جامعة أبو بكر بلقايد
UNIVERSITÉ DE TLEMCEN

Pan African University
Institute of Water
and Energy Sciences

Institute of Water and Energy Sciences (Including Climate Change)

Effect of Wet Coffee Processing Industries Waste on Water Quality of Receiving Water Body and its Trend on Downstream (Case Study of Gidabo Watershed in South Ethiopia)

Workinesh Takele Tessema

Date: 06/09/2017

Master in Water, Engineering track

President: Dr. Bernhard Tischbein

Supervisor: Dr. Mihret Dananto Ulsido

External Examiner: Dr. Joseph K. Sang

Internal Examiner: Dr. Hamid Bouchelkia

Academic Year: 2016-2017

DECLARATION

I Workinesh Takele Tessema hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

Name: Workinesh Takele Tessema

Signature: 18/09/2017

Supervisor: Dr. Mihret Dananto Ulsido

Signature:-- 20/09/2017

ACKNOWLEDGMENT

First I wish to express my sincere gratitude to my supervisor Dr. Mihret Dinanto for his unreserved advice and skillful contribution to this thesis and for allowing me to use some data of his own. Next I express my gratitude to my home university, Hawassa, school of Civil engineering for providing me an opportunity to work in Environmental Engineering Lab allowing me the laboratory facility and I am grateful for the special support from school of Natural resources and environmental studies. I also express my deepest thanks to Dr. Yosef for giving necessary advice and guidance on SPSS. I sincerely thank Mrs. Yosef Sumuel for his comment and help on field data collection.

I appreciate Pan African University of Water and Energy Science and its partners including African Union Commission, Government of Algeria, and University of Tlemcen, GIZ, who offered me an opportunity to pursue master studies.

Finally, I would like to extend my deep gratitude towards my family and my friends for their support in carrying out this work successfully, in all my way thanks to Almightily God.

ABSTRACT

Environmental pollution is a worldwide problem, currently it is a challenge to keep environmental quality while achieving sustainable development. Wet coffee processing is one of environmental polluting anthropogenic activities in Ethiopia. The effluents are discharged irresponsibly into nearby surface water and it may also infiltrate into ground water and become main threat to both ground and surface water qualities. The main objective of this study was to investigate the impact of wet coffee processing effluent on nearby surface and ground water bodies and assess the seasonal load of pollution and its extent of ecosystem degradation. The study was carried out in the southern part of Ethiopia, Gidabo watershed. The concentrations of different parameters were collected for upstream, middle stream and downstream of the catchment for both surface (two seasons) and shallow well. Analysis of variance was carried out to study the interactions among different factors (location, Season). The mean values of studied parameters were used to assess the extent of pollution in ecosystem by comparing with the Ethiopian national discharge limit. The result of analysis reveals that during wet coffee processing (dry season) the organic waste effluent increases the BOD to 473.0 ± 179.61mg/l thus, DO value diminished to a level almost zero. Parameters: pH, TDS, EC, DO, BOD, COD, turbidity, nitrate and phosphate shows significant difference in different season. Turbidity, BOD, pH, COD, DO, nitrate and phosphate were above the limit. Significant difference was not observed for pH, BOD, COD and nitrate in location variation at ($\acute{\alpha}$= 0.05). Where, for shallow well the variation along the altitude is not significant for most of the parameters. The results concluded that, the intensity of effects is seasonal. Still it puts the recover capacity of river under question since; it is continues processes and it may alter the ecology in general. As a recommendation, appropriate technology input and community involvement is essential.

Keywords: water quality, seasonal variation, parameters, waste water, wet coffee processing

Résumé

La pollution de l'environnement est un problème mondial, il est actuellement difficile de maintenir la qualité de l'environnement tout en réalisant un développement durable. Le traitement du café humide est l'un des facteurs anthropiques de la pollution environnementale en Éthiopie. Les effluents sont déversés de manière irresponsable dans les eaux de surface proches et ils peuvent également s'infiltrer dans les eaux souterraines et devenir une menace principale pour les qualités de l'eau de surface et souterraine. L'objectif principal de cette étude était d'étudier l'impact des effluents de traitement du café humide sur les eaux de surface et souterraines à proximité et d'évaluer la charge saisonnière de Pollution et son degré de dégradation de l'écosystème. L'étude a été menée dans la partie sud de l'Éthiopie, dans le bassin hydrographique de Gidabo. Les concentrations de différents paramètres ont été recueillies pour en amont, au milieu et en aval du bassin versant pour les eaux de surface (deux saisons) et les puits peu profond. L'analyse de la variance a été réalisée pour étudier les interactions entre différents facteurs (localisation, saison). Les valeurs moyennes des paramètres étudiés ont été utilisées pour évaluer l'étendue de la pollution dans l'écosystème en comparant avec la limite nationale de décharge éthiopienne. Le résultat de l'analyse révèle que, lors de la transformation du café humide (saison sèche), l'effluent des déchets organiques augmente la DBO à 473,0 ± 179,61mg / l, la valeur OD diminue à un niveau presque nul. Paramètres: pH, TDS, EC, DO, DBO, DCO, turbidité, nitrate et phosphate montre une différence significative en différentes saisons. La turbidité, la DBO, le pH, la DCO, la DO, le nitrate et le phosphate étaient au-dessus de la limite. Aucune différence significative n'a été observée pour le pH, la DBO, la DCO et le nitrate dans la variation de localisation à ($\acute{\alpha}$ = 0,05). Où, pour un puits peu profond, la variation le long de l'altitude n'est pas significative pour la plupart des paramètres. Les résultats ont conclu que l'intensité des effets est saisonnière. Pourtant, il met en question la capacité de renouvèlement de la rivière ; c’est un processus continu et pourrait modifier l'écologie en général. En tant que recommandation, l'apport technologique approprié et la participation communautaire sont essentiel.

