moves with groundwater (Ruth and Robin, 2003). In many coffee processing plants countries the wastewater is disposed from pulping, fermentation and washing of coffee beans and presents series of problem on receiving environment especially on water bodies (Braham and Bressani, 1979).

2.5.1. General Principles of Coffee Processing Plants Method

Attracted by the export potential, many large coffee growers have invested in coffee-processing plants. Coffee processing plants can have significant on the environmental impacts. Within twenty-four to seventy- two hours of being peaked coffee should be processed to retain its overall quality. This is the most serious time constraint associated with coffee production. The intensive production and processing methods have resulted in higher yields but, on the other hand, it had their impact on the environment (Narasimha *et al*., 2004). After harvesting, three different systems can be used for processing: dry-process; wet processed and semi-dry process. Dry processing (used for almost all Robustas coffees) implies that the whole cherries are dried and later the dried pulp removed mechanically. During wet processing (used for most Arabicas and small percentage Robustas), the pulp is removed mechanically and the mucilages are removed before drying (later hulling of parchment coffee). In the semi-dry process, the mucilage is not removed after pulping and parchment with mucilage are dried together (later hulling of parchment) (Sarah, 2011). The final product is called green coffee (Molina, 1999). In this research we will focus the wet processing, since the study was done in Guatemala were the wet mills are predominant (Sarah, 2011). After peaking of coffee parchment, the fruit has to undergo several processing steps in order to remove the outer parts of the fruit, i.e. skin (exocarp), pulp (mesocarp), the mucilage layer and the endocarpal parchment the way of processing determines the quality of the end product(Narasimha, 2004; Yared Kassahun *et al*., 2010).

2.5.1.1. Wet Method coffee processing plants

Wet coffee processing plants is widely accepted for selection of ripe coffee fruit (involves washing the coffee beans to remove the fruit from the beans along with any impurities) which is essential for producing good quality coffee beans (Rodrigo, 2003). Wet processing is considerably more complex than the dry processing method and involves different step yields coffee pulp, mucilage, fermentation, dries (natural/forced), sorting, floating and soaking that yield wet residues and waste water that may lead to considerable water quality ramifications depending on treatment (Antonio *et al.,* 1999; Yared Kassahun *et al*., 2010,).

There is conventional and advanced wet coffee processing pants method. In the case of conventional wet coffee processing system, the coffee beans once separated from the pulp are transported by water to fermentation tanks for mucilage breakdown and removal. Fermentation time is varied depending on the altitude and temperature of processing sites. This process is almost anaerobic in nature, and carried out for 36-72 hr (Braham and Bressani, 1979).

The effluents from the process containing matter in suspension, as well as organic and inorganic compounds in solution, have to be suitably discharged. Organic and acetic acids are formed from coffee mucilage as the result of fermentation of the sugars. This will make the wastewater very acidic (with pH as low as 3.8) a condition in which higher plants and animals can hardly survive (Antonio *et al*., 1999; Narasimha *et al*., 2004). Wet coffee processing requires a high degree of processing know how and produces vast amounts of processing effluents which have the potential to damage the river water quality. In addition, each processing technique has a different pollution potential (Yared Kassahun *et al*., 2010). Coffee wet processing pants cause's imbalances in the receiving ecosystem and its components, because the residual wastes are highly polluting by the acidity values, content of solids and COD. Coffee wet processing plant effluents without treatment can be toxic to the ecosystem at concentrations above 300 mg/L of COD (Sarah, 2011). According to the NRDC (Natural Resources Defense Council), wet coffee processing plants for a period of 6 months in 1988, the wet coffee processing in Central America contaminated 110, 000 $m^3$of water per day (Sarah, 2011). Wet coffee processing can allow obtaining coffee quality such as the "Colombian washes" or other Central American washes, but this process has been associated with the generation of organic pollution, affecting the water quality of water bodies. To produce 1 Kg of parchment coffee, by generating water for washing and pulping causes pollution equivalent to 5.6 people per day (Sarah, 2011).

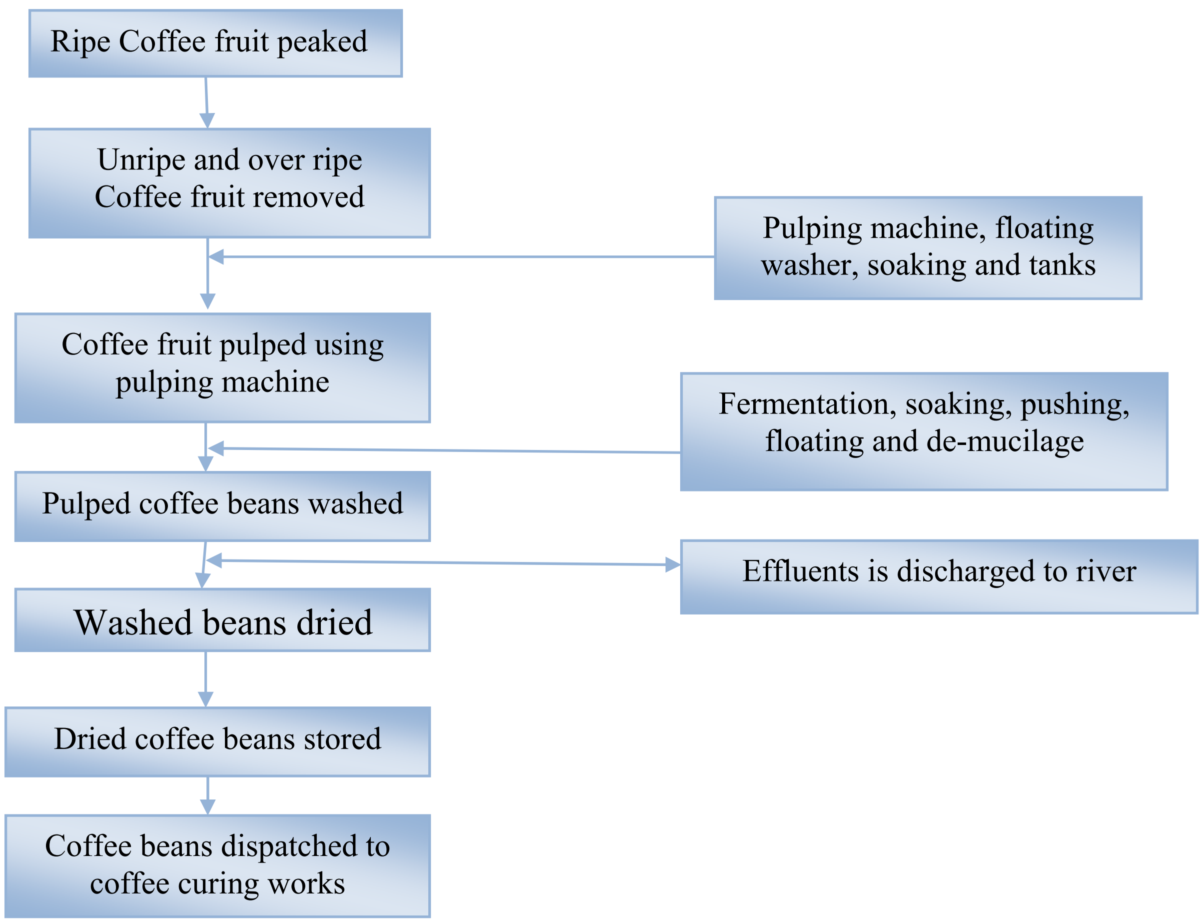

Figure 1. Schematic representation of "wet" coffee processing plants
Source: Yared Kassahun *et al* (2010)

2.5.1.2. The Nature of Wastewater from wet coffee processing plants

The coffee processing industry is one of the major agro-based industries contributing significantly to national income of a country. In wet processing, coffee fruits generate enormous quantities of high strength wastewater (Selvamurugan, 2010a). Coffee effluents are the main source of organic pollution in environment where intensive coffee processing is practiced without appropriate by product management systems. Environments that are exposed to the effluents generated from coffee processing plants show change in terms of its physical, biological and chemical behavior (JARC and EIARC, 2007; Tsigereda Kebede,2011). Fermentation or washing is the major cause for wastewater generation in wet coffee processing. Coffee wastewater is rich in sugars and pectin and hence it is amenable to rapid biodegradations. Other toxic substances or chemicals like tannins, alkaloids(caffeine) and polyphenolics make the environment for biological degradation of organic material in the wastewater more difficult (Alemayehu Haddis and Devi, 2008, Tsigereda Kebede,2011).

Table 1. Effluent characteristics from conventional wet coffee processing plants in case of Jimma Zone, Ethiopia

S.No	Parameters	Mean Values
1	Temperature	25
2	pH	2.5-3.57
3	BOD5	14200
4	COD	25600
5	TSS	5870
6	Orth-P	7.3
7	No3-N	23

Source: (Alemayehu Haddis and Devi, 2008) all units are in mg/L, except pH

Wet coffee processing effluents are complex mixtures of chemicals, varying in composition over time and from system to system as well as on coffee diversity. According to the (Alemayehu Haddis and Devi, 2008) noted that, effluent from wet coffee processing plants are highly colored and acidic and contain non-biodegradable compounds, and are high in Biological and Chemical Oxygen Demand. Coffee wastewater had high concentrations of suspended solids, dissolved solids and elevated nutrient. Moreover, wet coffee processing usually has high amount of conductivity, lower dissolved oxygen and elevated amount of turbidity to nearby water bodies or receiving environment (JARC and EIARC, 2007; Tsigereda Kebede). Pollutants in coffee wastewater emerge from the organic matter set free during pulping especially due to the difficulty in degrading the mucilage layer surrounding the beans. Wastewater generated from coffee processing plants is acidic and plants and animals hardily survive when exposed to it. The sugars contained in the mucilage undergo fermentation process. The organic and acetic acids from the fermentation of sugars make the wastewater very acidic. The digested mucilage in the wastewater builds a crust on the surface, clogging up waterways and further contributing to anaerobic conditions. Mucilage and coffee pulp are made of different components. Mucilage is composed of water, protein, sugar, pectic acid and ash (Van Der Vossen**,** 2005). Coffee pulp components are responsible for pollution of nearby water bodies and receiving environment. These components are, ether extract, crude fiber, crude protein, ash, nitrogen fiber extract, tannin, pectic substances, reducing sugars, and caffeine.

2.5.1.3. Health and Environment impact of effluent from coffee processing plants

Wet method of coffee processing result in a coffee of superior quality compared to dry method. This coffee processing method needs mechanical removal of pulp with the help of water. Due to this, a considerable amount of wastewater is generated. Wastewater generated from this process is acidic, rich in suspended dissolved and organic matter. It will pollute receiving water bodies when discharged without treatment (Selvamurugan *et al.*, 2010a). Wastewater directly discharged to the nearby water bodies and thus causing many severe health problems, these are spinning sensation, eye, ear and skin irritation, stomach pain, Nausea and breathing problem among the residents of nearby areas (Alemayehu Haddis and Ran, 2008).

Table 2. Average values of the characteristics of nearby water bodies (river) before and after receiving coffee processing plant effluent, Jimma Zone, Ethiopia

S.NO	Parameters	Water characteristics	
		Before	After
1	Temperature	15	18
2	pH	6.5	5.15
3	BOD5	120	7800
4	COD	176	9780
5	TSS	520	2880
6	Orth-P	2.3	4.1
7	No3-N	4.0	7.5

Source: (Alemayehu Haddis and Devi, 2008) all units are in mg/L, except pH

In addition to effect on human health, wet coffee processing plants are posing environmental hazards due to large-scale disposal of coffee pulp, husk, and effluents from these units. This practice poses a greater threat to water and land quality around the coffee processing units. Presence of toxic compounds like phenols in these byproducts restricts their direct use in agriculture and is affecting the soil. In addition, the indiscriminate use of fresh coffee pulp also affects crop through acid formation and local heat generation in the process of its fermentation (Braham and Bressani, 1979; Preethu *et al.*, 2007; Tsigereda Kebede, 2011).

2.6. Fresh Water Volume and Daily Consumption in Coffee processing plants

The volume of water used in coffee processing plants depends on the size of the siphon tank, the diameter of the siphon pipe, the machinery (i.e. drum or vertical pulper), used large quantities of water to remove the outer pulp and mucilage(fermentation) and transport the waste products from site to site (Sarah , 2011). As coffee production increasing, coffee processing used large quantities of water volume to remove the outer pulp and de-mucilage and transport the waste products (Figure 2). Each wet coffee processing plants consume greater than 1406.54m^3-1997.13m^3 of water per day and most are without water recirculation system and waste water produced by wet coffee processing plants is greater than 126588.6- 179741.7m^3 per year. About 80-93 L of water will be needed to process 1 kg of coffee parchment (the actual volume of water used depends on the pulping process fermentation or hydro pulping- and how much water is used in transporting the coffee) (Sarah, 2011; Rizal *et al*., 2012).

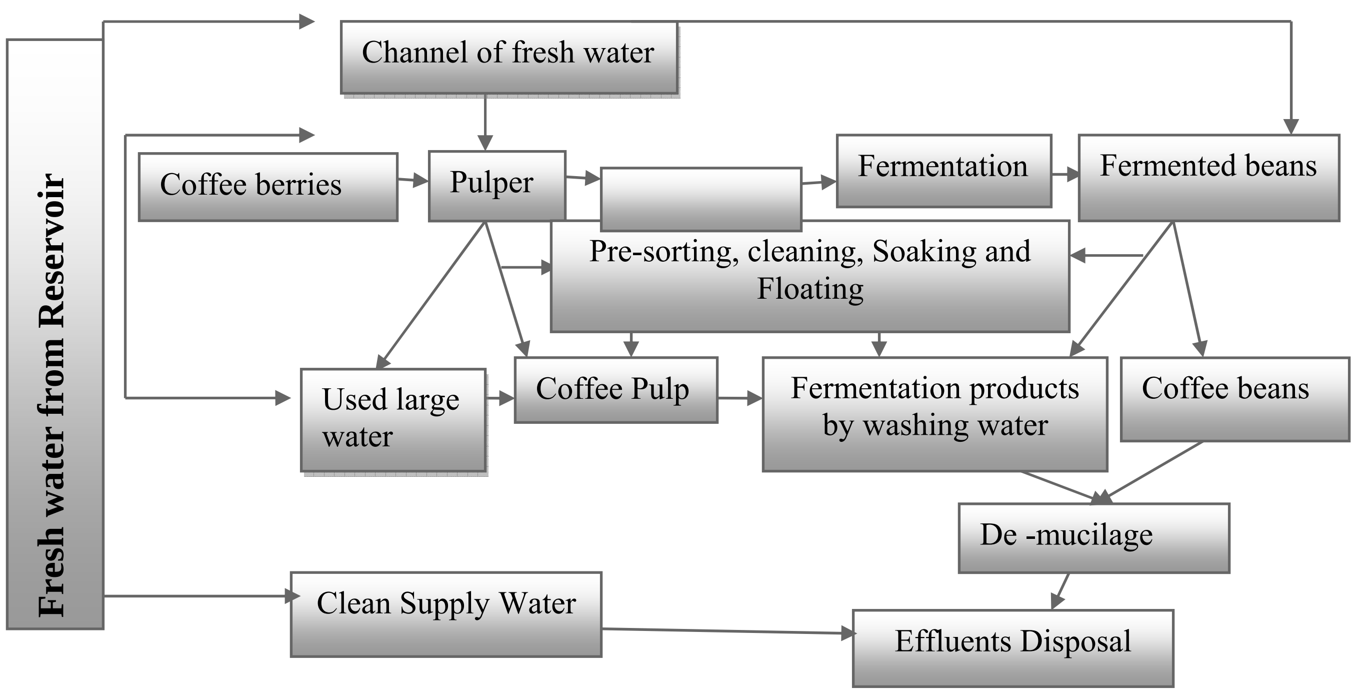

Figure 2. Water usage in a coffee processing plant system using the wet fermentation

Source: (Own design)

These effluents from 1000 kg of parchment coffee processed following the wet-processing method often generated a BOD comparable to the BOD of the human waste that can be generated by 2,000 people per day (Mburu *et al*., 1994). In Kenya, the coffee processing plant effluent BOD ranged from 1,800 to 9,000 mg/L for pulping waters and 1,200 to 3,000 mg/ L for fermentation and washing water depending on the volumes of water used (Mburu *et al*., 1994). This differs from conventional "washed coffee" in which the pulp is removed mechanically and the coffee is fermented in concrete tanks to remove the mucilage (Table 3).

Table 3. Water consumption in selected coffee processing systems

Location	**Authors**	**Process description**	**m^3/parchment**
Central America	(PEICCE, 1994)	Whole wet process	2 – 7.6
Colombia	(Zambrano and Zuluaga, 1993)	Pulping	7.2
		Full washing	4.8
Kenya	(Mburu *et al*., 1994)	Whole process	17 – 20
Kenya	(Finney, 1989)	Pulping	4.5
		Pulp discharge	0.8
		Pre-washing/grading	8.3
		Transportation to tanks	0.6
		Washing-Grading	3.1
		Soaking	0.3
		Plant cleaning	0.2
		Total	19.0
Colombia	(Merchán and Henao, 1976)	One-stage pulping Full washing	1.2

2.7. Water Pollution from Coffee Processing Plants

Coffee is a major international commodity, and because of this coffee production has the potential of coffee processing plants for considerable global effects. Conventional coffee processing use large water use quantities of water to the outer pulp and mucilage and transport the waste products. Technified coffee processing has worse water quality than traditional coffee due to the large amounts of chemicals used in technified coffee contaminate our water quality and they do not obey national or international boundaries. Damages include: (contamination of waterways and water tables (aquifers), damage to soil microorganisms, eutrophication (overgrowth of algae in river which depletes the oxygen in the water), creates air pollution, creates pesticide-resistant weeds and insects and contributes to the destruction of the ozone layer and more health impacts) as sited from (van Lynden, 1995).

Pollution of water affects the soil by different pathways airborne, terrestrial or by water indirectly. The pollutants in the soil in turn may follow different pathways or exposure routes to human beings and in some cases combine with contaminants from other sources. Pollution limits the ecological function of the soil and may reduce yields or food quality or safety. It is important to distinguish between the mere presence of a contaminating substance in the soil and its role as a pollutant because of its location, concentration and adverse biological or toxic effects. Nitrate and phosphate, for example, are essential nutrients to plants but may become pollutants if present in excessive quantities. Elements present in small amounts are referred to as trace elements. Several are micronutrients, required by plants. Cadmium, lead and mercury belong to the group of heavy metals. The trace elements mercury (Hg), lead, (Pb), cadmium (Cd), nickel (Ni), and cobalt (Co) show toxic effects if present in higher concentrations, as does the micronutrient copper (Cu)(van Lynden, 1995).

Largely irrespective of how coffee is grown, discharges from coffee Benefactions (processing plants) represent a major source of river pollution in northern Latin America. The process of separating the commercial product (the beans) from coffee parchment generates enormous volumes of waste material in the form of pulp, residual water and parchment. For example, the Guatemala-based Institution Central America investigation technologies industrial estimated that over a six month period during 1988, the processing of $547x10^5$ kg of coffee in Central America generated 110 million kg of pulp and polluted 110,000 m^3 of water per day, resulting in discharges to the region's waterways equivalent to raw sewage dumping from a city of four million people (Erick, 1995; Gilberto, 1996).