Mots-clés : qualité de l'eau, variation saisonnière, paramètres, eaux usées, traitement du café humide

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List of Abbreviations

ANOVA………..Analysis of Variance

BOD………..Biological Oxygen Demand

CL………..Confidence Level

COD………..Chemical Oxygen Demand

DO………..Dissolved Oxygen

EC………..Electrical Conductivity

EEPA………..Ethiopian Environmental Protection Agency

a.s.l……….. Above Sea Level

NTU………..Nephelometric Turbidity Unit

RNREPA………..Regional Natural Resources and Environmental protection Authority

SD………..Standard Deviation

SNNPR………..Southern Nations, Nationalities and Peoples Regional State

TDS………..Total Dissolved Solids

WCP……….. Wet Coffee Processing

WQP………..Water Quality Parameters

WRDB………..Water Resources development Bureau

µS/cm………..micro Siemens per centimeter

CHAPTER ONE: INTRODUCTION

1.1 Background

Environmental pollution is a problem across the whole world; even though is high in developing countries (Fereidoun et al, 2007). As stated by Awoke et al (2016), it is one of the most critical challenges facing global society is the failure to keep environmental quality while achieve sustainable development. Based on the sources, different waste quantity and quality were released to ecosystem.

Major component of ecosystem water, is easily contaminated with contaminants. Even though, it is the most precious resources which every life is impossible without it. Human beings benefited enormously from water, though they are actually one of the main causes of water resources pollution through marine dumping, industrial wastes, agricultural effluent and mining wastes, (Ninhoskinson, 2011).

Ethiopia is among the country's leading coffee production in Africa's and the fifth largest in the world after Brazil, Vietnam, Colombia, and Indonesia. Production is estimated about 6.508 million bags (390,500 metric tons) in 2015 (WTO, 2017). The country produces high-quality of coffee Arabica for both the domestic and international markets. Thus, coffee trade plays a major role in Ethiopia's economy and is deeply intertwined with cultural traditions and day-to-day living. There was an estimate about 15% of total population of the country's or approximately 15 million people who derive their livelihoods from coffee.

Coffee Arabica is considered as the honorable of all coffee plants species and it covers 75% of world coffee production (Belitz et al, 2009). It was originated in Ethiopia where still wild coffee trees are the primary source of harvest (Anthony et al., 2001).It was originally found and cultivated by Oromo people in the *Kaffa* province of Ethiopia from which it got its name around 1000 A.D. Arab people took the coffee seeds from this region and started the first coffee plantation and then it spread to the whole Europe (Haddis & Devi 2008).

After harvesting, coffee can be processed in two ways; dry method (using sun radiation) and wet processing (hydraulic washing) method. Wet processing is the most preferable method for high quality of coffee beans; comparably it is the yield of very high pollution load of wastewater. Because coffee processing plants are consumers of considerable amount of water and generate enormous volumes of waste material (Dejen et al, 2015). In addition, the composition of coffee pulp contains organic; mainly contains carbohydrates, proteins, fibers, fat, caffeine, polyphenols, and pectin (Gathua et al. 1991). It is a potential threat to the ecosystem since the effluent discharged from the coffee industries can easily reach the river. As stated by (Beyene et al, 2011) effluent generated by wet coffee processing of 1000kg is compared to the human waste that can be generated by 3000-5600 people per day.

South Ethiopia is among the famous coffee growing region in Ethiopia. It has a number of wet coffee processing industries situated along the bank of rivers or streams. The effluents are discharged irresponsibly into nearby surface water and it may also infiltrate into ground water and become main threat to both ground and surface water qualities (Dejen et al., 2015). Moreover, no satisfactory management and protection done for the environment, the legal proclamation in the country also allows very high concentrations as maximum levels that cannot safeguard biota of aquatic ecosystem. In addition to that even though there is polluters pay principle in the policy, there is no enforcing strong law or regulation stipulating how to penalize entities which exceed the standards (Awoke et al, 2016).

On the other hand, poor quality water causes different health problem to human being including death. In fact, the effects of polluted water are said to be the leading cause of death for humans across the globe. The pollution of water also directly affect aquatic fauna and flora and disturbs the whole aquatic ecosystem functioning. Moreover, water pollution affects whole water bodies and sources of water for drinking water and other purposes like; oceans, lakes, rivers, which making it a widespread and global concern (Scipeeps, 2009).

1.2 Problem Statement

In Ethiopian there are many wet coffee processing industries in coffee growing areas. However, those industries don't either treat or recycle waste effluent generated from their plant efficiently (WRDB, 2014, Haddis and Devi, 2008, Tsigereda, 2011). Most of times they directly discharge to the river or nearby streams, sometimes they kept it in detention basin near the water bodies which may over flow and not well constructed.

As is the case in the study area of this research, the lack of proper management of wastewater from coffee processing industries and directly discharged into the environment has resulted in several negative impacts: deteriorating water quality of the area, bring bad odors, reduced the aquatic life live in there. This research aims at analyzing the impacts of effluent from the coffee processing industries on river water quality and groundwater quality in shallow well of the area.

Several studies also reported that untreated waste effluent from wet coffee processing industries was a threat to both surface and ground water. This problem was facing the whole world and is severe in developing countries like Ethiopia (Beyene et al. 2009, Haddis and Devi, 2008). However, little study has been conducted with regard to seasonal pollution load as this may affect the self-purification ability of the receiving water bodies and recovering capacity to its normal ecology. Furthermore, this study wants to see the effluent effect on shallow well water. Its infiltration to recharges groundwater may highly impact the groundwater quality of the area. The community in downstream of the river use this water for different uses; small scale irrigation, livestock and for domestic uses. So the study was aimed also to assess the quality of receiving water bodies in different seasons.

1.3 Scope and Limitation

This study will be focused mainly on the investigation of the seasonal variation of pollution load in receiving surface water / river and assess shallow wells water quality of the study area. Moreover to study the wet coffee processing effluent effect on both water bodies of the area. Different characteristic of water quality parameters such as physicochemical, biological will be included. However, as, the coffee waste effluent is composed of organic compounds and due to lacks of enough budgets, logistics and distance of the study area from laboratory, more attention will be given to organic parameters and nutrients like; BOD, COD, DO, Nitrate and Phosphate .

1.4 Objectives of the study

1.4.1 General objective

The overall objective of this study was to evaluate the impact of wet coffee processing industries on the water quality of receiving water in different seasons.