2.8. Conventional and Advanced Wet Coffee Processing Plants Waste Reaction and Treatment Methods

In the study sites there were two types of wet coffee processing plants. These are conventional and modern coffee processing plants. Depending on their processing system, wastewater generated varies in quality and quantity. Some of the two systems variation measures were wastewater quantity, organic load, pH and the like. Depending on the processing technology applied, quantities of coffee wastewater are varying. Modern mechanical mucilages removal machines producing semi-washed coffee use about one m^3 per ton fresh parchment (without finish fermentation and washing) whereas the conventional uses up to 20 m^3 per ton parchment. According to (Selvamurugan *et al*.,2010a; Selvamurugan *et al*.,2010b), about 80-93m^3 water is required to process 100kg coffee using conventional system wet coffee processing pulper and washer. As demand for raw water is increased, the amount of wastewater to be discharged is also increases. This implies that pollution potential of the conventional wet coffee processing plants is higher comparing with advanced ones (Jan, 2008; Tsigereda Kebede, 2011).

Conventional wet coffee processing system is sometimes called fully washed process while the advanced wet processing is known as semi-washed wet coffee processing. There are several steps in both systems. In case of traditional wet processing de-pulping removes the outer red part, but leaves a slimy coating of mucilage surrounding the bean. Fermentation allows microbial decomposition of this layer, after which it can be washed away. The time required for fermentation depends on ambient temperature, which is often determined by altitude in coffee growing areas (Noah, 2009). According to coffee experts familiar with processing in Jimma zone Ethiopia, the time required may range from as little as twenty four hours in the hot lowlands to forty eight hours in the cool highlands. Advanced wet coffee processing plants follow similar procedure as traditional wet coffee processing plants. The variation among the systems is fermentation. In this case mucilage separation from coffee bean is done mechanically. As the beans pass between a revolving perforated drum and an inner perforated tube, the mucilage is removed by friction with a counter flow of water (Braham and Bressani, 1979). Wastewater from conventional system wet coffee processing plants is acidic when compared with advanced technology for several reasons. During the fermentation process in the effluents from pulper, fermentation tanks and mechanical mucilage removers, sugars will ferment in the presence of yeasts to alcohol and CO_2. However, in this situation the alcohol is quickly converted to vinegar or acetic acid in the fermented pulping water. The other means that make wastewater from conventional wet coffee processing acidic are, long chain pectins split by enzymes (pectinase, pectase) into short chain pectin oligosaccharides. Oligosaccharides are soluble in alkaline and neutral solutions, but in acid conditions they are thrown out of solution as pectic acid (Von Enden, and Calvert, 2002a; Von Enden, and Calvert, 2002b).

It is crucial to compare the two systems in terms of cost and time. It takes several days to get processed coffee in conventional system wet coffee processing plants. This is because conventional coffee processing systems undertake fermentation process for removal of mucilage from coffee beans. Fermentation process may take as little as six hours in the hot lowlands to sixty hours in the cool highlands (Von Enden, and Calvert, 2002a; Von Enden, and Calvert, 2002b). Higher cost of the conventional wet process compared to the advanced wet process is mainly due to the higher cost of washing water after fermentation (Wayan, 2005; Tsigereda Kebede, 2011).

Wastewater treatment is a broad term that applies to any process, operation or combinations of processes and operations that can reduce the objectionable properties of water- carried waste and render it less dangerous and repulsive to man. The primary objective of wastewater treatment is to remove or modify those contaminants detrimental to human health or the water, land, and air environment. The suspended, colloidal, and dissolved contaminants (both organic and inorganic) in wastewater may be removed physically, converted biologically, or changed chemically (Abebe Worku, 2008). Wastewater is characterized in terms of its physical, chemical, and biological composition. It should be noted that many of the physical properties and chemical and biological characteristics are interrelated. For example, temperature, a physical property, affects both the amounts of gases dissolved in the wastewater and the biological activity in the wastewater (Metcalf and Eddy, 2003; Abebe Worku, 2008). The physical parameters include color, odor, temperature, solids (residues), turbidity, oil and grease. Solids can be further classified into suspended and dissolved solids (size and settleability) as well as organic (volatile) and inorganic (fixed) fractions. Chemical parameters associated with the organic content of wastewater include the BOD, COD, TOC, and TOD (Abebe Worku, 2008).

The environmental effects of wet and semi-wet processing are considerable. Problems occur through large amounts of effluents disposed into watercourses heavily loaded with organic matter rather it’s than inherent toxicity. Providing the self purification of the watercourse is exceeded, the microbial degradation reduces the level of oxygen to anaerobic conditions under which no higher aquatic life is possible (Von Enden, and Calvert, 2002a; Von Enden, and Calvert, 2002b).

Wastewater treatment is a broad term that applies to any process, operation or combinations of processes and operations that can reduce the objectionable properties of water- carried waste and render it less dangerous and repulsive to man. Thus, treatment of wastewater is essential in order to reduce the spread of communicable diseases caused by the pathogenic organisms and to prevent the pollution of surface and ground water. It is carried out by a combination of physical unit operations and chemical and biological unit processes, before the end products can be safely disposed off (Bhatia, 2005; Tsigereda Kebede,2011).

2.9. Application of effluent generated from coffee processing plants and river water Management

The use of natural water resources is increasingly under dispute. Coffee processing plants activities use water constantly, both during production and in many other processes, but after its use, most producers do not care about the fate of the various effluents that were generated, although poor management of these effluents (coffee wastewater, also known as coffee effluent, is a byproduct of the coffee processing process) may cause the social, ecological and environmental damage. However, with increasing surveillance and the pursuit of environmental sustainability in coffee processing plant activities, many studies are now being directed towards the treatment and/or use of effluents (Arce *et al*., 2009). Water management and waste disposal had become a significant cost factor and an important aspect in the running of a Coffee processing plants operation. Every Coffee processing plants tries to keep waste disposal costs low whereas the legislation imposed for waste disposal by the authorities becomes more stringent. Water consumption in a Coffee processing plant is not only an economic parameter but also a tool to determine its process performance in comparison with other Coffee processing plants (Alemayehu Haddis and Ran, 2008). Discharging untreated coffee effluent to natural water streams and rive or to open lands is environmentally unsafe as it causes soil, water and land pollution. Use of untreated coffee effluent for irrigation is also prohibited by the law. Since, coffee processing coincides with the dry season when amount of water present in the natural rivers are at the minimum, causing further concern of higher degree of pollution. To meet the environmental standards and to protect environment, it has become necessary to find suitable environmental friendly and economically viable treatment technologies (Sri.G.V.Krishna Rau, 2008; Abebe Beyene *et al.*, 2011; Tsigereda Kebede, 2011).

The coffee effluents emanating from the pulper units are highly acidic and contains high amounts of dissolved and suspended biodegradable organic matters. These effluents, if discharged into natural water bodies without treatment, pollute the receiving bodies by depleting dissolved oxygen present in it. Polluting natural water bodies will have an adverse effect on domestic users, aquatic life, livestock and water course down the stream. The pollution load of coffee effluent is measured in terms of BOD and COD. Generally various techniques that could either solve the pollution problems associated with coffee wastes or significantly reduce the risks of pollution have been developed, tested, and used in different coffee producing countries. Also good if currently, environment-friendly processes that could significantly reduce the risks of pollution associated with coffee waste are developed and tested in different coffee producing countries. BMPs are any measure, practice, or control implemented to protect water quality and reduce the pollutant content in storm water runoff. Legal entities are required to define and implement a selection of BMPs to reduce the discharge of pollutants from their storm drain system. The Permit requirement is applicable to both permanent and temporary (construction) BMPs (Lawrence**,** 2010). Also good if establishing in order to protect the environmental health and to control the pollution on account of polluted water reaching the natural water bodies, agricultural land and open spaces, Central Pollution Control Board (CPCB), Government has imposed certain laws and guidelines for handling effluents. Generally good if focused on the promotion of 3R in the domestic solid waste management over- emphasizes “recycle and reuse”, and more focus is give to “reduction” (Visvanathan and Ulrich, 2006; Yeny and Yulinah, 2012).

2.9.1. Steps to be followed in the treatment of coffee effluent (Sri.G.V.Krishna Rau (2008))

1. The coffee effluent coming out of the washer unit should be stored in a lagoon for one day. The capacity of this lagoon shall be of one day’s water use capacity of the processing unit.
2. This coffee processing effluent should be neutralized with appropriate amount of Agricultural lime so that the pH of the effluent is around 6.9 to 7.0. Generally 5g of good liming material is adequate to neutralize 1L of the effluent.
3. After one day of storage, the effluent is allowed to the anaerobic lagoon. Before allowing the effluent to the lagoon, the anaerobic lagoon should be charged with 4% cow dung slurry up to 10% of the capacity of the lagoon. Charging of the anaerobic lagoon should be done one month before the pulping operation starts so that the methogenic bacteria present in the cow dung slurry which are responsible for the degradation of the biological materials get

stabilized. The capacity of the anaerobic lagoon should be equivalent to 21 days effluent production with a maximum depth of 3 meters.

4. Add 4.5 kg of urea and 2.5 kg of super phosphate per every 20000 L of effluent.
5. After 21 days, the effluent from anaerobic tank should be allowed to the aerobic tank. The depth of this lagoon should not be more than one meter and capacity should be of 7 days effluent production.
6. In aerobic lagoon, addition of 450 g of urea and 250 g of super phosphate per 20,000 L of effluent is essential.
7. The effluent coming out of the aerobic lagoon be then stabilized in another tank for one day and used for irrigation if the BOD level is around 100 mg/L.

Figure 3. Plastic sheet lined lagoons for treatment of coffee waste effluent

3. MATERALS AND METHODS

3.1. Descriptions of the Study Area

Limu Kosa is one of the 180 Districts in Oromia Regional State of Ethiopia. It was named after the former kingdom of Limu-Ennarea, whose territories included the whole area that this District now covers. Limu Kosa is bordered on the south by Kersa, in the south-west by Mana, in the west by Gomma, in the northwest by the Didessa river which separates it from the Illubabor Zone, on the north by Limu Seka, in the northeast by the Gibe River which separates it from the western Shewa Zone and the Southern Nations, Nationalities and Peoples Region, in the east by Sokoru, and on the southeast by Tiro Afeta. Administrative center of this District is Genet; other towns include Ambuye and Babu. Limu Kosa District is located at 75km in the northern part of Jimma town, between $7^{o}50'$-$8^{o}36'$N latitude and $36^{o}44'$-$37^{o}29'$E longitude. It has an area of 2770.5km^2. Topographically Limu Kosa District is characterized by dissected plateaus (Agelo, Menta and Budo Bekere), plains (Tolay, Kara Hinchini and Golu) and valleys (Dedessa and Gibe). Altitudinally, Limu Kosa District lies between 1200 to 3020 meters above sea level. Several perennial rivers (Gibe, Awetu, Kebena and Dembi), intermittent streams, springs and notable landmarks include Cheleleki Lake and Bolo Caves were found in the Limu Kosa District (data from the Limu Kosa District Agricultural and Rural Development Office).

The mean annual rainfall of the area is 1534mm with average minimum and maximum temperature of 12.9 ˚c and 31.4 ˚c respectively. Climatically, the District is classified into *dega* (10%), *woinadega* (65%) and *kola* (25%) zones. Altitudinal expressed as1750-1550 masl. Chromic, pellicvertisols, orthicacrisols and dystricnitosols are the major soil types found in Limu Kosa District. Soluble salts, calcium, and magnesium carbonates and their combination, sodium chloride, and calcium sulfate, occur in relatively large quantities in rocks. As a result, they are the most common major ions in most natural waters. High forest, woodland, riverine and manmade forests were available in the District. Coffee is an important cash crop of this District. It covers 26,554.6 ha and 6 stations of coffees pulping processing and 12 stations of coffees hulling processing. 82840.3x10^2 kg of coffee is supplied to the central market last year, while the remaining is locally consumed in current from the Limu Kosa District (data from the Limu Kosa District Agricultural and Rural Development Office, 2012).

Figure 4. Description of the study area

3.2. Methods

3.2.1. Data collection

A cross sectional study was conducted to assess the impact of wastewater discharge on river water quality by coffee processing plants in Limu Kosa District from September 2011 to February 2012. For conducting the research work, primary data collection through direct measurement of river water quality parameters on the selected study sites at in-situ and under laboratory condition.

3.2.2. Experimental design of the study and selection of sampling sites

The experiment was conducted using complete randomized design (CRD) with three replications and composite to minimize the variation of all sample collected from the same sample site. The four rivers were selected on the basis of differing effluents disposal generated from coffee processing plants activities (Table.4). These sampling sites were selected to represent different ecological and environmental variations within each river, in order to understand the influences of effluent discharge by coffee processing plants induced stress on physical, chemical, nutrient and biological attributes of the river water quality. Six sampling sites were selected along each river. These sites were upstream site (UPS), influent (INF), effluent (EFF), entry point (ENP), downstream one (DS_1) and downstream two (DS_2). UPS was as control sites without any effects from the effluent because of their sites. Influent (INF) waste water flowing into a treatment plants, in this case lagoons. INF was the point which was directly discharges effluents to lagoons. Effluent (EFF) is treated waste water to reduced pollution before disposing to river. EFF was located after the INF passes through a lagoon before it enters into the river water. Entry point (ENP) was located at adjacent of EFF where coffee processing plants effluents being directly deposed into the river water. Downstream one (DS_1) was located below of ENP after the industrial waste discharges in to river water. Downstream two (DS_2) was located below of DS_1 after the river water is received waste water discharges, to ensure composition of coffee processing plant effluent variations within each river. For each along the river water column (corners and center) once sample were taken at UPS, ENP, DS_1 and DS_2 with interval of 300m apart. Also, samples were taken from INF and EFF, no actual distance determined because it depends on the coffee processing plants designed (Table 4 and Figure 5) (Phiri *et al.*, 2005; Kobingi *et al.*, 2009; Yared Kassahun *et al*., 2010; Akali *et al.*, 2011).

Table 4. Name of river water with number of wet coffee processing plants in sampling sites

No.	Name of rivers	Private owners	Government	Sample site
1	Kebena river	Feyisal AbaMecca		6
2	Awetu river	Gidahe Barihe		6
3	Bonke river	-	Government	6
4	Ketalenca river	-	Government	6
Total				**24**

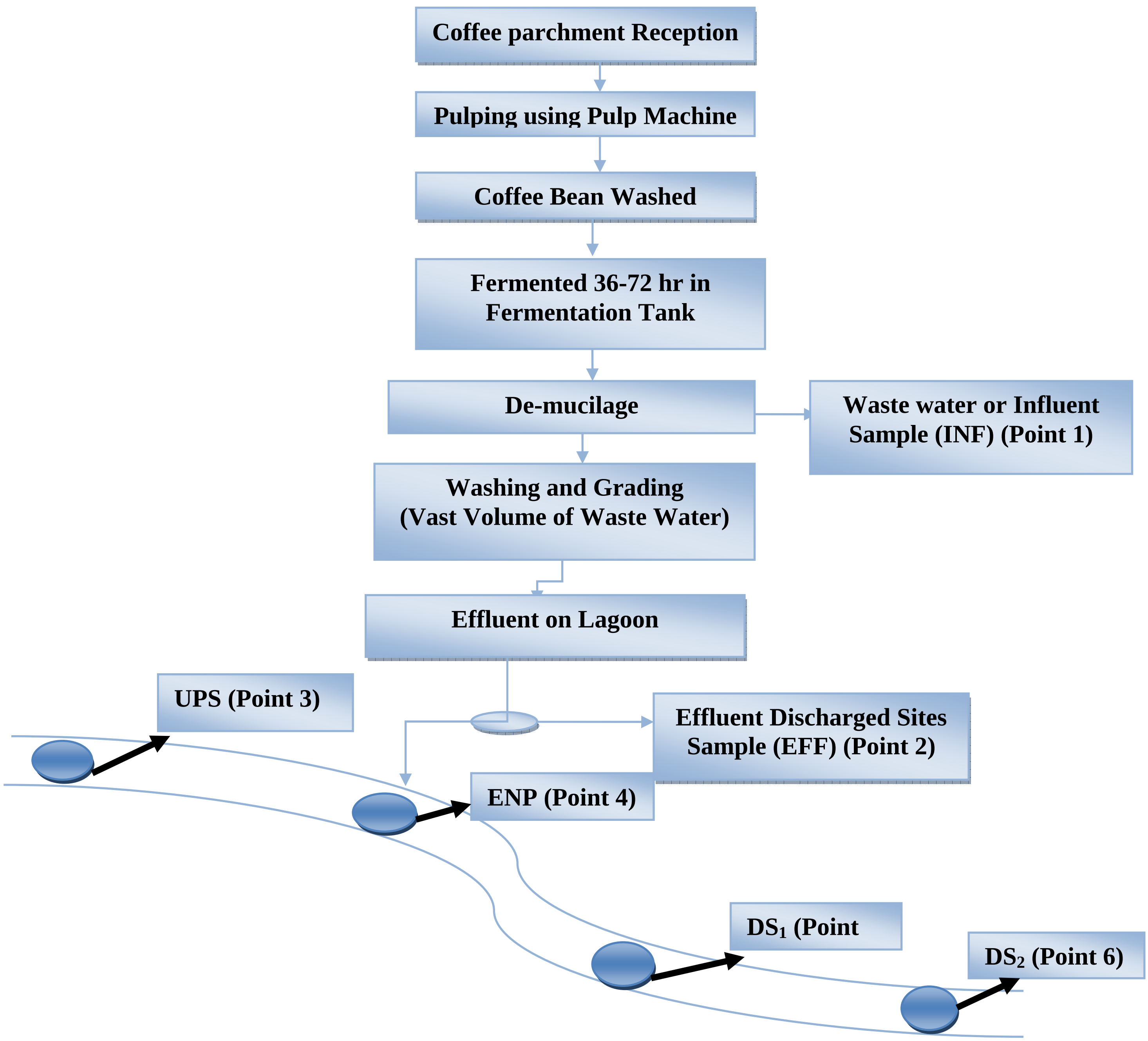

Figure 5. Map indicating schematic representation of among selected sampling sites of the river water quality characteristics, source: Own design

3.2.3. Sampling procedure of physico-chemical parameters data

One liter of plastic BOD bottle and glass bottle were used for sample collection. Samples were collected in sterilized plastic bottle and glass bottle used standard procedure of composite as per the method of (APHA, 2005). The river water sample were collected by inserted the plastic bottle and glass bottle used by depth-integrated composite sampled techniques to the opposite direction of the river flow and capped tightly immediately after filling to the tip of the mouth of this bottle. Ambient temperature(AMT), water temperature (WT), turbidity, pH, DO, and EC parameters were measured in-situ by using field meter (ambient thermometer, turbidity meter and Probe multi parameter method) respectively with appropriate probes according to the manufacturer's instruction(APHA, 2005).

TS were measured using gravimetric method and described as follows:-

Clean a porcelain evaporating dish and place it in an oven at 103-105 °C or 1 hour, or if the fixed and volatile solids determinations is also to be made, ignite at 550$\pm$50 °C in a muffle furnace for 1 hour. Place the dish in desiccators and weigh as soon as it has cooled to balance temperature. Thoroughly mix the sample and transfer a sample volume that will yield a residue between 2.5 mg and 200 mg to pre weighed dish. (Care must be taken to keep the solids in suspension while measuring). Place the dish on a steam bath and evaporate the sample to dryness. Dry the dish and residue in an oven maintained at 103-105 °C for I hour. Place the dish in desiccators and weigh as soon as it has cooled to balance temperature. Repeat cycle of drying cooling desiccating and weighing until a constant weight is obtained, or until weight loss is less than 4% of previous weight or 0.5 mg.