1.4.2 Specific objective

- To investigate the impact of wet coffee processing industries on surface /river water quality in Gidabo Watershed,
- To investigate the impact of wet coffee processing industries on Shallow well water quality,
- To analyze the seasonal variation of pollution load on the receiving water sources.
- To review possible measures

1.5 Research Questions

1. What is the impact of effluent from wet coffee processing industries on water quality of the river?

2. What is the impact of effluent on water quality of the shallow well in the area?

3. Which season has high pollution effect?

CHAPTER TWO: LITERATURE REVIEW

2.1 Water Pollution

Water is the most crucial constituents for human wellbeing and a healthy life. Unfortunately pollution of water and air are common all over the world (European Public Health Alliance, 2009). Water is a universal solvent and a medium for many solution and reactions. Thus, it can get polluted easily. Any physical, chemical or biological change in quality of water which adversely impacts life in the environment is commonly referred as pollution this makes, a water resource unsuitable for one or more of its beneficial uses.

Water pollution is caused by the additive of external compounds like: organic, inorganic, biological, radiological or physical substances in the water that tend to degrade its quality. The presence of undesirable and hazardous material and pathogens beyond certain limit also causes water pollution (Woldesenbet et al, 2014). The polluted water may consist of effluent discharge from, industries, sewerage from urban area, household wastes agricultural runoff that may contain fertilizer and other used chemicals and rain water. Some effects of water pollution are recognized immediately, whereas others don't show up for months or years (Ashraf et al, 2010).

In the past management and conservation of water resources remain understudied and extremely challenging in developing countries (Oki and Kanae, 2006). In present scenario industrialization and increased population leads to water scarcity and high expense of water treatment questioning the protection of water resources. In Ethiopia the industrial and municipal effluent was not well managed, the drains that are ultimately carried that polluted water to the streams and lakes. This poor quality water created multiple environmental hazards for mankind, irrigation, drinking and sustenance of aquatic life (Awoke, 2016).

Scarce and poor quality of water supply, as well as a decline in equitable distribution of freshwater is being reported from developing countries that are experiencing water pollution (Postel, 2000). Consequently, those countries are increasingly using polluted water sources. In addition to rapidly increasing consumption of freshwater by people, their livestock, agriculture, and industries, the often unregulated discharge of untreated wastewater tends to decrease the available safe water sources (Gadgil, 1998).

2.2 Parameters to determine the quality of water

About 75% of suspended solids and 40% of filterable solids in wastewater are organic matters. These organic compounds usually consist of combinations of carbon, hydrogen and oxygen, and, in some cases, nitrogen. Also other elements such as sulfur, phosphorus and iron may be present. The main groups of organic substances in the wastewater are proteins (40-60%), carbohydrate (25-50%), fat and oil. With the measurements of some physical and chemical parameters the amount of pollutants presented in wastewater can be determined (Tegereda, 2011). Temperature, color and odor: These parameters are more common to determinate the quality of the potable water Color, for example, may be related to the presence of iron or manganese. Temperature affects taste and odor perceptions. Corrosion and incrustations, which, in turn, affect color, taste and odor, can be directly related to pH (Ontario, 2006).

2.2.1 Temperature

Temperature is an important parameter in characterization of natural water bodies. It affects the water chemistry such as saturation and concentration of dissolved gases, especially oxygen. The rate of chemical reactions generally increases as temperature increases. Temperature also affects biological activity and regulates the kinds of organisms that can survive in the lake (Rasolofomanana, 2009).

2.2.2 pH

The pH of a solution is a measure of the concentration of hydrogen ions (H^+), which is a measure of acidity. PH indicates the intensity of acidity or alkalinity in water, and affects biological and chemical reactions held within the solution. As an example, very low pH reduces micro-organisms activities and growth, which affect biological reaction. The pH of water is determined by the solubility and availability of chemical constituents such as nutrients and heavy metals (Tegereda, 2011).

2.2.3 Turbidity

Turbidity is a measure of the virtual clarity of water. Turbidity in water body is caused by suspended and colloidal matter, such as clay, silt, organic material, algae and other inorganic material. The concentration of turbidity is an indication that the water is containing other particles than water molecules that contaminate or pollute the water bodies (Nicholas, 2002). It is an expression of the absorbent of optical light and causes light to be scattered rather than transmitted with no change in direction through the sample. The scattering of light increases as the presence of dissolved and suspended solids increases and turbidity is commonly measured in Nephelometric Turbidity Units (NTU). Even though, the weight and particle concentration of suspended matter is main regulating factor for turbidity it may also affected by the size, shape and refractive index of particles as this all affect the light-scattering properties of the suspension (copes et al, 2008).

2.2.4 Electrical Conductivity (EC)

Electrical conductivity (EC) is an expression of ions in the water body. It is the ability of water to conduct an electric current. It is considered as an incidental indicator of pollution because ability of water to conduct electric current which is mostly influenced by dissolved salts such as sodium chloride and potassium chloride present in the water (Hassan et al, 2017).

2.2.5 Dissolved Oxygen (DO)

DO is the actual amount of oxygen available in dissolved form in the receiving water body. The main anthropogenic activities like: the addition of organic matter mainly from sewage treatment, intense fertilizer application and agriculture based industries leads to the change the concentration of dissolved oxygen in the aquatic environment and contributing to upturn of oxygen demand. The nutrient loading of the water bodies from such activities enhance the eutrophication and leads to a threatened aquatic ecosystem (Hassan et al, 2017). When the DO drops sharply, the water life is unable to continue on at a normal rate, leading to fish kills, growth of certain types of water weeds, and finally conversion of the stream into an open sewer (Nicholas, 2002). One of the most important measures of water quality is dissolved oxygen, although oxygen is a gas poorly soluble in water, is fundamental to aquatic life. The concentration of dissolved oxygen depends other than human activities like: temperature, river flow, altitude, dissolved solids and suspended mater. The lowest DO values in dry months were possibly due to less oxygen holding capacity of water at high temperature along with increase in DO consumption matter by microorganism as the digestion organic matter. Without free dissolved oxygen, streams and lakes become uninhabitable to aerobic organisms, including fish and most invertebrates (Hassan et al, 2017).

2.2.6 Biological Oxygen Demand (BOD)

Biological oxygen demand is the amount of oxygen that is consumed during oxidation or decomposing of organic compounds which were by biological-oxidation or under aerobic conditions (Yang et al, 2009). It is a test applied to measure the amount of biologically oxidized organic matter present and determining the rates at which oxidation will occur or BOD will be exerted. It is also a measurement that allows comparing the relative polluting strength of different organic substances. According to (Ronaldo et al., 2006), oxygen demand is the measurement of amount of dissolved oxygen consumed in five days through biological oxidation for the breaking down organic matter available in the water. Biological oxygen demand could be determined by allowing biochemical oxidation to proceed, under conditions specified in standard methods, for 5 days.