Calculation

$$mg\ total\ solids\ /L = \frac{(A\_B)x1000}{ML\ sample}$$

Where: A= weight of dried residue + dish, mg, and B= weight of dish, mg

TSS was measured using gravimetric method and described as follows:-

First insert disk with wrinkled side up in filtration apparatus and apply vacuum and wash disk with three successive 20-mL portions of distilled water continue suction to remove all traces of water, and discard washing then remove filter from filtration apparatus along with the Gooch crucible, and dry in an oven at 103 to 105 °C for 1 hour. Assemble filtering apparatus and filter and begin suction and wet filter with a small volume of distilled water to seat it then filter a measured volume of well mixed sample through the glass fiber filter and wash with three successive 10-mL volumes of distilled water, allowing complete drainage between washings and continue suction for about 3 minutes after filtration is complete Remove the crucible and filter combination from the crucible adapter if a Gooch crucible is used and dry for at least one hour at 103 to 105 °C in an oven, Cool in a desiccators to balance temperature, and weigh.

Calculation

$$mg\ suspended\ \ solids\ /L = \frac{(A\_B)x1000}{ML\ sample}$$

Where: A= Weight of filter + dried residue, mg and B= Weight of filter, mg

TDS was measured using gravimetric method and described as follows:-

Filter measured 20 mL volume of well-mixed sample through glass-fiber-filter, wash with three successive 10-mL volumes of distilled water, allowing complete drainage between washings, and continue suction for about 3 minutes after filtration is complete. Transfer filtrate to a weighed evaporating dish and evaporate to dryness on a steam bath if filtrate volume exceeds dish capacity successive portions to the same dish after evaporation. Dry for at least 1 hours in an oven at 103-105 °C, cool in a desiccators to balance temperature, and weigh

Calculation

$$mg\ total\ dissolved\ \ solid\ /L = \frac{(A\_B)x1000}{ML\ sample}$$

Where: A= Weight of dried residue= dish, mg and B= Weight of dish, mg

SS was measured using gravimetric method and described as follows:-

Determine total suspended solids of well-mixed sample. Pour a well-mixed sample into a glass vessel of not less than 9 cm diameter using not less than 1 L and sufficient to give a depth of 20 cm. Let stand quiescent for 1 hour and without disturbing the settled or floating material, siphon 250 mL from the centre of the container at a point half way between the surface of the settled material and the liquid surface. Determine the total suspended solids (mg/L) of this supernatant liquor. These are the non-settle able solids.

Calculation, mg settle able solids/L=mg total suspended solids/L –mg Non settle able solids/L

TFS and TVS was measured using gravimetric method and described as follows:-

Ignite the residue produced from the total solids, total dissolved solids or total suspended solids determination to constant weigh in a muffle fumace at a temperature of 550 ± 50 °C about 15 to 20 minutes. Let dish or filter disk cool partially in air until most of the heat has been dissipated.

Transfer to a desiccators for final cooling in a dry atmosphere. Weigh dish or disk as soon as it has cooled to balance temperature. Repeat cycle of igniting, cooling, desiccating and weighing until constant weight is obtained or until weigh loss is less than 4% of previous weight.

Calculation,

$$mg\ total\ volatile\ solids / L = \frac{(A - B)x1000}{ML\ sample}$$

$$mg\ total\ fixed\ solids / L = \frac{(B\_C)x1000}{ML\ sample}$$

Where: A=Weight of residue + dish before ignition, mg, B=Weight of residue+ dish of filter after ignition, mg and C=Weight of dish of filter, mg.

BOD was measured using Azide Modification of the Winkler Method and described as follows:-
Preparation of dilution water was done. Two liters volume of water in a suitable bottle and add 1 mL each of phosphate buffer, $MgSO_4$, $CaCl_2$, and $FeCl_3$ solutions/L of water. From the prepared solution 349mL of samples were sampled with1 mL sample added in incubation bottles having capacity of 350-mL and initial dissolved oxygen was measured using dissolved oxygen meter. Incubation for five days at 20 Co was done that 350-mL whose initial dissolved oxygen measured. After five days final dissolved oxygen was measured. BOD Incubation for five days at 20 °C was done that 350-mL whose initial dissolved oxygen measured. After five days final dissolved oxygen was measured. After five days final dissolved oxygen was measured.

$$BOD_5(mg / L) = \frac{(DOi - DOf)}{DOf}$$

Where; DOi = initial dissolved oxygen, DOf = final dissolved oxygen and Df = dilution factor

Orth-P was measured using stannous Chloride Method and described as follows:-
Prepare the following series of phosphate standards by measuring the indicated volume of standard phosphate solution into separate 100 mL volumetric flasks (Or graduated cylinders).To the sample, add 0.05 ml 1 drop) of phenolphthalein indicator solution. If the sample turns pink, add strong acid solution drop wise until the color is discharged. With a measuring pipette, add 4 mL acid- molybdate solution to each of the standards and sample. Mix thoroughly by inverting each flask four to six times. With medicine dropper, add 0.5 mL (10 drops) of stannous chloride solution to each of the standards and sample. Stopper and mix by inverting each flask four to six times. After 10 minutes, but before 12 minutes, measure the color photo metrically at 690 nm

using distilled water as blank. Construct a calibration curve using the standards and determine the amount of phosphate in µg present in the sample.

The determination of COD loading with a kit (LANGE COD cuvette tests, LCk 614 and 114) could not be easier. The measurement cuvette test already contains all the necessary chemicals in exactly measured amounts, and the user simply adds a defined amount of the homogenized sample (two mL). The closed cuvette test is then heated for two hours at 148 °C in a dry thermostat.

The determination of TN concentration with a kit (LANGE TN cuvette tests, LCK 138 and 338) is simple and reliable. Simply adds a defined amount of the homogenized and digestion sample (two mL). The closed cuvette test is then heated for one hour at 100 °C in a dry thermostat. NO_3-N (Phenoldisulfonic Acid Method), NH_3-N (Direct Nesslerization Method), Organic nitrogen (TN- NO_3-N) (APHA, 2005). Both the filtered and unfiltered water sample was kept in a chilled ice chest during transport to the department of environmental health laboratory, Jimma University until they were analyzed. The water samples were kept in a refrigerator at a temperature below 4 °C to stop all the activities and metabolism of the organisms in the sample (APHA, 2005).

3.2.4. Sampling method of macro-invertebrates from river water sites

A triangular D-frame Dip-Net (mesh size = 500 µm, sampled area = 0.9 m^2) was placed on the river water bed in a 45° angle used to collect macro-invertebrates in the riffles and runs in each sites by disturbing the river water bed used kicker action over a distance of less than 100m for ≥3≤5 minutes was representative of the river water sampled in riffles and runs. These area of the river water comprised of cobble/gravel substrate with fast current, shallow water (usually less than 8 inch in depth) and non-laminar flow were selected (Kobingi *et al.*, 2009). Macro-invertebrates sample was conducted only once from each riffles and runs sample sites. In the field, the mesh net with the collected sample was then carefully turned inside out and shaken gently in a white plastic container filled with water was washed leaves, twigs, rocks and other debris were taken out of the collected sample through a 500 µm sieve. The sorted was preserved in a 70% ethanol and transported to laboratory of Environmental Health Sciences and Technology Department, Jimma University for later sorting and identification (Barbour *et al.*, 1999; Bouchard, 2004; Kobingi *et al.*, 2009).

In the laboratory, the collected sample were transferred into a petridishes containing sufficient amount of water, agitated and sieved with 500 μm mesh size to discard the mud and retain the macro invertebrates. This was repeated until all the macro-invertebrates were washed from the mud. The samples were then transferred to petridishes to easily pick them up used forceps. All macro-invertebrates were sorted and identified was counted used light compound microscope. Macro-invertebrates verification and identification was made up to family level for all taxa using standard identification keys (Macan, 1979; Edington and Hildrew, 1981; Bouchard, 2004).

3.2.5. Statistical analysis

The data were subjected to different statistical analyses to analysis of variance (ANOVA) using SAS version 9.2, Minitab Version 16.0 software, MS Excel. Different source of variation including single and interaction effect of river water and sites were investigated using the GLM procedure of SAS. When significant interaction effect were observed among the four rivers with river water and sites using a two-way ANOVA, One-way ANOVA was computed to see significant difference between each sample sites for the physico-chemical parameters and macro-invertebrate assemblages as biological indicators. Mean separation of different sources of variation among each all river water and sites were done using Tukey's test at $\alpha = 0.05$ level of minimum significance difference (MSD). The person correlation matrixes analysis was used to reveal the magnitudes and directions of relationship between different parameters of physico-chemical within and among macro-invertebrate assemblages as biological indicators of river water quality. Also the investigate results of physico-chemical and nutrient parameter values were compared with maximum allowable limit set by WHO.

To evaluate the accumulation factor (AF) & river recovery capacity (RRC) of water quality were calculated by respective formula as follow:-

Accumulation factor (AF) was calculated by dividing the average physico-chemical and nutrient parameters of DS_2 with UPS values. The degree of river recovery capacity (RRC) for river water quality was calculated using the formula adopted from (Ernestova and Seminova, 1994) as modified by (Fakayode, 2005) given as:

$$RRC = \frac{(S0 - S1)}{S0} X \ 100 \quad (Expressed \ \ in \ \%)$$

Where: S0 is the level of a parameter downstream sites (i.e. immediately after the discharge point) and S1 is the corresponding average level upstream sites where the water is relatively unpolluted.

To evaluate the diversity indices & evenness of benthos species were calculated by respective formula as follow:-

Macro-invertebrate assemblages as biological indicators of the river water bodies for each sampled station of UPS and DS were pooled to furnish the values of measuring diversity indices (Shannon-Wiener index (H'), Simpson's index (D) and Equitability index (E) were used to determining species diversity, taxa richness; and evenness respectively as shown below:

Shannon-Wiener Diversity Index was calculated from the proportional abundances of each species (abundances of the species/total abundances) (Shannon, 1948 and Mandaville, 2002) as shown below:

$$H' = -\sum \left[\left(ni/N\right) * \left(\ln ni/N\right)\right] \quad OR \quad H' = -\sum_{i=1}^{S} Pi \ln Pi$$

Where: H=Shannon- Wiener Diversity Index, ni= Number of individuals belonging to i family, N=Total number of individuals, and Pi = the proportion of the total individuals in a sampling of s families and ln = Log normal

Simpson's diversity index (*D*) was a simple mathematical measure that characterizes the families' diversity in a community. The proportion of species i relative to the total number of families (p_i) was calculated and squared. The squared proportions for all the families were summed, and the reciprocal is taken (Margalef, 1958) as shown below:

$$D = 1 - \sum_{i=1}^{S} Pi^2$$

Where: D = Simpson's diversity index, and Pi = the proportion of the total individuals in a sampling of s families

Equitability or Evenness (E) diversity indices assume a value between 0 and 1 with 1 being complete evenness. E could be calculated as follows (Pielou, 1966)

$$E = \frac{H'}{H'\max} = \frac{H'}{\ln S}$$

Where: E= equitability or evenness index, lnS = Log normal and S= total species number of species in the sample (in this study total number family in the sample)

4. RESULTS AND DISCUSSION

4.1. Physico-Chemical and Nutrient Parameters in Four River among All Sites

Results of physico-chemical and nutrient parameters along the four river water course among each six sites as well as compared with the WHO standard during study period had been depicted in (Appendices Tables 1-8, Tables 5-8 and Figures 6-11). Statistically, the results of all physico-chemical and nutrient parameters analysis revealed that highly significant difference in interaction effect among four rivers water and twenty four sites of river water courses at ($p<0.01$). The levels of physico-chemical and nutrient parameters analysis pollutant in the study showed a wide range of variation all through the twenty four sampling sites of the four rivers. This may be attributed to the differential inconsistence in the variation of these pollutants from the source coffee refineries and differential discharge of rampant effluents originating from coffee refineries. This study indicated that the mean values of all physico-chemical and nutrient parameters of the river water samples analysis were exceed the maximum permissible limit set by WHO. These parameters were discussed based on variations of upstream sites (UPS), effluent discharge site or effluent (EFF), influent (INF), entry point (ENP) and downstream sites (DS_1 to DS_2) and variations during the period of the studied(Appendices Tables 1-8, Tables 5-8 and Figures 6-11).

4.1.1. Physical parameters and their significance level in four river water among all sites

The results revealed that the mean values of river water temperature varied from 23.34±0.32, 31.367 ±0.32, 33.11±0.32 and 25.09±0.32 °C at Kebena, Awetu, Bonke and Ketalenca river water with 43.96 and 11.70 maximum at Awetu EFF and minimum at Kebena UPS respectively. The mean values of river water and ambient temperature varied between 18.45±0.40-36.31±0.40˚c to 20.45±0.13-30.27±0.13˚c at all sites respectively. Maximum and minimum differences in water and ambient temperature were 17.86 °C and 1.64 °C, 9.82 °C and 0.55 °C respectively among all sites. Mean values of water and ambient temperature levels were significantly different among river water as well as sites in over all models of interaction effects at ($p<0.05$). But, ambient temperature has not shown significant differences among Kebena and Awetu river water at ($p<0.05$). This implies that on many occasions, wastewater from the Kebena and Awetu coffee refineries had the same meteorological conditions and the geographical relief of the river water area and also the system of processing plants have the same character (Appendices Tables 1-8 and Table 5-6).

River water and ambient temperature plays an important role in influencing the quality and ecology of river water as well as aquatic ecosystem. It affects not only the physical nature of river water by changing the viscosity, density and surface tension, but also the rate and types of chemical characteristics reactions that occur within. Water temperature was also an important factor that influences rate of all macro-invertebrate assemblages as biological indicators characteristics attributes. Temperature could be used as a first step in predicting the effects of community residing DS activities on the aquatic ecosystem. As compared to other studies, it was lower than reported in a similar study (MA Kishe, 2004; Fakayode, 2005; Akan *et al.*, 2009; Wakawa *et al.*, 2008; Akali *et al.*, 2011).

There is highly significant difference in the concentration of EC between the four river water with river water and sites at ($p<0.01$). It revealed that the mean values of river EC varied from 755.27±23.63, 713.95±23.63, 596.98±23.63and 524.89±23.63°C at Kebena, Awetu, Bonke and Ketalenca river water with 755.27±23.63 °C maximum Kebena river water and minimum at Kebena 524.89±23.63 °C Ketalenca river water respectively. Neither EFF nor INF concentrations exhibited any significant variation of EC.This value was varied from 165.43µs/cm to 1227.16µS/cm minimum at UPS and maximum at INF in Bonke river water sites, respectively. The mean values of EC were ranged from 180.8±7.69-1169.62±7.69 µS/cm among all sites. In the present study DS_1 to DS_2 exhibited that not significant variation of EC and TDS in contrast to other sites. However, these values were generally higher than 180.8 µS/cm reported for the control site (UPS). Higher EC 1169.62 µS/cm at site INF could indicate high amount of ions that exceed the maximum allowable limit by WHO which could be discharged rampant of untreated to the river water. The EC increased with the increased in TDS and water temperature (Appendices Table1-8 and Table 5-6).

The observed turbidity mean values ranged from 432.29±5.52-1299.88±5.52 NTU amongst the polluted sites. The maximum mean value obtained from the polluted sites was higher than 4.85NTU recorded at UPS. The turbidity mean concentration at DS_1 to DS_2 was 432.29 to 436.49 NTU which were exceed the allowable limit set by WHO and EPA (10 mg/L). The present study exhibited that higher at ENP values and not significantly differences from DS_1 to DS_2. Turbidity in river water were caused by TSS and SS particles (as clay, silt, and finely divided organic and inorganic matter, plankton) or colloidal matter that reduced light penetration through the water column. These results revealed that the river water were extremely turbid and would affect the surface river water quality and vicinity (Appendix Table I-VIII and Table 5-6).

Turbidity in the river water as well as an increase in chlorophyll also accompany accelerated algal growth and indicate increased eutrophication.

Consequently, various analytical mean values of TSS and TDS fluctuated between 542.19-1429.±7.65 mg/L and 713.64-2600.92±26.85 mg/L amongst the polluted sites respectively. These mean values of TSS and TDS obtained from the polluted sites were higher than 22.03±7.65-275.8±25.85 mg/L recorded at UPS respectively. There were highly significant differences ($p < 0.01$) in the values of TSS and SS among the different sampling sites across the river water course. These results showed that significantly increased from DS_1 to DS_2 sites of the river water in TSS and SS, but not significant differences from DS_1 to DS_2 in TDS. Mean while, the accumulation factor of TS, TVS and TFS concentration of river water revealed that it was decreased following the EFF to DS_2, but not significantly differences from DS_1 to DS_2 proved in (Appendices Tables 1-8 and Table 5-6).

Haphazardous solid wastes and dumping of untreated coffee processing plants wastewater entering in to the river water as well as agricultural land use were observed as major environmental stressors that affected the river water quality. The pollution loads were generally increasing from DS_1 to DS_2 along the river water column. EC shows significant increased from DS_1 to DS_2 of the river water. This showed that EFF into the river water had a significant influence on its solubility characteristics. Several of the dissolved substances precipitate on merging with the factory effluent (Akan *et al*., 2009; Abebe Beyene.*et al*., 2011; Kanu *et al*., 2011; Oladele *et al*., 2011; Walakira, 2011; Walakira and James, 2011).

In the present study DS_1 to DS_2 exhibited that highly significant variation of TSS and SS in contrast to other physical parameters. Secondary organic pollution was defined as the surplus of organic matter, which was the sum of undecomposed organic material introduced into the river water body with primary pollution and of the material resulting from an extremely increased bioproductivity within the polluted ecosystem itself. Surface water bodies are hydraulically connected to ground water in most types of landscapes; as a result, surface-water bodies were integral parts of ground-water flow systems. The pollutants enter under-ground water, with the discharge of industrial effluents on the surface; as a result a significant increase in the concentration of contaminants takes place under the vicinity of leaching bed to downstream sites. Coffee processing plants effluent contains acid that could increase the acidity of water (Akan *et al*., 2009; Yared Kassahun *et al*., 2010; Oladele *et al*., 2011).

Table 5. Effects of effluent discharges by coffee refineries on physical characteristics of river water quality at different rivers within the interaction effects

	Mean separation of Physical parameters									
Rivers	**TSS**	**SS**	**TDS**	**TS**	**TVS**	**TFS**	**EC**	**TURB**	**WT**	**AMT**
Kebena	1104.01[a]	821.68[a]	1594.79[a]	2698.81[a]	961.26[c]	1422.79[a]	755.27[a]	974.34[a]	23.34[d]	29.15[a]
Awetu	731.92[b]	584.51[b]	1278.56[b]	1278.56[b]	466.46[d]	787.57[b]	713.95[b]	682.54[b]	31.367[b]	28.80[a]
Bonke	645.64[c]	206.6[c]	1184.20[c]	1829.84[c]	1632.40[a]	706.75[c]	596.98[c]	549.95[c]	33.11[a]	25.56[b]
Ketalenca	599.79[d]	131.76[d]	971.58[d]	1571.36[d]	1229.15[b]	693.78[c]	524.89[d]	527.73[d]	25.09[c]	21.72[c]
Max	1812	1274	2816	4302	3498	3105	1227.16	1397	43.96	34.90
Min	9.70	2.33	222.27	236.84	15.90	76.00	165.43	2.86	11.70	12.90
WHO	500	-	1000	500	-	-	1000	10	-	-
CV (%)	3.44	4.60	7.39	4.98	3.84	3.90	4.11	2.80	4.40	1.94
MSD(0.05)	23.52	17.81	82.53	89.66	36.54	31.31	23.63	16.98	1.20	0.40
SEM(±)	6.24	4.73	21.92	23.82	9.70	8.31	6.27	4.51	0.32	0.12
Rivers(0.05& 0.01)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Rivers*Sites(0.05&0.01)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test.

Except EC (μS/cm), TURB (NTU), and WT, and AMT (°C) the others parameters were expressed in mg/L.

Significant interactions and main effects were explored by Tukey's test, using the GLM Procedure at P<0.05 and 0.01 as established by MSD test

Table 6. Effects of effluent discharges by coffee refineries on physical characteristics of river water at different river among different sites

	Mean separation of Physical parameters									
Sites	**TSS**	**SS**	**TDS**	**TS**	**TVS**	**TFS**	**EC**	**TURB**	**WT**	**AMT**
EFF	1429.39^{a}	769.86^{a}	1805.93^{b}	3235.31^{b}	1906.3^{a}	1563.63^{a}	997.01^{b}	1299.88^{a}	35.08^{a}	28.203^{c}
INF	1271.92^{b}	614.09^{b}	2600.92^{a}	3872.83^{a}	1599.56^{b}	1188.09^{b}	1169.62^{a}	1247.84^{b}	36.31^{a}	30.27^{a}
ENP	761.30^{c}	561.42^{c}	1392.8^{c}	2154.1^{c}	1393.5^{c}	939.45^{c}	650.94^{c}	680.48^{c}	31.55^{b}	28.89^{b}
DS2	595.21^{d}	366.11^{d}	754.59^{d}	1349.8^{d}	731.21^{d}	755.19^{d}	450.64^{d}	436.49^{d}	22.50^{d}	23.587^{e}
DS1	542.19^{e}	298.17^{e}	713.64^{d}	1255.8^{d}	750.91^{d}	777.43^{d}	437.59^{d}	432.29^{d}	25.95^{c}	26.35^{d}
UPS	22.03^{f}	7.19^{f}	275.8^{e}	297.8^{e}	52.4^{e}	192.5^{e}	180.8^{e}	4.85^{e}	18.45^{e}	20.45^{f}
Max	1812	1274	2816	4302	3498	3105	1227	1397	43.96	34.90
Min	9.70	2.33	222.27	236.84	15.90	76.00	165.43	2.86	11.70	12.90
WHO	500	-	1000	500	-	-	1000	10	-	-
CV (%)	3.44	4.60	7.39	4.98	3.84	3.90	4.11	2.80	4.40	1.94
MSD(0.05)	23.52	17.81	82.53	89.66	36.54	31.31	23.63	16.98	1.64	0.55
SEM(±)	7.65	5.79	26.85	29.17	11.88	10.18	7.69	5.52	0.40	0.13
Sites(0.05&0.01)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Rivers*Sites(0.05&0.01)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test.

Except EC (µS/cm), TURB (NTU), and WT, and AMT (°C) the others parameters were expressed in mg/L

Significant interactions and main effects were explored by Tukey's test, using the GLM Procedure at P<0.05 and 0.01 as established by MSD test

4.1.2. Chemical parameters and their significance level in four river water among all sites

In the study area, the mean values of pH at all six sites of river water ranged between 5.28±0.05-4.26 ±0.05 which deviates from the maximum permissible limit set by WHO and the pH values of the river water showed acidic ranges. These results of pH values in all sampled sites between the four river water with river water and sites revealed that acidic. The minimum value of pH (2.9±0.08 mg/L) was recorded at the EFF of Kebena river water and this pH value of the river water was exhibited high acidic range. Apart values of pH from 300m to 900m (ENP to DS_2) sampled site (4.15±0.05-4.94±0.05), the rest exhibited that high acidity at the ENP being the highest with a value of 4.15±0.05. But, pH has not shown significant differences among $DS_1$and DS_2 river water at ($p<0.01$). There were highly significant variation in the pH value during the study period; the observed values were in the range 2.9 to 7.93 at Kebena EFF and Awetu UPS river water respectively. The mean value of pH recorded was 4.26±0.04, 4.43±0.04, 5.24±0.04 and 5.28 ±0.04 for Kebena, Awetu, Bonke and Ketalenca river water respectively. pH values in DS_1 to DS_2 sites exhibited that no significant difference (Appendices Tables 1-8 and Table 7- 8).

A significantly reduction of pH value (7.93 to 2.9) might be attributed to the very low assimilation capacity of river water. Decreased pH values from 7.9 to 2.9 increased ammonium nitrogen concentration from 0.067mg/L to 7.01 mg/L (Appendix Table I-VIII and Table 7- 8). Several studies have reported (Alemayehu Haddis and Devi, 2008; Yared Kassahun, *et al*., 2010) on the Bore river water in Bilida kebele and Gomma area of Jimma Zone (5.87) and (5.15) respectively. The pH value has not shown significant differences among DS_1 and DS_2 of river. This was probably due to the effluent from coffee processing plants containing high organic wastes that are rampant or untreated and dumped into the river water bodies and its vicinity close to this point (Akan *et al*., 2009; Abebe Beyene *et al*., 2011; Oladele, 2011; Walakira, 2011; Walakira and James, 2011).

Table 7. Effects of effluent discharges from coffee refineries on chemical characteristics of river water quality at different rivers within the interaction effects

Mean separation of chemical parameters									
Rivers	**pH**	**BOD**	**COD**	**DO**	**TN**	**NO_3-N**	**Org-N**	**NH_3-N**	**Ort-P**
Kebena	4.26^{c}	1953.13^{a}	1802.15^{a}	1.36^{d}	70.47^{a}	2.65^{a}	67.82^{a}	5.94^{a}	11.41^{a}
Awetu	4.43^{c}	1389.6^{b}	1237.23^{b}	2.27^{c}	54.59^{b}	2.55^{b}	52.04^{b}	5.79^{b}	10.83^{b}
Bonke	5.24^{a}	1201.36^{c}	1057.42^{c}	2.77^{b}	50.86^{c}	2.28^{c}	48.58^{c}	4.21^{c}	10.56^{b}
Ketalenca	5.28^{a}	1059.97^{d}	975.16^{d}	3.01^{a}	45.47^{d}	2.24^{c}	43.22^{d}	4.03^{d}	6.46^{c}
Max	7.93	2993	2867	8.31	99.23	3.99	95.80	8.37	23.31
Min	2.90	2.03	3.19	0.00	0.30	0.03	0.27	0.05	23.31
WHO	65-8.5	10	40	6	-	10-45	-	0.2-5	5
CV (%)	6.03	6.74	8.16	5.80	3.71	2.17	3.87	2.30	3.97
MSD(0.05)	0.16	46.51	46.67	0.14	1.83	0.05	1.82	0.102	0.35
SEM(±)	0.04	12.35	12.40	0.03	0.48	0.01	0.48	0.02	0.09
Rivers (0.05&0.01)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Rivers*Sites(0.05&0.01)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: Means with different letters in the same column are significantly different (Tukey's test at $P<0.05$) as established by MSD test. Except pH, the others parameters were expressed in mg/L.

Significant interactions and main effects were explored by Tukey's test, using the GLM Procedure at $P<0.05$ and 0.01 as established by MSD test

Table 8. Effects of effluent discharges from coffee refineries on chemical characteristics of river water at different river among different sites

Mean separation of chemical parameters									
Sites	**pH**	**BOD**	**COD**	**DO**	**TN**	**NO_3-N**	**Org-N**	**NH_3-N**	**Ort-P**
EFF	3.59[d]	2173.86[a]	1881.37[b]	0.52[d]	88.72[a]	3.13[b]	85.59[a]	6.14[b]	12.07[b]
INF	3.69[d]	2203.45[a]	1986.31[a]	0.13[e]	87.39[a]	3.76[a]	83.63[a]	6.98[a]	17.86[a]
ENP	4.15[c]	1646.6[b]	1411.1[c]	1.46[c]	72.22[bc]	2.79[c]	69.43[b]	6.15[b]	11.13[c]
DS2	4.94[b]	1185.4[c]	1164.9[d]	2.56[c]	36.08[d]	2.08[e]	33.99[d]	5.28[c]	8.7[d]
DS1	4.93[b]	1191.1[c]	1157.4[d]	2.55[b]	43.65[c]	2.32[d]	41.32[c]	5.34[c]	8.69[d]
UPS	7.53[a]	5.79[d]	6.82[e]	7.2[a]	4.02[e]	0.51[f]	3.52[e]	0.06[d]	0.43[e]
Max	7.93	2993	2867	8.31	99.23	3.99	95.80	8.37	23.31
Min	2.90	2.03	3.19	0.00	0.30	0.03	0.27	0.05	23.31
WHO	65-8.5	10	40	6	-	10-45	-	0.2-5	5
CV (%)	6.03	6.74	8.16	5.80	3.71	2.17	3.87	2.30	3.97
MSD(0.05)	0.29	63.53	63.74	0.2	0.05	0.05	1.82	0.102	0.35
SEM(±)	0.05	15.13	15.18	0.04	0.59	0.01	0.59	0.03	0.11
Sites(0.05&0.01)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Rivers*Sites(0.05&0.01)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test.
Except pH, the others parameters were expressed in mg/L.
Significant interactions and main effects were explored by Tukey's test, using the GLM Procedure at P<0.05 and 0.01 as established by MSD test

During the present study, DO values were fluctuated between 1.36±0.03 to 3.01±0.03 mg/L in river water samples collected among the four river water with river water and sites. The mean values of DO were found to be 1.36±0.03, 2.77±0.03, 2.77±0.03 and 3.01±0.03 for Kebena, Awetu, Bonke and Ketalenca river water respectively. At the ENP DO decreased drastically to 1.46±0.04 mg/L and was increased as it moves further DS_1 to DS_2 (2.55±0.04- 2.56±0.04 mg/L). The EFF and INF showed the lowest value of DO as 0.52±0.04-0.13±0.04 respectively (Appendices Table 1-8 and Table 7- 8). The minimum value of DO was EFF (0.00±0.04 mg/L) and maximum at UPS of the Kebena river water (8.04 ±0.04 mg/L) (Figure 6). It may be due to temperature variations. DO reveal that inverse relationship with physico-chemical and nutrient parameters. Similar type of results was observed in present study as dissolved oxygen decreased with increase in temperature. This level of oxygen in the river revealed that it was almost normal in the UPS (7.2 mg/L), while it should be not able to support fauna and flora. When DO concentrations below 5 mg/L may also adversely affect the functioning and survival of biological communities and hence all pollution-sensitive taxa failed to retrieve (Figure 6).

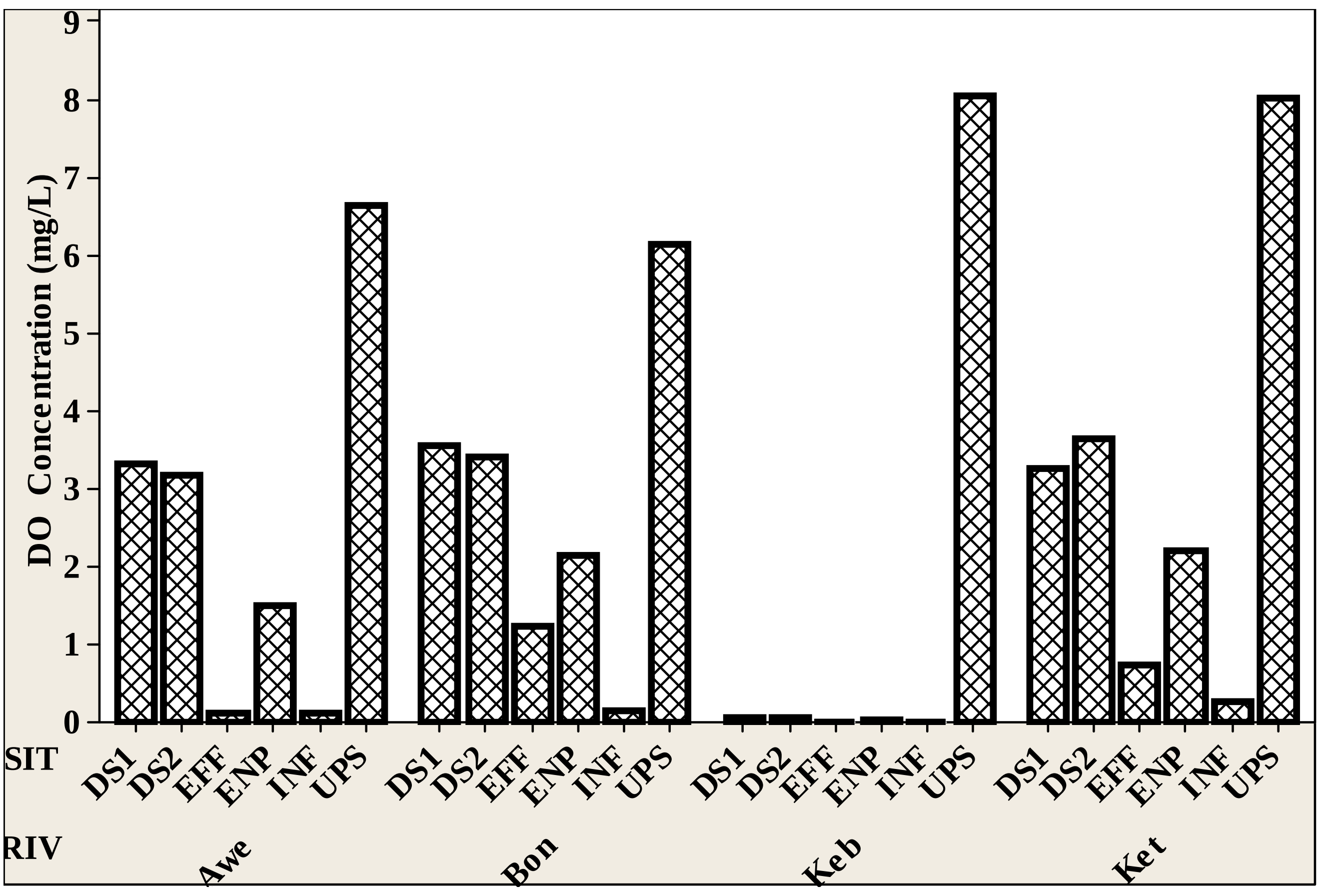

Figure 6. DO concentration rate variations among all river water of sampling sites

Dissolved oxygen (DO) was very crucial barometer for the survival of aquatic organisms and it was also used to evaluate the degree of freshness of river water. DO was the fundamental factor for the metabolism of the aerobic aquatic organisms and therefore its dynamic was important for the understanding of their distribution, behavior and growth. The distribution of DO affects the solubility of physico-chemical and nutrient. The solubility of DO was affected by temperature and its concentration varies with the dynamics of losses and productions mainly due to consumption by bacteria and other organisms through respiration, oxidizable organic matter and photosynthesis.

The persistence of DO anoxic indicated that the deoxygenation rate due to biological decomposition of organic matter was higher than reoxygenation from the atmosphere or probably due to the oxygen demanding coffee processing plants effluent into the river water body and vicinity. Concentrations of unpolluted fresh river water would be close to 100% or 6 mg/L. This indicated that the low level of DO from DS_1 to DS_2 during study was due to turbulences and flow rate of river water at different sites, which might be beneficial for dissolved solid breakdown through self-pollution regulating mechanisms of fresh water system was not found here (Alemayehu Haddis and Devi, 2008; Yared Kassahun, *et al*., 2010; Abebe Beyene *et al.*, 2011; Ugwu and Wakawa, 2012). DO was inversely proportional to physicochemical and nutrient parameters showed that there was no oxygenated water.

The difference in water quality status between the four river water with river water and sites as the interaction effect could be attributed due to with intensification of wet coffee processing plant and uncontrolled waste discharge. Low DO values and higher temperature at stations EFF and INF were due to organic wastes industrial discharges into the river water whose decomposition utilizes most oxygen in the water creating anoxic conditions. High concentrations of phosphates and low DO indicate organic pollution, this results in line with the (Nyakeya *et al*., 2009). A surprisingly low DO was also observed at EFF (0.00). This reduced the survivorship of oxygen sensitive aquatic ecosystem results in lined findings by (Alemayehu Haddis and Devi, 2008; Akan *et al*., 2009; Nyakeya *et al*., 2009; Oladele *et al*., 2011; Aina, 2012a; Aina, 2012b).

There were highly significant variations of interaction effect of BOD and COD among four river water with river water and twenty four sites of river water at ($p<0.01$). BOD and COD at UPS were significantly different from EFF, INF, ENP and DS1 to DS_2. BOD and COD were lowest in UPS (5.79 and 6.82 mg/L) as comparing to DS_2 (1185.4 and 1164.9). This concentration of BOD and COD was less than 40 mg/L and 20 mg/L at UPS of river water respectively. Higher values of BOD and COD at DS_2 might indicate that the pollution from industrial effluents in INF (2203.45±15.13 and 1986.31±15.18 mg/L) just before it entered into the river water (Appendices Table 1-8, Table 5-6 and Figure 7 and 8). Although the neither BOD nor COD concentrations exhibited that not significant variation in accumulation factor of the parameter illustrated that river water from DS_1 to DS_2 were (1191.1 to 1185.4 and 1157.4 to 1164.9) (Figure 8 and 9).