2.2.7 Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) is commonly used to determine the amounts of organic pollutants in wastewater from different sources (Yao et al, 2014). It is the amount of oxygen consumed by the organic compounds and inorganic matter which were oxidized in water. The higher the equivalent oxygen content of a given waste, the higher is its COD and the higher is its polluting potential (Tsigereda, 2011). The COD test normally yields higher oxygen equivalent values than those derived using the standard BOD_5 test, because biological oxygen demand measure, only biodegradable organic matter, however; both biodegradable and non-biodegradable compounds could be measured in chemical oxygen demand system. In other word Chemical oxygen demand is the amount of oxygen in mg/L required to oxidize both organic and oxidizable inorganic compounds (Gray, 2004).

2.3 Seasonal variation of pollution load

The pollutants enter into the river system by direct discharges or surface runoff. Consequently, surface water has the highest susceptibility to pollution because of waste and effluent accessibility (Ahmed et al, 2011). However, the pollution levels showed a seasonal pattern of change. As there is the pollutant level may vary for different seasons. The finding of Islam et al (2015) shows that the BOD value was high during the dry season as a result of higher concentrations of organic pollutant in the water body. Whereas, for the rainy season the BOD value remained minimum at one-third of that the dry season value. The values of most of the parameters were elevated during the dry season with a lower river flow as compared to the rainy season. Alternatively, during the rainy season the concentration was lower as there was dilution effect from the higher water flow. Therefore, river pollution is largely dependent on the upstream river flow, which indicates that the control of different upstream rivers. Anthropogenic activities, as well as the variation in river water flow during different seasons were the main reasons for this high degree of water pollution.

As stated by Knee et al, (2010), higher caffeine concentrations were measured in different water bodies like; ocean , river and stream samples in August 2006 in Hawaii State. The high caffeine concentrations measured in August 2006 may reflect the pollution load would be higher in this season and there is seasonal differences in caffeine inputs, transport, or degradation. Differences in rainfall between the two seasons could result in differences in caffeine transport through coastal groundwater and surface water.

2.4 Coffee Processing and water requirement

After the harvest coffee fruit was processed either by wet method or dry method to produce washed and unwashed coffee beans respectively. The processing of coffee initiates with the conversion of coffee cherries or fruit into green coffee beans, and starts with the removal of both the pulp and hull using either a wet or dry method. Almost half of the coffee fruit as, coffee pulp represent about 40 to 43% of the fresh coffee fruit weight (Adams, 2006).

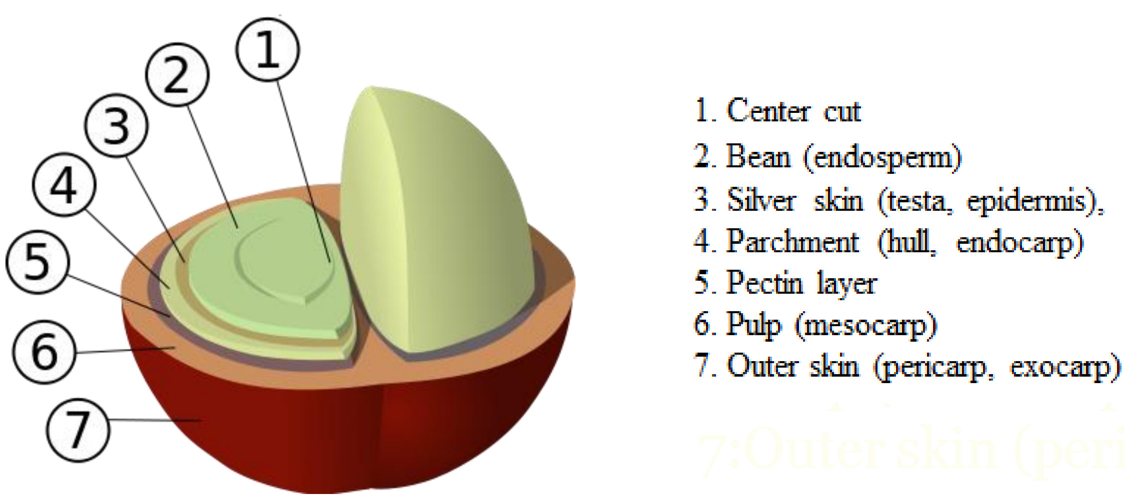
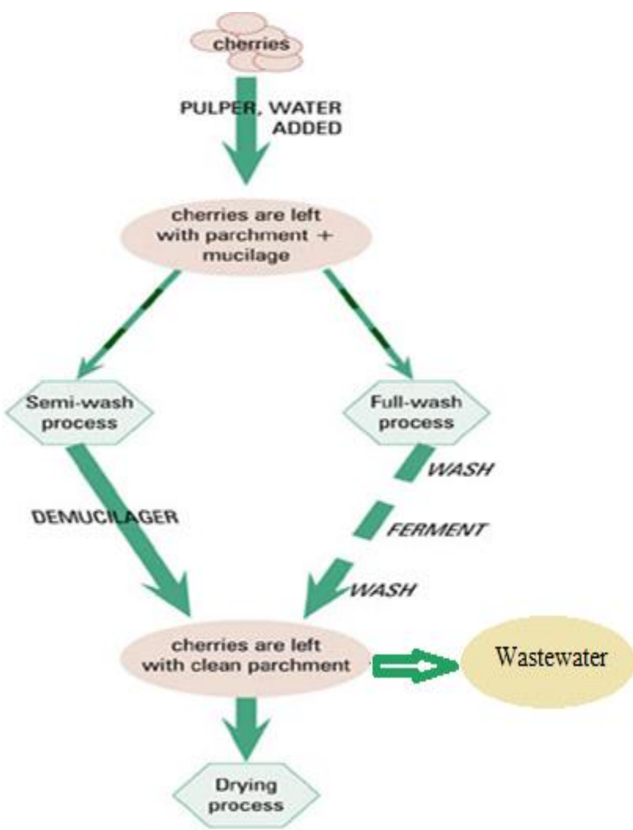