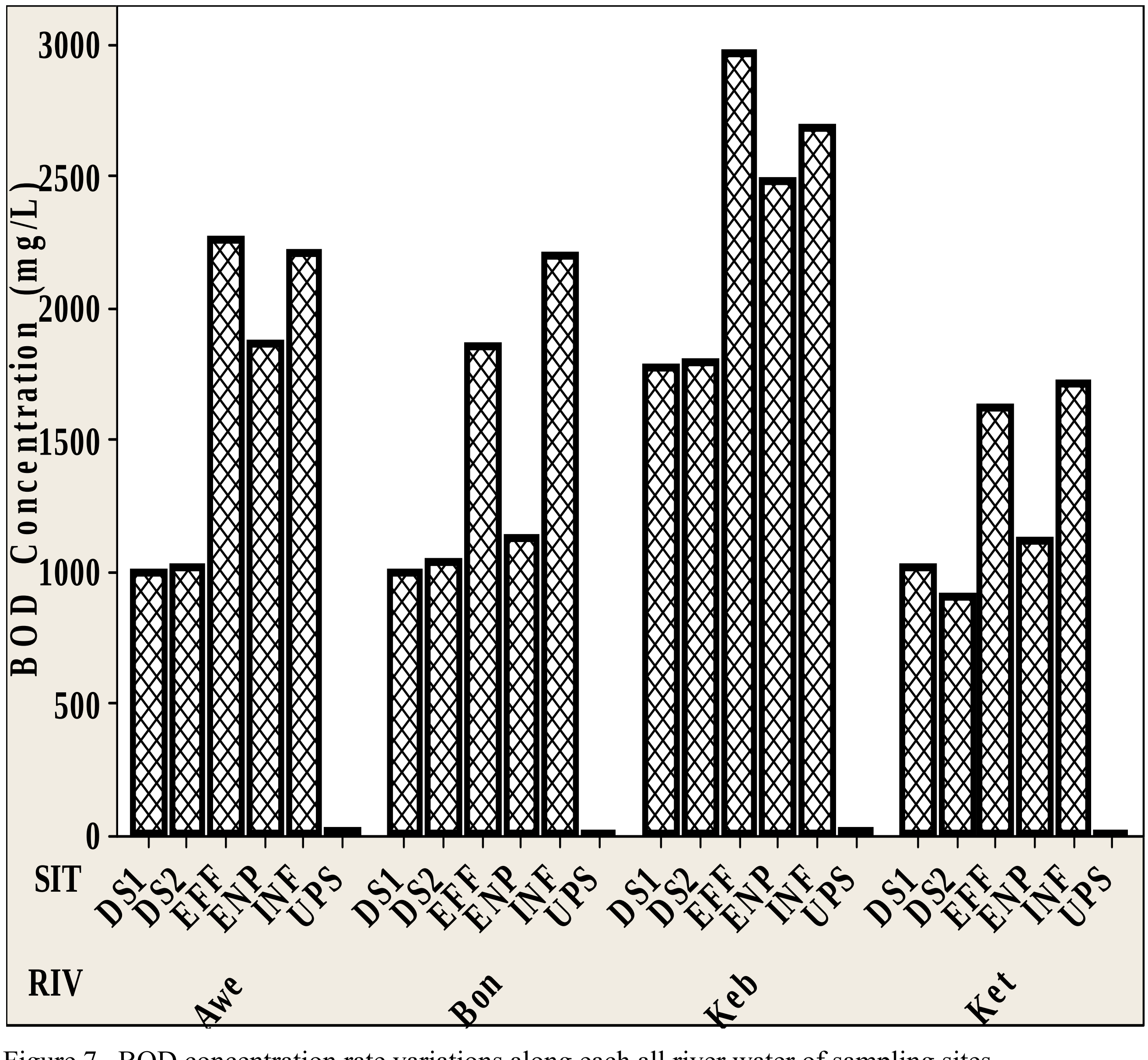

Figure 7. BOD concentration rate variations along each all river water of sampling sites

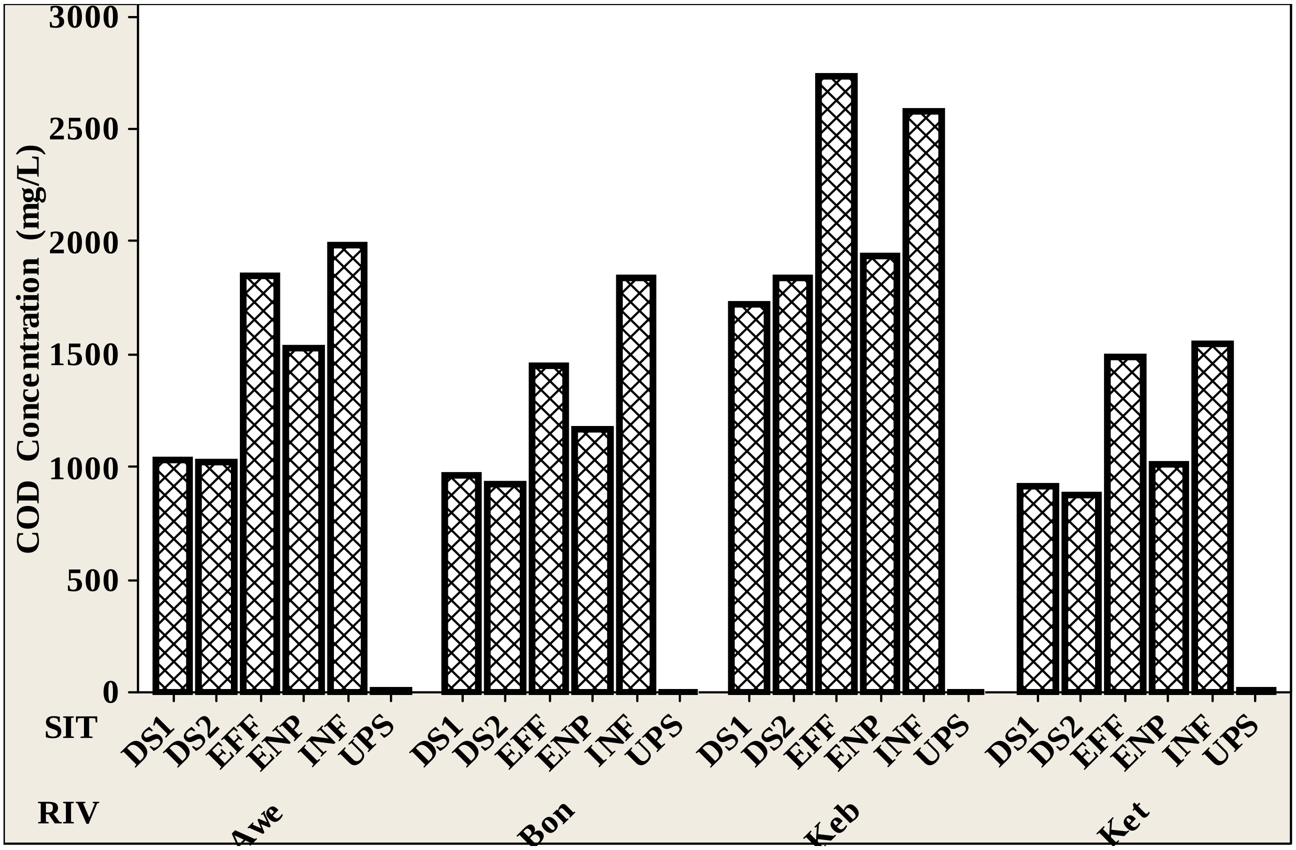

Figure 8. COD concentration rate variations along each all river water of sampling sites

High BOD and COD value at the EFF could be due to high organic load of TDS and TSS from these coffee processing plants. Moreover, high BOD and COD values at the EFF could be attributed to the low DO level, since low DO would result in high BOD and this was a strong indication of pollution. BOD test was useful in determining the relative waste loading and higher degree consequently to indicate the presence of large amount of organic pollutant and relatively higher level of microbial activities with consequent depletion of oxygen content. Similarly, the COD is the amount of oxygen used up from a water sample by organic and inorganic chemicals as they break down. The very high BOD and COD concentration was mainly related to organic waste enrichment from the coffee processing plants effluent and its effect was much more pronounced at the DS_2 of Kebena and Awetu river water (Figure 7 and 8). The BOD and COD values recorded in this study were low compared to several findings by (Alemayehu Haddis and Devi, 2008) reported BOD values up to 7800 mg/Lin a river at Bilida area of Jimma zone and very inline with (Akan *et al*., 2009; Yared Kassahun *et al*., 2010; Abebe Beyene *et al*., 2011; Ihejirika *et al*., 2011; Chikogu *et al*., 2012).

4.1.3. Nutrient parameters and their significance level in four river water among all sites

The NO_3-N was also one of the important factors of river water quality. Nitrate was an essential nutrient but also a good indicator of contamination from natural and anthropogenic activities. The variations of NO_3-N among the sampled at all sites were statistically, highly significant at $p<0.01$ (Table 7 and 8). However, NO_3-N was in higher concentrations throughout the sampled, values ranging from 2.32-2.80 mg/L at DS_1 to DS_2, while the level of UPS was 0.51 mg/L. Mean levels of NO_3-N were 2.65±0.01, 2.55±0.01, 2.28±0.01 and 2.24±0.01 mg/L at Kebena, Awetu, Bonke and Ketalenca river water respectively. Pattern of NO_3-N increment at DS as compared with UPS was observed during the sampled period respectively (Appendices Table 1-8, Table 7 and 8, and Figure 9).

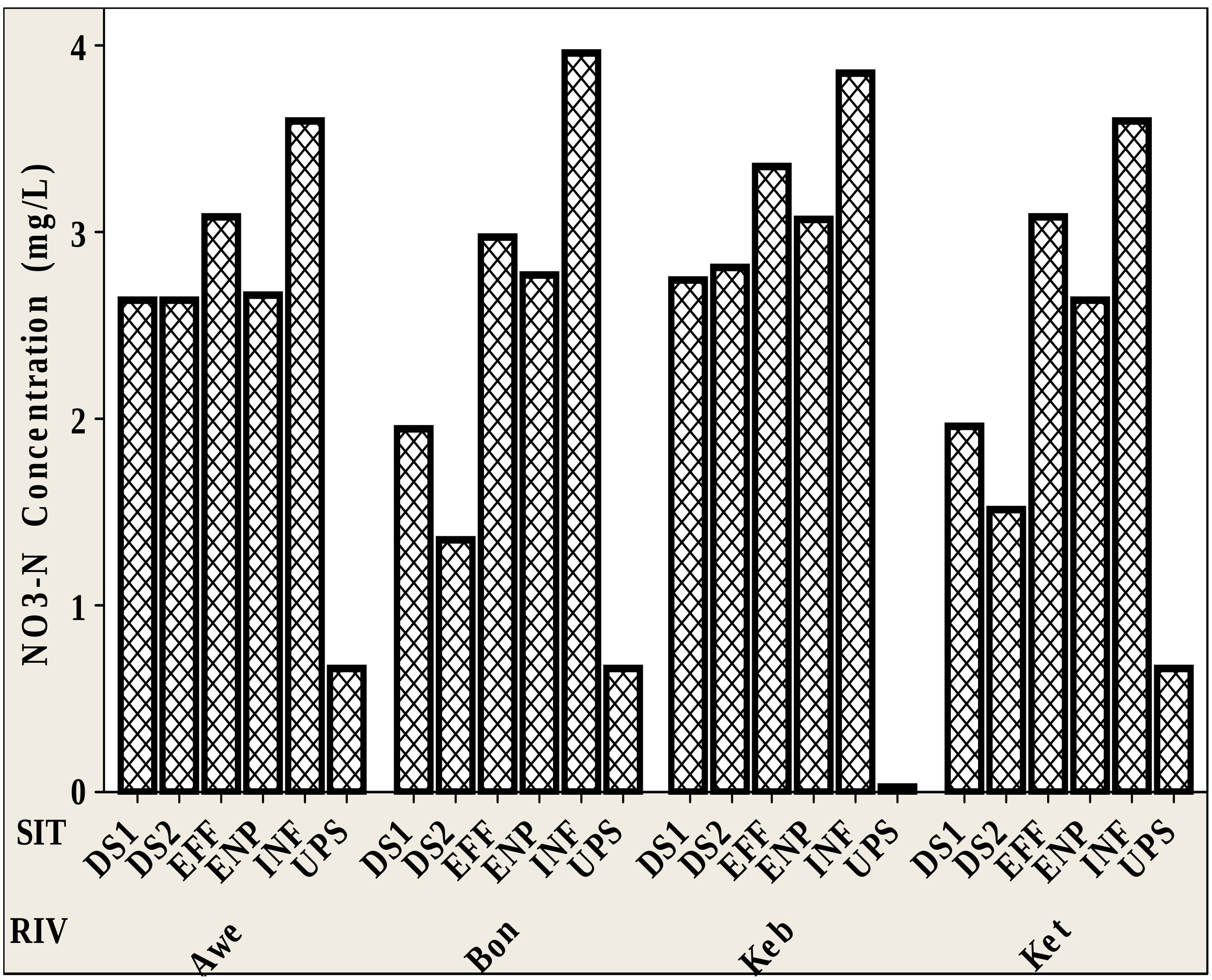

Figure 9. NO_3-N concentration rate variations in four consecutive rivers qualities along twenty four sites

Ammonia in natural waters is the product of the breakdown of nitrogenous organic and inorganic matter in soil and water as well as excretion by biota and reduction of nitrogen gas by microbes. Ammonia is a common pollutant that occurs in the free un-ionized form or as ammonium ions. Both are reduced forms of inorganic nitrogen derived from the decomposition of organic material. Ammonia is commonly associated with sewage and industrial effluents and forms part of many fertilizers. The toxicity of ammonia is directly related to concentration of the un-ionized form. The ammonium ions has very little or no toxicity. Mean levels of NH_3-N_2 were 6.14±0.1, 6.98±0.1, 6.15±0.1, 5.28±0.1 and 5.34±0.1 mg/L for EFF, INF, ENP, DS_2, DS_1 and UPS respectively. The concentrations of NH_3-N_2 in the Limu Kosa District Rivers for the duration of the study were alarmingly increased at from UPS to DS_1 due to high anthropogenic activities reaching the river. The impact intensity of the coffee refineries on river water NH_3-N_2 concentrations varied according to the intensity of coffee refineries technologies; the river NH_3-N_2 concentrations were higher in coffee refineries of private sector areas than in coffee refineries of government based on enormous volumes disposal of wastes into ambient environment and water bodies area (Annalakshmi and Amsath, 2012).

The total nitrogen concentration analysis revealed that highly significant difference in interaction effect among four rivers water at ($p \leq 0.01$). But among all river sites neither increased nor decreased concentrations exhibited not significant inconsistence (deviate) variation except at UPS. This due to highly mobility of TN along river courses. The total nitrogen concentration at the reference sites was slightly higher than 0.3 mg/L, the threshold set by ministry of water resources. This was probably due to the nature of the stagnant flow pattern that resulted in the decomposition of tree leaves and coffee wastes. This site was sampled during the present study since there was no better reference site along river water column (Figure 10). NO_3-N and Orth-P concentrations were higher in Kebena River than those of located in other river water. In the present investigation same thing was encountered (Akan *et al*., 2009; Nyakeya *et al*., 2009).

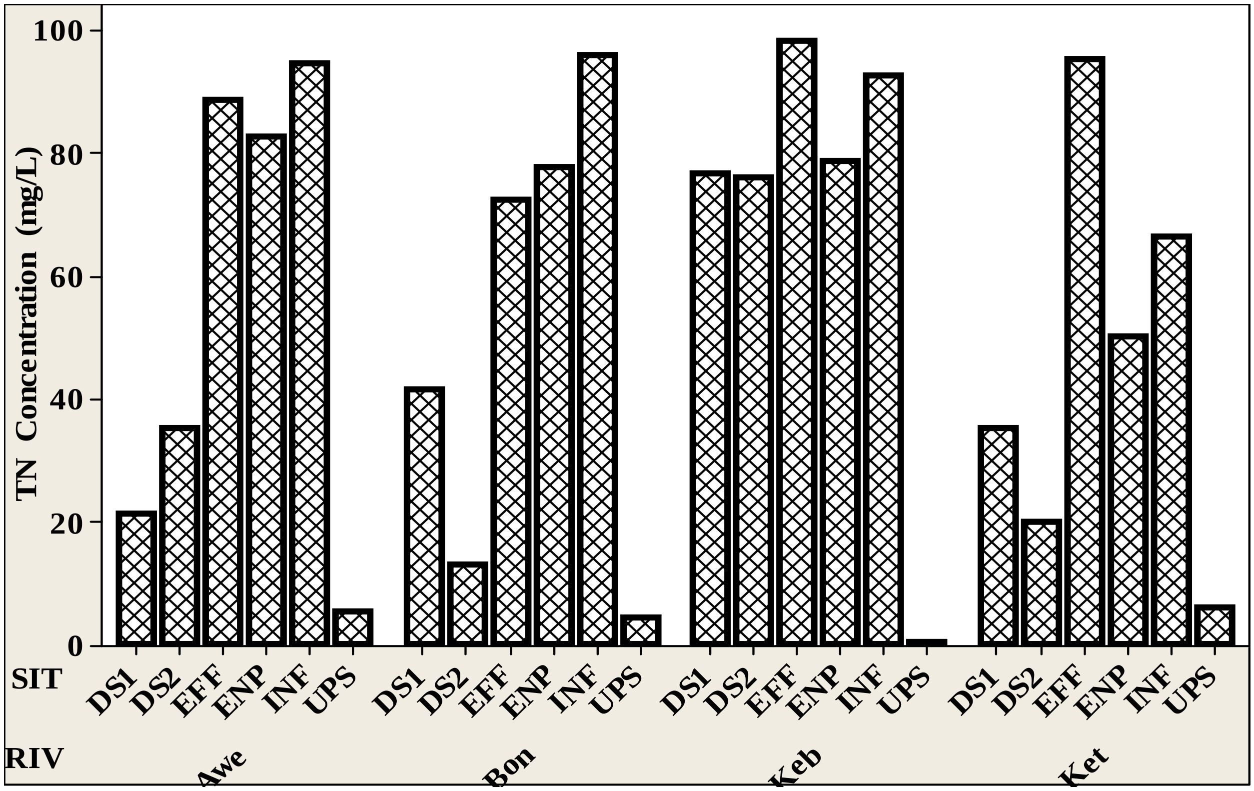

Figure 10. TN concentration rate variations in four consecutive rivers qualities along twenty four sites

Phosphate is present in natural waters as soluble phosphates and organic phosphates. Phosphorus is an important macronutrient and plays a major role in the structure of nucleic acids and in molecules (e.g. ATP) that are involved in the storage and use of energy in cells. In surface waters it occurs most commonly either as orthophosphates or as polyphosphates. Orthophosphate (Orth-P) is in a form that is immediately increased pressure on fauna & flora of river water bodies. Orth-P is seldom found in high concentrations in -polluted river water due to the fact that it is un utilized by fauna & flora. During the present study, Orth-P values were fluctuated between 0.43±0.11 mg/L to 12.7±0.11 mg/L in river water samples collected from twenty four sampling sites. Orth-P values of water samples were found minimum (0.43±0.11 mg/L) at UPS and maximum (12.7±0.11 mg/L) at EFF. The average value of Orth-P was found to be 11.41±0.09, 10.83±0.09, 10.56±0.09 and 6.64±0.09 for Kebena, Awetu, Bonke and Ketalenca river respectively.

Orth-P sample between four river water with river water and sites interaction effect during the study were alarming increased due to uncontrolled waste discharge of coffee processing plants activities reaching the river water followed the EFF. This was the case in the study area, as higher values of TN and low DO recorded were point of coffee processing plants at EFF. These concentrations of inorganic nitrogen (NH_3-N and NO_3-N) greater than 0.3 mg/L could cause algae to grow in abundance. This concentration was exceeded in all sample sites included the reference sites (Appendices Table 1-8I and Table 5-6). As indicated in the (Figure 9-11), nutrient contamination leading to eutrophication could eventually result in low dissolve oxygen conditions for much surface river water. Ammonia in waste water was the product of the breakdown of nitrogenous organic and inorganic matter in river water as well as excretion by biota and reduction of nitrogen gas by microbes. Ammonia was a common pollutant that occurs in the free un-ionized form or as ammonium ions. This toxicity of ammonia was directly related to concentration of the un-ionized form of coffee waste in to river. The sampling sites investigated that all situated among the sampled at all sites and along the river water column and thus higher nitrate levels were to be expected during the high flow due to an increase in runoff from the coffee processing plants effluent (Annalakshmi and Amsath, 2012).