Fig 2. 1 Structure of coffee fruit Sources: (Ulsido and Li, 2015)

In the dry processing, entire coffee fruits are dried (in the sun) on plat forms and/or on a floor without prior removal of the pulp (Silva et al., 2008). In contrast to the dry method, wet processing of coffee fruits results in superior quality beans (Pandey et al., 2000). This processing, on the other hand, removes the cover of the cherry which surrounding the coffee bean prior to the drying stage. In wet coffee processing the water helps to removes spoiled berries and unwanted materials and act as the transportation media. During processing, exocarp and coffee pulp (mesocarp) are mechanically removed before the gelatinous and hygroscopic mucilage cover, which is coating the parchment, is removed. Pulping of coffee cherry requires large amount of water and wastewater generated also much. This is done during an approximate fermentation time of 36 hours depending on natural conditions like altitude and temperature (Von Enden, et al, 2010). During fermentation of the mucilage, only little amount of water is absorbed by raw fruits and thus the wet process discharges large quantities of the effluent.



(Von En den and Calvert 2010)

Fig 2. 2: Coffee Processing Methods

The consumption of water varies up to 20 m^3 per ton of coffee beans processed without recycling (Nagesh, 2012). Besides for every ton of beans produced, about one ton of husks were generated. It is estimated that coffee processing is generating about 9 million $m^3$of wastewater, and 600,000 tons of husks annually in the East Africa region (Amelia et al., 2010). As stated by Woldesenbet et al, (2014), about 5-15 liters of water are required to get 1 kg of clean washed coffee beans (the actual volume of water usually depends on the pulping process, fermentation time and amount of coffee bean in the given volume. Similarly, in practice 1 to 15 $m^3$of fresh water per ton cherry, have been reported for different countries (GTZ, 2002).

Table 2. 1 Experience on water use in wet coffee processing industries

No	Country	Water use(L/Kg)	Recycling	Remark	Reference
1	Costa Rica	22.5	Yes	Minimum water use	(Adams, 2006)
		90	No	Maximum water use	(Adams, 2006)
2.	India	3	Yes	Semi-washed, wet processing	(Selvamurugan et al, 2010)
		14-17	Yes	Traditional, fully washed	(Selvamurugan et al, 2010)
4	Vietnam	10	No	Maximum use	Von Eden and Calvert, 2006)
		4	Yes	Recycling	Von Eden and Calvert, 2006)
5	Hawaii	5 – 15	Average	Both	(Hue, 2006)

Water used for wet coffee processing in the South Ethiopia

It is confirmed that the average amount of water used for wet coffee processing in the study area by the Agarid and Roter machines was about 60 to 70 liters per a kilogram of coffee beans for both pulping and fermentation. This depends on types of machine used by the plant. On the other hand, the manual operating aforementioned machines that undertake water recirculation system is totally used 23 liters of water for a kilogram of coffee cherry. If water recirculation system is partly used 38L of water will be used to finish washing of one kilogram of coffee, and if the recirculation system is not functioning 63L of water is required (RNREPA, 2013).

Thus, during peak production period particularly from October to December individuals (coffee washing machine owners) on average purchase 12,000 Kg to 15,000 Kg red cherry coffee per day. To calculate the total amount of daily water used by each industry, can computed as = Daily average purchasing capacity times amount of water used to wash one kilogram of red cherry coffee.

- That is if we take the minimum average becomes 12,000 Kg * 60L=720,000L of water is used by single machine per day.
- For instance, for Sidama Zone coffee washing industries = Total number of functional industries = 316 (RNREPA, 2013) (daily minimum purchasing capacity) (Amount of water used to wash a kilogram of coffee)

  = 316*12,000*60L =227,520 m^3 of water is daily used in Sidama Zone in peak coffee processing season

- Accordingly, for three months of peak production period

  = (227,520 cubic meter of water daily) (90)

  = 20,476,800 m^3 of water is polluted in average each year round

2.5 Characteristics of coffee wastewater

During coffee processing, only about 20% of the resource taken directly as a useful product, the remains was waste, including pulp, mucilage and wastewater represent about 80% of the biomass of coffee cherry which has to be treated for more valuable uses or, discharged in local water ways. This contributes to environmental degradation because the effluents contain high BOD, COD and suspended solids (Adams, 2006). The quantities of coffee wastewater generated by the industries varying depending on the processing technology applied.

The wastewater emanating from wet coffee processing industries can be divided into two. Firstly, the pulping water with high content of quickly fermenting sugars and secondly, the effluents from the mechanical mucilage removers. This effluent had high concentrations of suspended solids, dissolved solids and elevated nutrient like; pectin's, proteins and sugars. Internationally coffee wet processed yields 2.25 million tone of BOD that area discharged annually to the rivers and waterways of some world's poorest nations (Adams, 2006).

Moreover, wet coffee processing effluents usually had elevated amount of conductivity, turbidity and lower dissolved oxygen to nearby water bodies or receiving environment. The physicochemical parameters of coffee effluent consist of very high amount of BOD reaches up to (2200 mg/ dm^3) and zero DO values (Kebede et al, 2010).

Additionally the finding Tsigereda et al, 2013 indicate that the water quality of effluent from conventional wet coffee processing plants after wet coffee processing activity like: Pulping, fermentation and washing water contain high parametric concentration (Table 2.2).

Table 2. 2 Physicochemical Characteristics of Conventional wet coffee processing plant

Parameters	Range
pH	3.9-4.4
BOD_5(mg/l)	1210-2130
COD(mg/l)	5470-6120
Nitrate(mg/l)	3.15-6.65
Phosphate (mg/l)	2.71-3.45
TSS(mg/l)	1564-210
TDS(mg/l)	1580-2133
Conductivity (μS/cm)	663-821
Turbidity (NTU)	185-458
DO (mg/l)	1.09-2.7

Sources: Tsigereda et al, (2013)

2.6 Impact of wet coffee processing waste on surface and ground water quality

Wet coffee processing method result superior quality of coffee beans as compared to dry method, this method is the main source of organic pollution in environment (Woldesenbet et al, 2014). Since, this coffee processing method needs mechanical removal of pulp with the help of water, a considerable amount of wastewater is generated which are heavily polluted with organic load, nutrients and suspended matter (Haddis and Devi, 2008). While this wastewater released untreatably to the surrounding surface water it could leads to, deterioration of the river water quality, reduction in volume of river water and also impede the free flow of the river water. This effect is high during the peak time of coffee processing or during high discharge of effluent (Ejeta and Haddis, 2015). Similarly**,** (Dejen et al, 2015) sated that coffee pulp and effluents which are discharged unwisely into nearby natural water way which flow into rivers and/or infiltrate into groundwater become main threat to the surface and groundwater qualities.