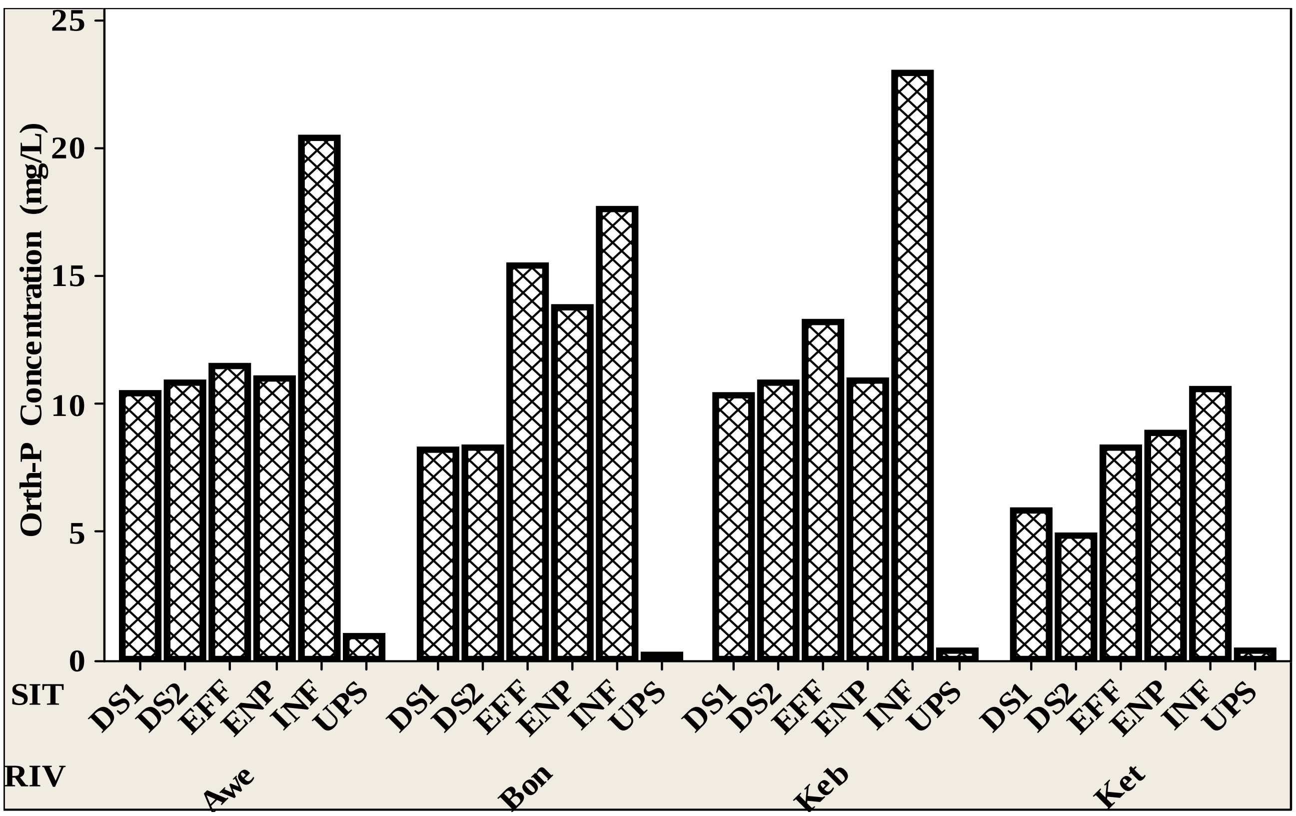

Figure 11. Orth-P concentration rate variations among all rivers water qualities of sampling sites

High Ortho-P and NO_3-N levels may contribute to the eutrophication of Didessa and Gibe river water (personal observation). The accumulation rate of these nutrients was continuing than it could be naturally controlled through the self purification process (Figure 9 and 10). When discharged in excessive amounts on river water, they could also lead to the pollution of groundwater. Many researchers have observed an increased in Orth-P and NO_3-N concentration in such of the river water bodies that receives coffee waste (Mehrdadi *et al*., 2006; Alemayehu Haddis and Devi, 2008; Akan *et al*., 2009; Dube, 2010; Abebe Beyene *et al*., 2011).

The effects of discharging rampant coffee refineries into freshwater ecosystems depend on the quality and quantity of the effluent, and on the condition, type and resilience of the receiving ecosystems. UPS of Limu Kosa District showed good river water quality parameters as well as macro-invertebrate assemblages act as good biological indicators of river water quality. Whereas, entry point segment receive huge volume of effluents that acts as physical-chemical barrier, which restrict the movement of macro-invertebrates from DS to UPS. In DS_2 segment of Kebena and Awetu river water, a small scale head works was present that is used to divert river water for irrigation purposes. But, for Kebena and Awetu river water, all the measured physico-chemical and nutrient parameters showed an increasing trend from UPS to DS_2. These results of Kebena and Awetu river water also depicted significant loading of pollution parameters in waste water from the coffee processing plants of Feyisal AbaMecca and Gidahe Barihe of DS_2 segment these receive effluents than Bonke and Ketalenca river water. Therefore, the industrial discharge contributes larger portion of the flow of the river water during the peak time of coffee processing plants season, with the result that the water quality of the river water were further deteriorated. It could lead to the reduction in volume of river water and also impede the free flowing of the river water. The hydrological regime was disrupted by most processing, because coffee processing plants use large quantities of water for fermentation and processing. This was because of abstraction of large volumes of water and discharge of large volumes of effluents into the environment (Aina, 2012a; Aina, 2012b; Ugwu and Wakawa, 2012).

Now a day, the use of this river water by local community for their daily needs has exposed them to serious health hazards such as intestinal problems, feelings of irritation on their body after washing with waste water, respiratory and skin irritation, stomach pain and nausea. Many of river water bodies in Limu Kosa District experience seasonal fluctuations, leading to a higher concentration of pollutants during the peak time of coffee processing plants, when effluents were very low diluted. Effluent generated from private coffee processing plants that are discharged to the river water column as well as vicinity revealed highly significant variation of physico-chemical and nutrient characterization as compared to government site. It was also noted that most of these coffee processing plants were set up without carrying out environmental impact assessment (EIA) and also most do not carry out the mandatory periodical environmental audits (EA). Strict measures should be exercised by the local authority to ensure that industrial effluent discharged into river water is treated. There is also a need to revise penalties for the different private categories of coffee processing plant so as to discourage pollution by industrialists (Alemayehu Haddis and Devi, 2008; Akan *et al*., 2009; 2012a; Aina, 2012b).

The distance of coffee refineries of effluent discharge sites far from Kebena and Awetu river water was less than 200m, implying that it was difficult for self purification. So, it had good harnessing as the natural self-purification process in conserved wetlands where optimum conditions could be maintained as treatment of coffee wastewater was also successfully in downstream site of Ketalenca, as compared to other. Therefore, along Ketalenca river water column, a self-purification process was observed to occur which was significant for physico-chemical and nutrient (Mehrdadi *et al*., 2006; Akan et al., 2009; Dube, 2010; Abebe Beyene *et al*., 2011). It is worthy to note that the BOD and COD values of Ketalenca river water DS_2 (after the point of effluent discharge) were low. This could be attributed to net dilution and decomposition of organic load as they move away from the point of discharge. The physico-chemical and nutrient parameters values recorded in this study were low compared to several findings (Taurai, 2005; Akan *et al*., 2009; Vivan *et al*., 2012; Aina, 2012a; Aina, 2012b). In addition, the lagoon that were intended to serve as wastewater stabilization were neither properly constructed nor were they of the right dimension to accommodate the generated waste during peak time of coffee processing plants, lead to overflow of raw effluents into natural river water column. There was a marked difference in mean values of river water quality parameters (i.e. physico-chemical, nutrient properties and biological) measured UPS and those DS from that received discharge (Alemayehu Haddis and Devi, 2008; Akan *et al*., 2009; Aina, 2012a; Aina, 2012b).

Combination of high acidity with high physico-chemical and nutrient parameters widely exceeds self purification capacity of river water quality and does not allow for aquatic life and complex effects on flowing river water. Temperature of water and ambient samples at all river water sites was said to be tolerable when compared to WHO and EPA acceptable limits. This finding was in agreement with the findings of other studies in the same and other rivers (Akan *et al*., 2009; Akali *et al*., 2011; Abebe Beyene *et al*., 2011).

As wet coffee processing plants methods expansion was situated along the river water banks with coffee waste water accelerated and intensified the use and abuse of water resources over the past few months, a greater and greater imbalance between river water availability and river water demand had been resulted. This imbalance of physico-chemical and biological parameter has brought a veritable crisis with regard to river water in many kebeles of the Limu Kosa District including but not limited to such problems as widespread water scarcity, water quality deterioration, and the destruction of freshwater resources (Alemayehu Haddis and Devi, 2008; Akan *et al*., 2009; Yared Kassahun *et al*., 2010; Abebe Beyene *et al*., 2011).

High or low levels of physico-chemical and nutrients characteristics of river water quality parameters in Limu Kosa District could be attributed to poor agricultural practices and high use of agro-chemicals. When use of this river water quality, it wasn't suitable for agriculture, domestic, aquatic ecosystem; and irrigation (the germination of almost all the crops would be seriously affected resulting in much reduced yield). This remarkably high value might be connected with continuous discharged of organic wastes into the aquatic ecosystem from the processing plants. Other effects include a negative influence on the root growth, infiltration (permeability) problems in soils structure, absorption of water and nutrients and poor amenities to DS_2 inhabitants. It might also be major cause for rapid deterioration of soil properties like irregulate the flow dynamics of salt, storage and distribution of nutrients and water uptake by ambient. Anoxic level of DO reduce the self-affining capacity of these rivers to recover from the coffee waste impact during the peak time of coffee processing plants season (Solaimalai and Saravanakumar, 2004; Akan *et al*., 2009; Abebe Beyene *et al*., 2011; Walakira, 2011; Walakira and James, 2011).

Various methods and techniques used in several other coffee producing countries, such as reducing water use, reusing wastewater, using water-efficient machinery, and preparing coffee waste for feeds, beverages, biogas, caffeine, protein, compost, and several other products, had not been applied in Ethiopia (Alemayehu Haddis and Devi, 2008; Akan et al., 2009).The significantly low levels of physico-chemical and biological analysis at UPS could be due to dilution effect and natural affining systems along the river site, while the increased values of DS could be due prone deterioration of the water quality likely caused by the discharge of coffee processing plants waste water (Adeyemo *et al*., 2008; Akan *et al*., 2009; Sivakumar *et al*., 2012).

4.2. Correlation Matrix (r) among Selected Physico-Chemical and Nutrient Parameters of River Water Quality Characteristics

In order to find out the relationship among physico-chemical and nutrient parameters of the river water samples, correlation coefficients were worked out and a large number of significant correlations were obtained. The statistical analysis shows that the correlation matrixes of the physico-chemical and nutrient parameters were summarized in (Table 9). AMT and WT are revealed positively highly significant correlated among all physico-chemical and nutrient parameters, except DO (-0.94,-0.93) and pH (-0.93,-0.91) which are negatively highly significantly correlated, respectively at ($p<0.01$). TDS was highly positively significantly correlated among all TSS, TURB, TS, EC, BOD, COD, TN, NO_3-N_2, NH_3-N_2, Org-N, Orth-P, WT and AMT at ($p\leq0.01$), mean while, TDS were moderately positively significant correlated with SS (0.63), TVS (0.55) and TFS (0.67). But, TDS was highly negatively significant correlated with DO (-0.78) and pH (-0.76) at ($p<0.01$). This indicates that TDS was main contributory source of TS. So, it was revealed these anions and cations combine and precipitate as TDS. TSS were revealed that positively highly significant correlated among all physico-chemical and nutrient parameters, except DO (-0.86) and pH (-0.84) which were negatively highly significantly correlated at ($p<0.05$) (Table 9). Turbidity showed that highly positive significant correlation with all physico-chemical and nutrient parameters, except TVS (0.52), which was moderately positive significant correlated with Turbidity and highly negative significant correlation with DO (-0.88) and pH (-0.86). Turbidity also exhibited decreased or increased in their values and also reverse for DO and pH values. The turbidity was a striking characteristic to know the physical status of a river. The suspended particles, soil particles, discharged effluents; decomposed organic matter, TDS as well as the microscopic organisms increase the turbidity of water, which interferes with the penetration of light.

EC showed that highly positively significant correlation with all physicochemical and nutrient river water quality parameters, except SS(0.69) and TVS(0.49) were moderately positive correlated significantly at ($p<0.05$). EC indicated that highly negatively significant correlation with DO (-0.84) and pH (-0.84) at ($P<0.01$). EC was a measure of capacity of a substance or solution to conduct electricity. It is an excellent indicator of TDS which is a measure of salinity which affects taste of potable water. This shows that with increased or decreased in the values of EC; TDS, TSS, TS, BOD, COD, TN, NO_3-N, Org-N, NH_3-N, Orth-P. EC of river water depends upon the concentration of ions and its nutrient load.

Statistically, the results exhibited that the DO and pH were negatively highly significant correlation with all physico-chemical and nutrient parameters, except TVS (0.52) at DO and TVS (0.47) at pH at ($p<0.01$) (Table 9). Mean while, this accounted for the positively highly significant correlation between pH and DO in river water parameters. Theoretically, DO decreases with an increase in altitude because of the impact of pressure on the amount of oxygen to be dissolved in water. But, the sampled sites (DS) with lower DO due to increased load of pollution from point sources were found at relatively lower altitude when compared with UPS. These indicated that with any increased or decreased in the values of DO and pH also exhibited decreased or increased respectively in their values of all physico-chemical and nutrient parameters. It has been observed that COD and BOD were highly positively significant correlated among all physico-chemical and nutrient of river water parameters, except TVS (0.48) at BOD and TVS (0.48) at COD, meaning that two parameters were likely from the same source at ($p<0.05$and $P<0.01$). The TN, NO_3-N, Org-N and Orth-P positively highly significant correlated among each ($p<0.05$). TVS and TFS were moderately positive significant correlated with all physico-chemical and nutrient parameters, except DO and pH which were negatively highly significantly correlated at ($p<0.05$). TVS and SS were not significant correlated at ($p<0.01$and 0.05).

The determination of correlation coefficient analysis could be used as an important method for the interpretation among the physico-chemical parameters and pollution levels of the various river water of the locality and mutual relationship among two parameters. The study of correlation reduces the range of uncertainty associated with decision making. Direct correlation exists when increase or decrease in the value of one parameter was associated with a corresponding increase or decrease in the value of the other parameter.

Finally, it could be revealing the correlation matrixes studies of the river water quality parameters had great significance in the study of river water column. This indicated that the reliability of the relationships which suggests that it could be used to predict the levels of pollution by investigated interrelationships of parameters and possibly proofing a preventive measure prior to detailed investigation of Limu Kosa District river water in pollution monitoring. This result is in agreement with the findings of the study conducted in the same and other river water (Narendra and Kapil, 2007; Temesgen Negash, 2009; Usharan *et al*., 2010; Venkatesharaju *et al*., 2010; Waziri and Ogugbuaja, 2010).

Table 9. Pearson`s Correlation coefficient (r) among selected physico-chemical and nutrient parameters of river water quality characteristics

	TSS	SS	TDS	TS	TVS	TFS	BOD	COD	DO	TN	NO_3	Org	NH_3	Orth	EC	TUR	WT	pH	AMT
TSS	1																		
SS	0.80	1																	
TDS	0.78	0.63	1																
TS	0.92	0.74	0.97	1															
TVS	0.43	0.13	0.55	0.53	1														
TFS	0.82	0.71	0.67	0.77	0.36	1													
BOD	0.93	0.83	0.85	0.93	0.48	0.82	1												
COD	0.91	0.83	0.83	0.91	0.48	0.84	0.98	1											
DO	-0.86	-0.74	-0.78	-0.86	-0.52	-0.73	-0.97	-0.95	1										
TN	0.87	0.79	0.81	0.89	0.55	0.71	0.91	0.94	-0.91	1									
NO_3	0.82	0.66	0.84	0.88	0.58	0.69	0.89	0.90	-0.94	0.90	1								
Org	0.87	0.79	0.81	0.88	0.54	0.72	0.91	0.90	-0.91	0.99	0.89	1							
NH_3	0.75	0.75	0.73	0.78	0.42	0.68	0.88	0.85	-0.92	0.82	0.92	0.81	1						
Orth	0.72	0.66	0.84	0.84	0.60	0.55	0.94	0.88	-0.91	0.81	0.94	0.80	0.86	1					
EC	0.88	0.69	0.94	0.97	0.49	0.70	0.88	0.85	-0.84	0.89	0.89	0.89	0.77	0.82	1				
TUR	0.89	0.76	0.89	0.94	0.52	0.75	0.90	0.88	-0.88	0.90	0.88	0.90	0.78	0.78	0.94	1			
WT	0.93	0.92	0.73	0.89	0.84	0.91	0.95	0.92	-0.93	0.90	0.79	0.89	0.75	0.94	0.91	0.93	1		
pH	-0.84	-0.76	-0.76	-0.83	-0.47	-0.71	-0.94	-0.95	0.93	-0.93	-0.96	-0.88	-0.95	-0.99	-0.84	-0.86	-0.91	1	
AMT	0.86	0.92	0.83	0.86	0.81	0.96	0.93	0.91	-0.94	0.92	0.92	0.92	0.91	0.77	0.87	0.94	0.91	-0.93	1

0.70 to 1.0 and -0.70 to -1.0= Correlation are highly significant at $p < 0.05$ probability levels, +0.30 to 0.70 and -0.30 to -0.70= Correlation are moderately significant at $p < 0.05$ probability levels and '-' indicate negative correlation

4.3. Accumulation Factor and River Recovery Capacity among Selected Physico-Chemical and Nutrient Parameters of River Water Quality Characteristics

The Accumulation Factor (AF) and River Recovery Capacity (RRC) of the water quality parameters during the sampling period were presented in (Table 10-11). The degree of river water pollution concentration of recovery in percent efficiencies of water pollutants were calculated as the percent change in concentrations or accumulation factor loading rates from influent to effluent due to coffee refineries ramifications .

TURB and SS were the highest accumulated deposition of solid or particulate materials in river water bodies along the column of DS_2, and were 90.00 and 50.92 times more than the average levels of UPS, whereas TSS and TVS showed an accumulation of about 27.02 and 13.95 times more than average levels upstream sites for river water respectively. Other parameters showed an average accumulation factor of DS were less than 5 times the values observed at UPS. All the solids, except TDS and EC showed a RRC of >95% and >74.51% DS_2 for river water bodies respectively. RRC values for TDS and EC were 63.45% and 59.88% in water indicating that there was little or no change in values DS_2 compared to values UPS.

Table 10. AF and RRC for physical parameters of river water quality

	TSS	SS	TDS	TS	TVS	TFS	EC	TURB	WT	AMT
AF	27.02	50.92	2.74	4.53	13.95	3.92	2.49	90.00	0.93	0.91
RRC	96.30	98.04	63.45	77.94	92.83	74.51	59.88	98.89	-7.39	-10.24

AF: Accumulation factor, RRC: River Recovery Capacity.

The trend in AF of the parameters revealed that the BOD, COD, NH_3-N_2, Ort-P, Org-N, TN and NO_3-N of water DS were about 204.73, 170.81, 88.00, 20.23, 9.66, 8.98 and 4.08 times, more than the values observed at UPS respectively. Similarly, the trend in AF of the parameters revealed that the pH and DO of river water DS were about 0.66 and 0.36 times more than the values observed at UPS respectively. BOD, COD, NH_3-N, Ort-P, and TN showed the highest percentage recoveries of 99.51%, 99.41%, 98.86%, 95.06% and 88.86%, whereas NO_3-N showed the higher recoveries of 88.86% and 75.48% respectively in water DS_2. In other words there was an increase in BOD, COD, NH_3-N, Ort-P, TN and NO_3-N showed the highest percentage RRC of 99.51%, 99.41%, 98.86%, 95.06%, 88.86% and 75.48% respectively in river water DS_2 as compared to the values at the effluent discharge sites of impact, introduced at effluent discharge sites that was not removed by self-purification DS_2 (Table 11).This was probably true for the pH, DO and temperature where negative percentage recoveries amounts were recorded (Table 8-9).

Table 11. AF and RRC for chemical and nutrient parameters of river water quality

	pH	BOD	COD	DO	TN	NO_3-N	Org-N	NH_3-N2	Ort-P
AF	0.66	204.73	170.81	0.36	8.98	4.08	9.66	88.00	20.23
RRC	-52.43	99.51	99.41	-181.25	88.86	75.48	89.64	98.86	95.06

AF: Accumulation factor, RRC: River Recovery Capacity.