Moreover, high acidity and declining of life supporting oxygen from the water are major concerns for surface water receiving the effluent (Tsigereda, 2011). This indicates that large amount of chemical and biological oxygen demanding substances in the effluent are released from the coffee processing wastewater into the river. Available oxygen in the wastewater is low to support biological digestion and chemical reaction with in the water bodies. This results in sedimentation and forming oxygen demanding sludge deposit, which cause turbidity in the receiving water bodies. As described by (Von Enden and Calvert, 2002),while high suspended material (especially the digested mucilage) precipitated out of the solution builds a crust on the surface, clogging up water ways and further contributing to anaerobic condition. This would allow for growth of algae which would lower the dissolved oxygen levels and it is important to note that high nitrate level in the downstream could be a source of eutrophication for the receiving water bodies.

2.7 Health and Ecosystem impact of effluent from wet coffee processing plants

Effluent from wet coffee processing result in bad odor in the surrounding areas, breeding of disease vectors, and its direct 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 (Haddis and Devi, 2008). 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. 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 (Tsigereda, 2011).

The eco hydrology of river water banks were disrupted by effluent from wet coffee processing. High organic and inorganic nutrient concentration widely exceeds assimilation capacity of eco-hydrological integrity of river water quality and do not allow for aquatic life. As well, has a complex effect on flowing river water and increased eutrophication concentration in downstream. In an aquatic ecosystem, a greater number of species of organisms are supported when the dissolved oxygen (DO) concentration is available in appropriate amount. Oxygen depletion due to organic waste digestion has the effect on the numbers organisms present in the ecosystem. As stated by Endris et al, (2008) decline in aboundance and diversity of EPT taxa (Ephemeroptera (mayflies) has been noted in rivers, receiving wasterwater from coffee processing factories. Likewise; plants grown around wastewater of conventional wet coffee processing did not resist and grow properly (Tsigereda, 2011).

2.8 Treatment of coffee wastes

There are a number of waste treatment options, but very few have been adopted. Using of aerobic and anaerobic pond is main treatment method in Central America. Its result shows poor operating and breeding sites for mosquitoes and other insects. In India and Costa Rica water usage minimization by modifying and utilizing recirculation techniques and pulping machines. However, this does not minimize the total pollution load in wastewater. Conventional waste treatment means is technically feasible. Biological filters, anaerobic digestions, activated sludge (aerobic treatment) all demonstrated reliable removal of BOD, COD and suspended solids from coffee waste. Simple treatments such as stabilization ponds have been implemented, poor operations limit their effectiveness. The use of anaerobic lagoons and stabilization ponds run the risk of accumulation of the toxic pesticides used during cultivation. The use for irrigation was reported to be suitable for coffee tree as an organic fertilizer, but its effectiveness depend on soil type. But, the application of pulp without composting enhances soil acidity (Adams, 2006). Costa Rica is probably the only country that has aggressively approached the problem of pollution due to wet coffee processing, all mills are required by law to treat all wastewater and compost all coffee pulp.

Irradiation of wastewater is an effecrive process, capable of distroying toxic organic compounds. the result by Hue, (2006) indicated that the presence of air it was possible to destroy upto 70% of COD at different flow rates (Aguilera et al, 1998). This technique may not be achieved in large scake due to high expence.

2.9 Application of coffee waste

Almost all developed and underdeveloped countries are trying to reduce pollution from industrial activities by modifying their processes so that their residues can be recycled. Consequently, most major companies no longer consider residues as waste, but as a raw material for other processes (Mussatto et al., 2006). By product of coffee processing can be used for different purpose in different area. The coffee pulp can replace up to 20% and up to 16% of commercial concentrates in feeds for milking cows and pigs respectively. In Brazil, the pigs fed with up to 15% ensiled coffee pulp and 5% of bagasse showed the same weight this, means that by the end of the raring period, each pig has left nearly 50 kg of corn available for alternative uses (Echeverria and Nuti, 2016). In dairy farming with no adverse effects and about 30% cost of feeding could be saved. Further, coffee pulp feeding tried on other animals like: fish, chicks, lambs, and rabbits.

Coffee pulp is rich in nutrients like: nitrogen, phosphorus, potassium and other. Thus, it is important to use as an organic fertilizer. The pulp kept, for 3 to 12 months, turns into rich, black humus that can be used for composting. The use of organic fertilizer helps to improve soil properties and increasing yield. The pulp of coffee is also used as planting soil for mushroom production. The pulp is also used as a source of substrate for fermentation to produce alcoholic beverages. The chemical extraction of these bioactive compounds has been proposed, to be commercialized as food supplement. Coffee silver skin aqueous extract may be used for other applications, such as cosmetics and dermaceutics, due to the presence of antioxidant compounds, phenols and other bioactive components. On the other hand, compost made from coffee pulp as an amending topsoil with 20%of coffee pulp by volume improved the soil physicochemical and biological properties, that enhanced the plant growth and yield attributes, indicating the potential use of composted coffee pulp on the field as an alternative source of bio-fertilizer to improve the organic carbon content of poor soils in Ethiopia (Ulsido and Li, 2016).

Table 2. 3 Use of liquid and solid residues from coffee processing

Residue	**Production of energy**	**Other end –of –use**
Mucilage and wastewater	Biogas	Fert-irrigation, infiltration, aerobic/anaerobic, reed bed
Pulp	Biogas, pyrolysis/gasification, combustion	Cultivation substrate (mushrooms), compost, amendment, animal feed, caffeine, tannins, alcohol, paper
Parchment	Compost, paper, polymers	Compost, paper, polymers

Sources;(Echeverria and Nuti, 2016)

Some studies carried out in Tanzania suggest high methane (CH_4) yields from coffee residues; 730 m^3 CH_4 / tons of Coffee Arabica solid waste (Kivaisi, 2002). Likewise, (Mihret et al, 2016) reported that biogas could be produced by the co-digestion of coffee-pulp and cow-dung mixture under solar radiation. Averagely the coffee husk gave 56.6 ml of biogas and 30.85 ml of methane everyday from10 grams of the substrate for 40 days showing the potential of the husk for gas production.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Descriptions of Study area

3.1.1 Location and Topography

The study was conducted in Gidabo sub-catchment of Bilate watershed located in SNNPRS of Ethiopia. Gidabo River is the main river in the catchment and the river crosses four districts in the region namely: Dara, Chuko, Alleta-wondo, Dale, Dilla Zuria and Dilla town. The geographical location of the area is between $6.09^0$and 6.6^0N and $38.0^0$and 38.38^0E with an area of 3302 km^2 (WRDB, 2014).

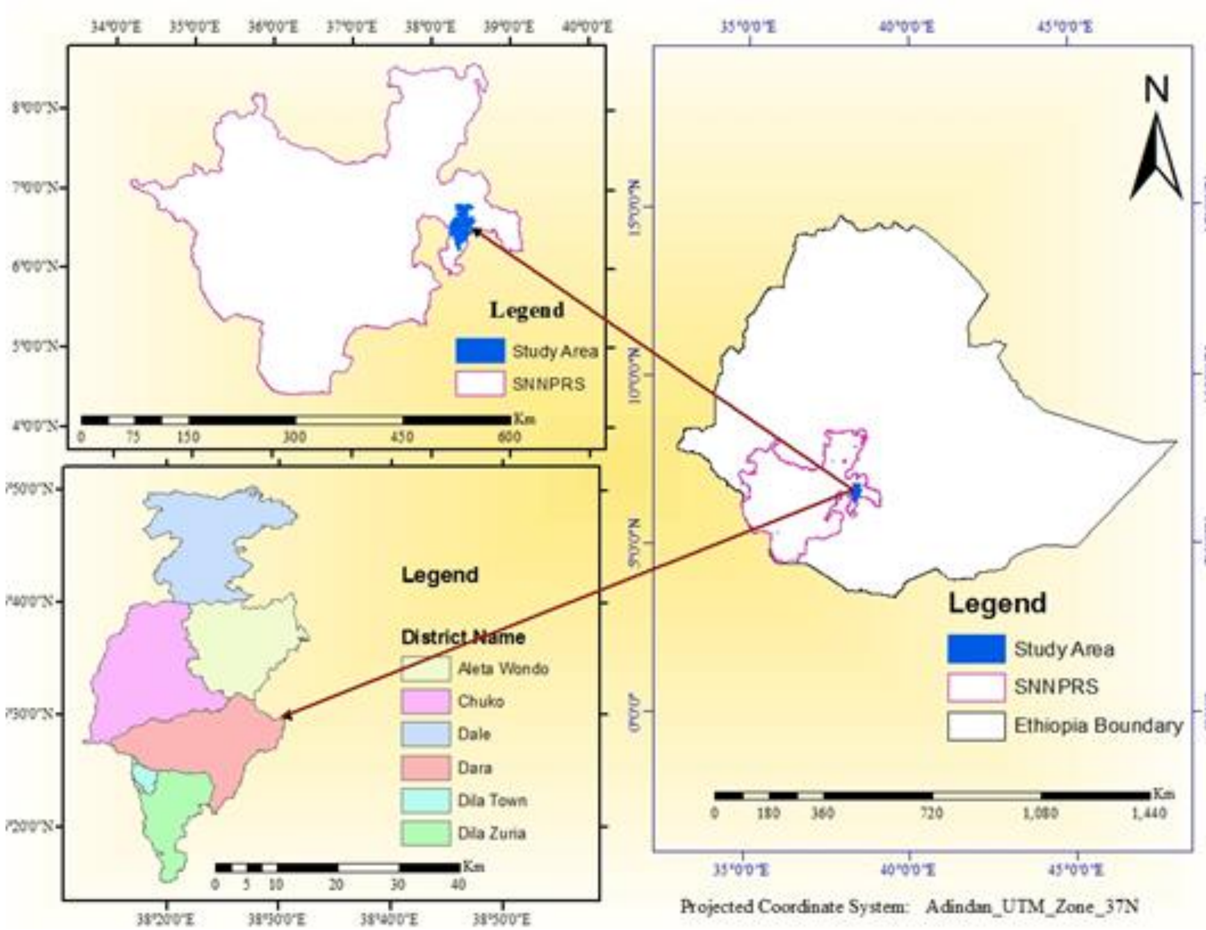
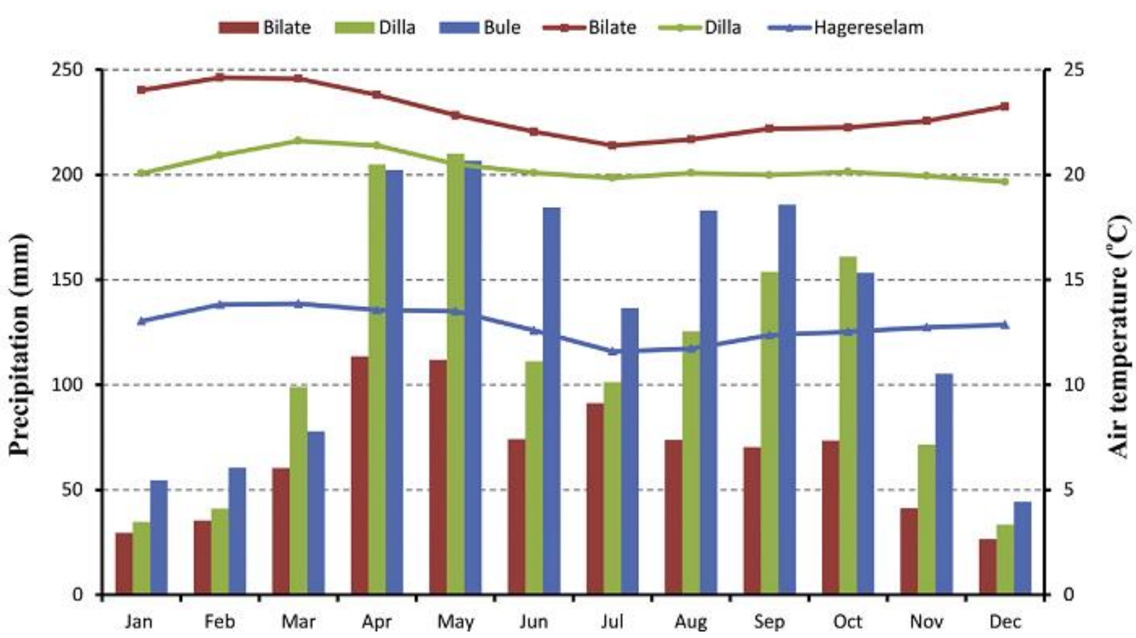