Self-purification capacity of a river water body was a good indicator of its ecological status. It involves complex mechanism which depends on several factors such as flow rate, time, temperature, serial dilution, chemical oxidation, biodegradation of organic materials, deposition of solid or particulate materials into sediment, dilution of contaminants, presence of micro organisms, pH and DO content of the water(Adeogun *et al.*, 2011). The AF of the physico-chemical and nutrient parameters (Table 10-11) clearly indicates that elevated values DS_2 as compared to the reference point UPS and was clear pointer of coffee processing plant ramifications. The RRC values for these parameters indicated that the level to which the self-purification mechanism of the river water was able to refresh water in the presence of pollutants was very low. The observed values showed that about 90% of most of the physico-chemical and nutrient changes due to industrial input into entry point was alleviate about 900m downstream sites of the effluent discharge site. This suggests that a longer stretch of unimpacted river would be required for higher recovery values. The low recovery values observed for phosphate and nitrate suggests that these substances were being released into the river water in quantities that cannot be single-handedly removed by aquatic-plants and facultative algae which constitute part of the river's self-purification mechanism (Adeogun *et al.*, 2011; and Fakayode, 2005). The high levels of these physico-chemical and nutrient parameters clearly overwhelm the RRC thus indicating poor river water quality. The high RRC of BOD, COD and NH_3-N DS might be a pointer to the efficiency of the river's no aeration mechanism which was no free flow of river water (Adeogun *et al*., 2011; Aina, 2012a; Aina, 2012b). The increased values of deposition of solid or particulate materials into sediment DS_2 compared to average values UPS strongly implicate coffee processing plant activity and this was confirmed by the accumulation factor reported for each deposition of solid or particulate materials into sediment downstream sites compared to upstream sites values (Table 10-11). Although all the heavy deposition of solid or particulate materials into sediment showed a level of accumulation DS_2, TDS, ambient and water temperature and EC showed the higher accumulation. This suggests a high abundance of this deposition of solid within this stretch of river studied hence there was significant change in availability DS_2 compared to UPS values. The continuous deposition of solid or particulate materials from these industries could lead to a reduction in volume of water by impeding the free flow of the river. Long term deposition of materials into Limu Kosa River may also result in flooding, particularly during heavy rain fall which could have both economic and ecological implications. During the study, some physico-chemical and nutrient parameters of the river water acted as sources of nutrients instead of sinks resulting in negative percentage recoveries values (Table 10-11). This suggests that previously retained physico-chemical and nutrient parameters that might have been re-suspended during storms or extra nutrients were coming from other sources in the river water. In the present investigation same thing was encountered (Fakayode, 2005; Adeogun *et al*., 2011; Aina, 2012a; Aina, 2012b).

4.4. Macro-Invertebrate Assemblages as Biological Indicators of River Water Quality

From the selected sampled sites of the different four rivers in Limu Kosa District, macro-invertebrate assemblages act as excellent biological indicators were collected to assess the quality of DS river water that receives discharges from wet coffee processing plants stations. Statistically, the results of macro-invertebrate assemblages as biological indicators analysis illustrated that highly significant differences between the four rivers with river water and eight sites at ($p<0.01$). Among UPS and DS, macro-invertebrates of fauna from 8 taxonomic orders were collected from Limu Kosa District Rivers. A total of 30 families under 8 orders representing class one and comprising of 1293 individuals were collected from the eight sampling sites. A total number of individuals found at DS were 387 which were compared to 906 individuals collected from their respective UPS. The mean percent abundance of UPS of all rivers were dominated by pollution sensitive taxa (Ephemeroptera, Hemispheres, Trichoptera, Plecoptera and Coleoptera) whilst DS were dominated by pollution tolerant families (Simulidae, Chironomidae, leeches).The mean percent abundance of individuals in the Chironomidae family was 67.35, 26.75, 57.41 and 62.99 at DS of Kebena, Awetu, Bonke and Ketalenca rivers which were compared to 0 individuals collected from their respective UPS (Appendix Table IX).

In order to understand the effects of wet coffee processing plants discharges on the biotic environment of the rivers, different diversity indices were tested (Table 10 and 11). Diversity calculations of H'and D for Limu Kosa District Rivers showed a range of 0.87 to 2.62 and 0.50 to 0.92, respectively (Table 12 and 13).

Table 12. Summary of benthic macroinvertebrates diversity indices and taxa richness

Water	F		S		D		H'		E		Min		Max	
	UPS	DS	UPS	DS	UPS	DS	UPS	DS	UPS	DS	UPS	DS	UPS	Ds
Awetu	9	11	266	157	0.88	0.85	2.15	2.09	0.98	0.89	0	0	42	42
Bonke	9	6	169	54	0.88	0.63	2.14	1.32	0.97	0.74	0	0	29	31
Katta	15	8	266	127	0.92	0.58	2.62	1.31	0.97	0.63	0	0	41	80
Kebena	13	3	205	49	0.92	0.50	2.54	0.87	0.99	0.79	0	0	25	33
Total			906	387	0.90	0.64	2.36	1.40	0.98	0.76	0	0	35	47
Grand			1293		-	-	-	-	-	-	-	-	-	-
Average			647		0.77		1.88		0.87		0		41	

This results revealed that there is a significant difference in all diversity indices between sites ($p<0.05$). Statistically, distinctly different in macro-invertebrates assemblages was also shown at ($p<0.05$). These macro-invertebrates assemblages would indicate the environmental effects of coffee processing activities on the river water quality and ambient. The average diversity indices (Shannon, equitability and Simpson) were reduced at the DS as compared to the UPS (reference) sites during the peak time of coffee-processing plant (Appendix Table IX and Table 12 and13).

Table 13. Results of ANOVA for macro invertebrate composition, abundance and distribution

Mean separation of diversity indices and taxa richness					
Site	**F**	**S**	**H'**	**D**	**E**
UPS	12^{a}	227^{a}	2.36^{a}	0.90a	0.98^{a}
DS	7^{b}	97^{b}	1.40^{b}	0.64^{b}	0.76^{b}
CV (%)	29	7	19.35	11.42	6.17
MSD(0.05)	2.98	12.52	0.40	0.097	0.052
SEM(±)	0.95	4.02	0.13	0.03	0.02

Note: Means with different letters in the same column are significantly different (Tukey's test at $P<0.05$) as established by MSD test.

As the BOD and COD load increased and as oxygen levels drop, certain species of macro invertebrates could be killed and pollution-tolerant species that require less oxygen replace the original species. Changes in species of macroinvertebrates, bottom-dwelling organisms (benthos) and aquatic ecosystem were, therefore biological indicators of oxygen depletion. Higher diversity of pollution tolerant families such as Chironomidae, Simuliidae and Leeches were dominated at DS as compared to pollution sensitive taxa. These pollution tolerant families were able to survive under extreme toxic pollutant conditions including low oxygen levels (Micheal and Kelso, 2007; Mary and Macrina, 2012). The ambient and river water bodies at DS were inhospitable since pollutant tolerant macro-invertebrates were also showing very low species richness. The Ambient and river water bodies at DS were also dominated with pollutant tolerant organisms though there was not resurgence of low and moderately sensitive macro-invertebrates. This might be possibly effects of no dilution from DS which contributes to deterioration along the river water column and the accumulation rate of these nutrients would continue than if it could be naturally controlled through the self purification process (Machena, 1997; Mary and Macrina, 2012). The biological assemblages at DS sampling also exhibited that the impact of wet coffee processing plants on the biotic environment following untreated coffee waste disposal or discharge into the water bodies. This finding was in agreement with the findings of other studies in the same and other rivers (Machena, 1997; Dube, 2010; Henry *et al*., 2011; Abebe Beyene *et al*., 2011; Mary and Macrina, 2012).

4.5. Correlation Matrix (r) among Selected Physico-Chemical Parameters and Macro-Invertebrates Assemblages as Biological Indicators of River Water Quality

The correlation matrixes found between physico-chemical parameters of river water and biological indicators have been summarized in (Table.14). PH and DO exhibited that there is highly significant positive correlated with benthic macro-invertebrates assemblages, while BOD and COD has shown highly significant negative correlated with benthic macro-invertebrates assemblages at ($p<0.05$). Meanwhile, TN, NO_3-N and Orth-P has showed a negative correlation with all diversity indices and taxa richness, except evenness with TN. i.e. no significant difference was found between TN with evenness at ($p<0.05$).

The richness and all diversity revealed that highly significant dependence on pH and DO parameters. This suggests that a local increase in pH and DO was responsible for increase in the richness of benthic macro-invertebrates. At same time, highly significant negative correlation of BOD and COD affected taxa richness and all diversity indices. This implies that, an increase in BOD, COD and nitrogen nutrients was responsible for decrease in the richness of benthic macro-invertebrates (Henry *et al.*, 2011; Mary and Macrina, 2012). This, in turn, could reduce the oxygen content of the river water, since warm water holds less DO than cold. Macro-invertebrates, especially the bottom-dwellers, were sensitive to temperature and would move to areas in the river where they find their optimal temperature. If BOD were outside their optimal range for a prolonged period of time, organisms are stressed and could die. A study of all diversity and abundance of macro-invertebrates in a river in Langat and Mananga reports that the sampled sites with the lowest BOD and COD with highest DO level had the highest all diversity index and taxa richness (Sharma and Samita 2011;Mary and Macrina, 2012). High BOD and COD in a river water body could often mean higher concentrations of bacteria, nutrients, organic wastes and inorganic wastes in the river water, because suspended and dissolved particles provide attachment places for these other pollutants (Mary and Macrina, 2012).

The trend of variations in E value was more or less the same as the H'. Lower values for evenness during the study period in river might be accounted to pollutant disturbances. When all species in a sample were equally abundant, it seems reasonable that an E index should be maximum and this value decreases toward zero as the relative density of the species diverges away from evenness was observed in the DS. However, this result might indicate that the pollutant load condition of the river water quality systems had reached their critical level that can markedly manifest in the levels of Physico-chemical of river water parameters. Since diversity indices values for real communities were often found to fall between 1.0 and 6.0, this means that diversity in all the sampled sites of Limu Kosa District River were relatively low since none had an H' value higher than 2.62 (Tables 12-13). This is in agreement with the report by the (Azrina *et al.*, 2005; Sharma and Samita, 2011; Mary and Macrina, 2012).

Table 14. Correlation matrixes among physico-chemical parameters with biological indicators of river water quality characteristics

	pH	DO	BOD	COD	TN	NO_3.N	Orth-P	F	S	H'	D	E
pH	1.00											
DO	0.93**	1.00										
BOD	-0.94**	-0.97**	1.00									
COD	-0.95**	-0.95**	0.98**	1.00								
TN	-0.93**	-0.91**	0.91**	0.94*	1.00							
NO_3-N	-0.96**	-0.94**	0.89**	0.90**	0.90**	1.00						
Orth-P	-0.99**	-0.91**	0.94**	0.88**	0.81**	0.94**	1.00					
F	0.88**	0.85**	-0.89**	-0.78**	-0.67*	-0.59*	-0.62*	1.00				
S	0.89**	0.86**	-0.86**	-0.80**	-0.65*	-0.65*	-0.78*	0.82**	1.00			
H'	0.79**	0.91**	-0.88**	-0.85**	-0.72*	-0.69*	-0.72*	0.93**	0.88**	1.00		
D	0.77**	0.87**	-0.88**	-0.85**	-0.71*	-0.65*	-0.69*	0.86**	0.86**	0.97**	1.00	
E	0.86**	0.88**	-0.83**	-0.81**	-0.43	-0.53*	-0.60*	0.82**	0.75**	0.84**	0.89**	1.00

**= Correlation are highly significant at $p < 0.05$ probability levels, *= Correlation are moderately significant at $p < 0.05$ probability levels and '-' indicate negative correlation. (E= Equitability or Evenness index, BOD= Biological Oxygen Demand, COD = Chemical Oxygen Demand, DO= Dissolved Oxygen, D= Simpson's diversity index, F=Total number family in the sample, H' = Shannon-Wiener Diversity Index, Orth- P= Orthophosphate, NO3-N= Nitrate nitrogen, S= Specious richness taxa and TN= Total nitrogen)

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Wet coffee processing is coffee growing belt of SW Ethiopia is found to be a source of river water pollution. Statistically, the results of all physico-chemical and nutrient parameters analysis revealed that highly significant difference in interaction effect among four rivers water and twenty four sites of river water courses at ($p<0.01$). Mean while r results of revealed that significant difference among benthic macro-invertebrate assemblages as biological indicators between the four rivers and eight sites at ($p<0.05$). The results also depicted significant loading of pollution parameters in waste water from the coffee processing plants into Limu Kosa District. The level of pollution generally increases from UPS to DS_2 of the Limu Kosa District river water. Considering the results of the measured physico-chemical and nutrient river water parameters and biological indicators and showed that, the coffee processing plants were the most contributing factors to the pollution of the river water. Therefore, coffee processing plants activities were the main source of organic pollution in this river water quality.

DS_2 of river water was found to be highly impacted as compared to the UPS due to the discharge of coffee processing plants activities BOD and COD load in river water exceeded the maximum permissible limit set by WHO. For this reason the river water could not be used for irrigation and other domestic purposed. The alteration in river water quality parameter was more pronounced immediately during the peak time of coffee processing plants. UPS showed good river water as well as biological indicators, whereas, ENP segment receive huge volume of effluents that acts as physical-chemical barrier, which restrict the movement of macro- invertebrates from DS to UPS. So, DS were significantly elevated than the corresponding levels of UPS.

The degree of river water pollution concentration of recovery in percent efficiencies of water pollutants were calculated as the percent change in concentrations or accumulation factor loading rates from influent to effluent due to coffee refineries ramifications . In this study, the concentration recovery factor and percent were relatively high (>78%) despite the inconsistence variations that were recorded. The AF and RRC values of the physico-chemical and nutrient parameters clearly indicated that elevated values at DS compared to the reference point at UPS and were a clear pointer of coffee processing plants impact. DO and pH have shown highly significant positive correlated, while all physico-chemical have shown significant negative correlation with biological assemblages indicators.

The diversity indices were able to capture water quality impairment during the peak time coffee processing pants. The mean percent abundance of UPS of all river water was dominated by pollution sensitive tax richness (Ephemeroptera, Hemispheres, Trichoptera, Plecoptera and Coleoptera), while DS of effluent discharges were readily recovered by pollution tolerant families (Simulidae, Chironomidae, leeches).

Values of correlation matrixes of studies of river water quality parameters analysis would have significant contribution in the selection of the proper treatments to minimize the contaminations of Limu Kosa District nearby ambient water and in river water bodies. From the present physicochemical study of the river water quality of Limu Kosa District, it could be concluded that river water of this region was acidic. The Ketalenca river water, almost all the measured physico-chemical and nutrient parameters showed an increasing trend from UPS to $DS_{2,}$ it has not yet been so polluted and might not causes any health effects on aquatic ecosystem as compared to that of the Kebena and Awetu river water. Therefore, thus concluded that the quality and quantity of effluent is a significant contributor to the ecological degradation of the freshwater and estuarine systems, and the site-specific standards are required in order to formulate appropriate standards to maintain or conserve the systems in an agreed condition.

5.2. Recommendation

On the basis of the findings of the present study, the following recommendations can be suggested:

- Both planners, regulatory agencies and the scientific community should work together to establish sustainable coffee production that is economically viable, environmentally acceptable and maintain ecological integrity of receiving water bodies.
- Increasing conservations of riparian vegetation nearby river water bodies that could be used in wastewater management because of their ability to absorb large amounts of organic and inorganic nutrient wastes as well as a variety of toxic substances. Other alternative waste water treatment methods such as neutralization, dilution, volatilisation, coagulation, flocculation, filtration and sedimentation could also be applied
- Use of well-designed treatment technologies for coffee waste treatment as the poorly designed and constructed lagoons do not curb pollution of water bodies and are resulting in longer-term threat to irrigation, aquatic life, human health and wildlife. Moreover, introduction of cost-effective cleaner production technologies must be enforced. On the other hand, as high concentration of waste water is a potential to produce biochar or compost as one of alternative fertilizers, due emphasis should be given to realize the potential.
- It should be immediately ensured that not a rampant dispose of any kind of waste water is allowed to enter the river water without treatment. It is necessary to monitor continuously the coffee effluent wastewater before disposing it into ambient water bodies and in river water.
- The result of the present study is used as a basis for further research needs to be conducted on the effects and extent of effluents generated from coffee processing plants. Further in depth study and technology assessment is highly recommended.

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7. APPENDICES

Appendix Table 1. Results of ANOVA for physical parameters among comparison of Kebena river water sites

	Mean separation of Physical Parameters									
Site	**TSS**	**SS**	**TDS**	**TS**	**TVS**	**TFS**	**EC**	**TURB**	**WT**	**AMT**
EFF	1800.35[a]	1063.93[a]	2239.3[b]	4039.64[a]	1608.64[b]	3037.83[a]	1045.79[b]	1335.23[a]	28.12[b]	30.39[a]
INF	1527.23[b]	1060.06[a]	2681.23[a]	4208.46[a]	2272.02[a]	1452.33[b]	1160.68[a]	1363.67[a]	37.27[a]	31.06[a]
ENP	146.03[b]	1006.7[b]	2052.26[b]	3512.29[b]	751.67[c]	1402.33[b]	858.64[c]	1190.48[b]	24.27[c]	30.95[a]
DS2	1063.4[c]	928.4[bc]	1197.37[c]	2260.72[c]	677.00[c]	1321.60[b]	661.09[d]	980.58[c]	19.6[d]	27.72[b]
DS1	756.35[d]	866.50[c]	1095.64[c]	1852[d]	396.33[d]	1126.3[c]	616.73[d]	972.10[c]	18.67[d]	230.42[a]
UPS	16.79[e]	4.52[d]	302.9[d]	319.7[e]	61.92[e]	196.4[d]	188.6[e]	3.99[d]	12.11[e]	23.4[c]
Max	1812	1097	2792	4302	2344	3105	1192	1397	38.21	31
Min	16.24	4.36	292.8	309.03	59.84	189.8	185.72	3.52	11.70	23
WHO	500	-	1000	500	-	-	1000	10	-	-
CV (%)	3.70	3.60	5.0	3.69	5.62	159.24	2.92	3.78	8.03	1.96
MSD(0.05)	112.2	81.3	219.03	273.25	148.17	4.08	60.68	101.27	3.30	1.71
SEM(±)	23.62	17.11	46.10	57.52	31.19	33.52	12.77	21.31	0.69	0.36
PV(0.05)	**<.0001**									

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test. Except EC (µS/cm), TURB (NTU) and WT and AMT (°C) the others parameters were expressed in mg/L.

Appendix Table 2. Results of ANOVA for chemical and nutrients parameters among comparison of Kebena river water sites

Mean separation of chemical and nutrient Parameters									
Sites	**pH**	**BOD**	**COD**	**DO**	**TN**	**NO_3-N**	**Org-N**	**NH_3-N**	**Ort-P**
EFF	3.12[c]	2972.67[a]	2735.50[a]	0.00[b]	98.40[a]	3.36[b]	95.04[a]	7.01[b]	13.18[b]
INF	3.33[c]	2689.67[b]	2576.05[a]	0.01[b]	92.60[a]	3.86[a]	88.75[a]	8.11[a]	22.90[a]
ENP	3.36[c]	2478.88[c]	2576.05[b]	0.02[b]	78.61[b]	3.08[c]	75.53[b]	6.92[b]	10.87[c]
DS2	4.06[b]	1797.89[d]	2576.05[b]	0.05[b]	76.22[b]	2.81[d]	73.40[b]	6.83[b]	10.83[c]
DS1	4.28[b]	1773.00[d]	1719.83[b]	0.07[b]	76.66[b]	2.74[d]	73.92[b]	6.65[b]	10.34[c]
UPS	7.43[a]	6.70[e]	4.57[c]	8.04[a]	0.31[c]	0.03[e]	0.28[c]	0.06[c]	0.34[d]
Max	7.68	2993	2867	8.31	99.2	3.96	95.8	8.36	23.3
Min	2.90	4.00	3.75	0.00	0.29	0.03	0.26	0.06	0.33
WHO	65-8.5	10	40	6	-	10-45	-	0.2-5	5
CV (%)	3.48	1.94	4.61	8.13	4.73		4.90	3.34	3.98
MSD(0.05)	0.41	103.81	228.18	0.3047	9.15	0.21	9.12	0.54	1.25
SEM(±)	0.08	21.85	48.03	0.06	1.92	0.04	1.91	0.11	0.26
PV(0.05)					**<.0001**				

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test. Except pH, the others parameters were expressed in mg/L.

Appendix Table 3. Results of ANOVA for physical parameters among comparison of Awetu river water sites

	Mean separation of Physical Parameters									
Sites	**TSS**	**SS**	**TDS**	**TS**	**TVS**	**TFS**	**EC**	**TURB**	**WT**	**AMT**
EFF	1778.87^{a}	1235.15^{a}	1508.64^{b}	3287.51^{b}	663.74^{b}	1290.38^{a}	1035.56^{b}	1195.25^{a}	43.09^{a}	29.52^{b}
INF	1126.52^{b}	943.28^{b}	2773.59^{a}	3900.10^{a}	844.38^{a}	877.23^{d}	1187.26^{a}	1188.10^{a}	36.75^{b}	27.79^{dc}
ENP	586.98^{c}	687.02^{c}	1537.99^{b}	2124.97^{c}	440.01^{e}	829.82^{cb}	844.003^{c}	675.94^{b}	34.97^{b}	34.45^{a}
DS1	434.23^{d}	158.25^{e}	753.82^{c}	1188.1^{d}	363.14^{d}	695.43^{d}	513.28^{d}	514.56^{c}	29.75^{c}	28.21^{c}
DS2	431.65^{d}	480.92^{d}	762.07^{c}	1193.7^{d}	388.79^{d}	803.28^{c}	505.65^{d}	514.38^{c}	25.40^{d}	26.79^{d}
UPS	33.2^{e}	2.41^{f}	335.2^{d}	368.48^{e}	98.68^{e}	229.30^{e}	197.93^{e}	6.993^{d}	20.08^{e}	26.05^{e}
Max	1808	1274	2816	3983	870.96	1331	1200	1201	43.96	34.90
Min	32.14	2.33	323.98	356.12	95.37	221.6	194.69	6.66	19.4	25.6
WHO	500	-	1000	500	-	-	1000	10	27-35	-
CV (%)	3.69	4.21	3.17	3.27	3.25	3.33	1.70	0.68	3.41	1.73
MSD(0.05)	74.13	67.51	111.38	180.66	41.59	71.98	33.34	12.87	2.18	1.12
SEM(±)	15.60	14.21	23.44	38.03	8.75	15.15	7.01	2.70	0.45	0.23
PV(0.05)					**<.0001**					

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test. Except EC (µS/cm), TURB (NTU), and WT and AMT (°C) the others parameters were expressed in mg/L.

Appendix Table 4. Results of ANOVA for chemical and nutrients parameters among comparison of Awetu river water sites

Mean separation of chemical and nutrient Parameters									
Sites	**pH**	**BOD**	**COD**	**DO**	**TN**	**NO_3-N**	**Org-N**	**NH_3-N**	**Ort-P**
EFF	3.59^{d}	2254.95^{a}	1850.27^{b}	0.11^{d}	88.72^{b}	3.09^{b}	85.62^{b}	7.00^{b}	11.47^{b}
INF	3.31^{d}	2205.32^{b}	1982.94^{a}	0.12^{d}	94.57^{a}	3.60^{a}	90.97^{a}	7.49^{a}	20.37^{a}
ENP	3.70^{cd}	1868.24^{c}	1525.88^{c}	1.49^{c}	82.56^{c}	2.67^{c}	79.89^{c}	6.93^{c}	11^{c}
DS1	4.20^{b}	1010.05^{d}	1035.08^{d}	3.33^{b}	21.10^{e}	2.64^{c}	18.46^{e}	6.63^{d}	10.4^{e}
DS2	4.12^{cb}	989.30^{d}	1020.21^{d}	3.16^{b}	35.14^{d}	2.64^{c}	32.50^{d}	6.63^{d}	10.82^{d}
UPS	7.67^{a}	9.75^{e}	8.96^{e}	6.64^{a}	5.44^{f}	0.66^{d}	4.77^{f}	0.06^{e}	0.91^{f}
Max	7.93	2279	2030	6.90	96.51	3.63	92.89	7.52	20.49
Min	3.12	9.50	8.33	0.11	4.75	0.64	4.06	0.06	0.88
WHO	65-8.5		40	6	-	10-45	-	0.2-5	5
CV (%)	3.77	1.05	3.45	7.69	1.88	0.98	1.96	0.21	0.49
MSD(0.05)	0.23	39.89	117.29	0.52	2.82	0.07	2.80	0.035	0.15
SEM(±)	0.09	8.39	24.69	0.11	0.59	0.01	0.59	0.0073	0.03
PV(0.05)					**<.0001**				

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test. Except pH, the others parameters were expressed in mg/L.

Appendix Table 5. Results of ANOVA for physical parameters among mean values comparison of Bonke river water sites

Mean separation of Physical Parameters										
Sites	**TSS**	**SS**	**TDS**	**TS**	**TVS**	**TFS**	**EC**	**TURB**	**WT**	**AMT**
INF	1382.24[a]	340.78[b]	2202.7[a]	3584.9[a]	1682.97[c]	834.26[ba]	1151.17[a]	1202.01[b]	37.28[a]	31.46[a]
EFF	757.29[b]	348.667[b]	2298.4[a]	3055.7[b]	3405.00[a]	836[ba]	890.99[b]	1316.66[a]	37.82[a]	27.07[b]
ENP	578.45[c]	394.417[a]	1227.2[b]	1805.7[c]	2510.7[b]	874.53[a]	582.78[c]	520.62[c]	36.86[a]	27.43[b]
DS1	584.03[c]	88.610[c]	569.8[c]	1153.9[d]	1111.5[d]	785.73[b]	393.62[d]	128.39[d]	35.78[a]	25.77[c]
DS2	543.76[c]	48.343[d]	577.0[c]	1120.8[d]	1051.6[d]	643.94[c]	395.69[d]	128.7[d]	23.64[b]	22.41[d]
UPS	28.07[d]	18.78[e]	230.0[d]	258.1[e]	32.56[c]	266.06[d]	167.65[e]	3.30[e]	27.32[b]	19.23[e]
Max	1391	406.83	2516	3843	3498	902.05	1227.16	1334	40.07	31.89
Min	27.46	18.15	222.27	249.73	31.79	257.12	165.43	2.86	23.02	18.90
WHO	500	-	1000	500	-	-	1000	10	-	-
CV (%)	2.68	4.55	12.81	8.15	3.34	3.27	7.31	1.41	3.30	2.20
MSD(0.05)	47.47	25.81	416.07	409.12	149.82	63.44	119.71	21.36	6.08	1.21
SEM(±)	9.99	5.43	87.58	86.12	31.53	13.35	25.20	4.49	1.28	0.26
PV(0.05)	**<.0001**									

Note: Means with different letters in the same column are significantly different (Tukey's test at $P<0.05$) as established by MSD test. Except EC (µS/cm), TURB (NTU), and WT, and AMT (°C) the others parameters were expressed in mg/L.

Appendix Table 6. Results of ANOVA for chemical and nutrient parameters mean values among comparison of Bonke river water sites

Mean separation of chemical and nutrient Parameters									
Sites	**pH**	**BOD**	**COD**	**DO**	**TN**	**NO_3-N**	**Org-N**	**NH_3-N**	**Ort-P**
INF	3.55[e]	2201.63[a]	1835.09[a]	0.14[e]	96.02[a]	3.97[a]	92.05[a]	6.01[a]	17.56[a]
EFF	4.15[d]	1849.67[b]	1451.67[b]	1.23[d]	72.47[c]	2.98[b]	69.49[c]	5.4[b]	15.4[b]
ENP	4.95[c]	1129.35[c]	1163.20[c]	2.15[c]	77.62[b]	2.78[c]	74.84[b]	6.14[a]	13.79[c]
DS1	5.56[b]	992.55[c]	961.88[d]	3.55[b]	41.52[d]	1.95[d]	39.57[d]	3.81[c]	8.19[d]
DS2	5.68[b]	1030.60[c]	928.69[d]	3.40[b]	13.06[e]	1.35[e]	11.71[e]	3.83[c]	8.28[d]
UPS	7.52[a]	4.34[d]	3.99[e]	6.14[a]	4.47[f]	0.66[f]	3.81[f]	0.06[d]	0.13[e]
Max	7.78	2255	1877	6.35	97.23	3.99	93.28	6.24	17.86
Min	3.22	4.00	3.19	0.14	4.46	0.64	3.8	0.06	0.13
WHO	65-8.5	10	40	6	-	10-45	-	0.2-5	5
CV (%)	3.94	7.07	2.54	4.45	2.72	2.86	2.89	2.56	5.16
MSD(0.05)	0.57	233.05	73.94	0.34	3.80	0.18	3.86	0.3	1.5
SEM(±)	0.11	49.06	15.56	0.07	0.79	0.03	0.81	0.06	0.31
PV(0.05)					**<.0001**				

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test. Except pH, the others parameters were expressed in mg/L.

Appendix Table 7. Results of ANOVA for physical parameters among mean values comparison of Ketalenca river water sites

	Mean separation Physical Parameters									
Sites	**TSS**	**SS**	**TDS**	**TS**	**TVS**	**TFS**	**EC**	**TURB**	**WT**	**AMT**
EFF	1381.05[a]	431.70[a]	1177.33[b]	2558.38[b]	1947.83[a]	1090.32[b]	1015.70[b]	1352.37[a]	31.29[b]	24.13[b]
INF	1051.68[b]	112.23[c]	2746.18[a]	2558.38[a]	1598.85[c]	1588.52[a]	1015.70[a]	1237.58[b]	33.95[a]	30.75[a]
ENP	419.74[c]	157.51[b]	753.73[c]	1173.47[c]	1598.85[b]	651.13[c]	240.14[c]	334.88[c]	30.10[b]	22.75[c]
DS1	394.14[c]	79.32[d]	435.26[d]	829.39[d]	1132.7[d]	502.31[d]	226.71[d]	114.10[d]	19.60d[c]	20.99[d]
DS2	342.09[d]	6.77[e]	481.92[d]	824.02[d]	807.42[e]	251.93[e]	240.14[d]	114.10[d]	21.36[c]	18.55[e]
UPS	10.02[e]	3.05[e]	235[e]	245.1[e]	16.45[f]	78.47[f]	169.1[e]	5.12[e]	14.28[e]	13.13[f]
Max	1398	445.29	2788	3846	1978	1607	1191	1363	34.79	31.16
Min	9.70	2.95	227.14	236.84	15.9	76	166.83	4.95	13.80	12.9
WHO	500	-	1000	500	-	-	1000	10	-	-
CV (%)	1.73	4.67	6.15	4.19	2.07	2.83	3.27	0.84	3.47	1.76
MSD(0.05)	28.57	16.91	164.08	180.69	70.064	53.912	47.21	12.11	1.59	0.79
SEM(±)	6.01	3.55	34.54	38.03	14.74	11.34	9.93	2.54	0.34	0.17
PV(0.05)	**<.0001**									

Note: Means with different letters in the same column are significantly different (Tukey's test at $P<0.05$) as established by MSD test. Except EC (µS/cm), TURB (NTU), and WT, and AMT (°C) the others parameters were expressed in mg/L.

Appendix Table 8. Results of ANOVA for chemical and nutrient parameters mean values among comparison Ketalenca river water sites

Mean separation of chemical and nutrient Parameters									
Sites	**pH**	**BOD**	**COD**	**DO**	**TN**	**NO_3-N**	**Org-N**	**NH_3-N**	**Ort-P**
EFF	3.48^{d}	1618.17^{a}	1488.03^{a}	0.73^{d}	95.29^{a}	3.09^{b}	92.20^{a}	5.12^{b}	8.25^{b}
INF	4.54^{c}	1717.18^{a}	1551.15^{a}	0.25^{d}	66.36^{b}	3.60^{a}	62.76^{b}	6.29^{a}	10.60^{a}
ENP	4.59^{c}	1109.83^{b}	1014.92^{b}	2.19^{c}	50.09^{c}	2.64^{c}	47.45^{c}	4.62^{c}	8.84^{b}
DS1	5.66^{b}	1009.38^{c}	912.93^{cb}	3.27^{b}	35.31^{d}	1.96^{d}	33.35^{d}	4.26^{d}	5.84^{c}
DS2	5.89^{b}	902.88^{c}	874.23^{c}	3.64^{b}	19.88^{e}	1.51^{e}	18.37^{e}	3.83^{e}	4.86^{d}
UPS	7.52^{a}	2.36^{d}	9.74^{d}	8.01^{a}	5.87^{f}	0.66^{f}	5.20^{f}	0.05^{f}	0.34^{e}
Max	7.78	1778	1586	8.28	98.29	3.63	95.17	6.31	10.68
Min	3.28	2.03	9.07	0.14	5.81	0.64	5.170	0.05	0.33
WHO	65-8.5	10	40	6	-	10-45	-	0.2-5	5
CV (%)	3.47	4.35	4.09	7.04	3.71	0.97	3.86	0.84	4.94
MSD(0.05)	0.50	126.62	109.47	0.58	4.63	0.06	4.58	0.09	0.88
SEM(±)	0.10	26.65	23.04	0.12	0.97	0.01	0.96	0.01	0.18
PV(0.05)					**<.0001**				

Note: Means with different letters in the same column are significantly different (Tukey's test at P<0.05) as established by MSD test. Except pH, the others parameters were expressed in mg/L.

Appendix Table 9. Total number (n) of macro-invertebrates caught at four river water in Limu Kosa District

Taxa	Kebena				Awetu				Bonke				Ketalenca			
	UPS		DS		UPS		DS		UPS		DS		UPS		DS	
	N	%	N	%	N	%	n	%	n	%	n	%	n	%	N	%
Odonata	**37**	**18.05**	**0**	**0.00**	**91**	**34.21**	**41**	**26.11**	**67**	**39.64**	**6**	**11.11**	**74**	**27.82**	**6**	**4.72**
Coenagrionidae	10	4.88	0	0.00	37	13.91	9	5.73	23	13.61	4	7.41	22	8.27	0	0.00
Gonphidae	8	3.90	0	0.00	0	0.00	0	0.00	18	10.65	0	0.00	10	3.76	0	0.00
Libellulidae	19	9.27	0	0.00	27	10.15	13	8.28	26	15.38	2	3.70	11	4.14	6	4.72
Aeshnidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	31	11.65	0	0.00
Lestidae	0	0.00	0	0.00	0	0.00	11	7.01	0	0.00	0	0.00	0	0.00	0	0.00
Cordulegastridae	0	0.00	0	0.00	27	10.15	8	5.10	0	0.00	0	0.00	0	0.00	0	0.00
Hemiptera	**30**	**14.63**	**0**	**0.00**	**28**	**10.53**	**12**	**7.64**	**29**	**17.16**	**6**	**11.11**	**31**	**11.65**	**16**	**12.60**
Belostomatidae	14	6.83	0	0.00	28	10.53	12	7.64	0	0.00	0	0.00	13	4.89	5	3.94
Gerridae	16	7.80	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	18	6.77	0	0.00
Corixidae	0	0.00	0	0.00	0	0.00	0	0.00	29	17.16	6	11.11	0	0.00	11	8.66
Coleoptera	**42**	**20.49**	**0**	**0.00**	**36**	**13.53**	**0**	**0.00**	**30**	**17.75**	**0**	**0.00**	**9**	**3.38**	**1**	**0.79**
Gyrinidae	25	12.20	0	0.00	36	13.53	0	0.00	19	11.24	0	0.00	9	3.38	0	0.00
Dytiscidae	17	8.29	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.79
Elmidae	0	0.00	0	0.00	0	0.00	0	0.00	11	6.51	0	0.00	0	0.00	0	0.00
Trichoptera	**46**	**22.44**	**0**	**0.00**	**71**	**26.69**	**8**	**5.10**	**18**	**10.65**	**0**	**0.00**	**63**	**23.68**	**3**	**2.36**
Hydropsychidae	17	8.29	0	0.00	0	0.00	0	0.00	18	10.65	0	0.00	0	0.00	0	0.00
Hydroptilidae	11	5.37	0	0.00	29	10.90	0	0.00	0	0.00	0	0.00	16	6.02	0	0.00
Leptoceridae	18	8.78	0	0.00	42	15.79	0	0.00	0	0.00	0	0.00	17	6.39	0	0.00
Brachycentridae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	12	4.51	0	0.00
Polycentropodae	0	0.00	0	0.00	0	0.00	8	5.10	0	0.00	0	0.00	0	0.00	3	2.36
Psychomyiidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	18	6.77	0	0.00

Continued Appendix Table IX

Diptera	**13**	**6.34**	**40**	**81.63**	**0**	**0.00**	**92**	**58.60**	**13**	**7.69**	**39**	**72.22**	**19**	**7.14**	**101**	**79.53**
Ceratopeganidae	13	6.34	0	0.00	0	0.00	0	0.00	13	7.69	0	0.00	0	0.00	9	7.09
Chironomidae	0	0.00	33	67.35	0	0.00	42	26.75	0	0.00	31	57.41	0	0.00	80	62.99
Pschodidae	0	0.00	0	0.00	0	0.00	6	3.82	0	0.00	0	0.00	0	0.00	0	0.00
Simuliidae	0	0.00	7	14.29	0	0.00	38	24.20	0	0.00	8	14.81	0	0.00	12	9.45
Tipulidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	19	7.14	0	0.00
Syrphidae	0	0.00	0	0.00	0	0.00	6	3.82	0	0.00	0	0.00	0	0.00	0	0.00
Ephemeroptera	**20**	**9.76**	**0**	**0.00**	**26**	**9.77**	**0**	**0.00**	**12**	**7.10**	**0**	**0.00**	**70**	**26.32**	**0**	**0.00**
Baetidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	41	15.41	0	0.00
Ephemeridae	20	9.76	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	14	5.26	0	0.00
Heptageniidae	0	0.00	0	0.00	26	9.77	0	0.00	0	0.00	0	0.00	15	5.64	0	0.00
Caenidae	0	0.00	0	0.00	0	0.00	0	0.00	12	7.10	0	0.00	0	0.00	0	0.00
Plecoptera	**17**	**8.29**	**0**	**0.00**	**14**	**5.26**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**
Perlidae	17	8.29	0	0.00	14	5.26	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Hirudinea	**0**	**0.00**	**9**	**18.37**	**0**	**0.00**	**4**	**2.55**	**0**	**0.00**	**3**	**5.56**	**0**	**0.00**	**0**	**0.00**
Leeches	0	0.00	9	18.37	0	0.00	4	2.55	0	0.00	3	5.56	0	0.00	0	0.00
Total	205		49		266		157		169		54		266		127	

Total # of Taxonomic order= 8 and Total # of individuals = 1293 UPS=906 DS=387