Fig 3. 1 location of the study areas

The watershed has a wide range of elevations from 1175 m a.s.l. at Lake Abaya in the west to about 3200 m a.s.l. at the Gelala summit in the north east. The Gidabo catchment can be classified in three sub watershed: The Upper terraced area is characterized by stepped slope. Middle one is fragmented patches and pockets of considerable open lands largely in Sidama zone and Lower courses is confined to the rift valley floor. It is characterized by relatively flat and plain of extensive land (WRDB, 2014).

3.1.2 Climate and Hydrology of the Study Area

The Climate in the Gidabo catchment ranges from semi-arid in the rift floor to humid in the mountains of the escarpment. In the upstream and middle escarpment rainfall exceeds 1600 mm/year, whilst at the lowest altitude in the rift floor precipitation is often below 800 mm/year. Precipitation is characterized by a bimodal annual rainfall pattern with maximum peaks during April and May ("small rainy" season) and during June and September in the "main rainy" season. Like in most parts of Ethiopia, the diurnal variation of air temperature in the basin is more visible than its seasonal variation. Average monthly temperature varies from 21^0C to 25^0C in the rift floor to less than 11.5^0C to 13.5^0C in the high altitude (Mechal, 2015).



Sources: (Mechal, 2015)

Fig 3.2 Mean monthly precipitation and air temprature in lower and uper escrapment of Gidabo watershed

The catchment is drained by some major rivers running from the east into Lake Abaya. Gidabo, Chichu, Kolla and Dara are the main rivers draining the catchment. Buna from the South-East, Koll from the North-East, Tiliku-Mencha from the North and Amalake from the South of the study area are some of the tributaries of the Gidabo River (WRDB, 2014).

3.1.4 Land use and land cover of the area

The area has tropical mountains rainforest character, and agro-forestry is the specialized land use and vegetation cover both at the upper and lower courses of the major rivers in the catchment. In particular, Gedeo Zone has been known by intense traditional agro-forestry practice. Ensete (*EnseteVentricosum*) makes the staple food crop. The lower courses of the major rivers are covered with savanna types and humid mountainous (1800-2400 m.a.s.l) is characterized by a few Juniper and conifer trees. In this range of altitude Coffee Arabica plant is commonly cultivated with the upper 2,200 meters limit of altitude (WRDB, 2014).

3.1.5 Socio Economic activity

In the agro-forestry zone, mainly in Gedeo Zone, coffee is cultivated as cash crop and forms the largest cash source of the majority of the population. In the lower courses the main livelihood of the population depends on Pastoralism and semi pastoralism while, the community in northern part of the catchment depend intensive farming practice, including cultivation of grain for subsistence and specialized cultivation of various fruits (pineapple, mango, papaya, banana and others) as cash crops are carried out (WRDB, 2014).

3.2 Methods

3.2.1 Methods of data collection

Both primary and secondary data were used in this study, Secondary data was obtained from various sources such as reports of previous research findings, Internet and other published and unpublished materials, which were found to be relevant and the starting point to the study. Primary data was collected from field visit and laboratory findings.

3.2.2 Parameters that were measured and selection of sampling sites

In order to assess the impact of wet coffee processing waste effluent in the study area, water samples were taken from the river and shallow wells of up to 15m depth. The samples of from river were analyzed for parameters like: Temperature, pH, TDS, Turbidity, Nitrate (NO_3^-), Phosphate (PO_4^-), BOD, COD, DO and Conductivity for peak coffee processing seasons and off seasons of coffee processing (rainy seasons). The peak season data were gained from secondary data collected by (Ulsido and Li, 2015) for the three sampling site means: upstream, middle and lower stream. The rainy season samples were taken from upstream, middle stream and downstream of the catchment in three rounds. From the sampling sites selected along the receiving river, replicate samples were taken. The aim of taking two replicate samples was to minimize the spatial variations and minimize sampling error. Groundwater samples from shallow wells taken from upstream, middle stream and downstream were considered the same way for each site sample, and were taken with the radius of 1Km around the sampling point of surface water. The delineation of the map was done Using ARCMAP Ver. 10.3.

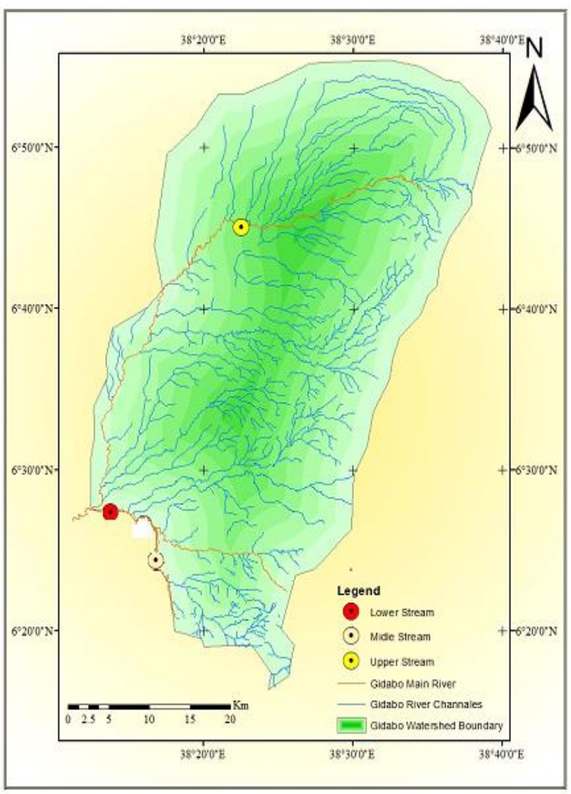


Fig 3. 3: Gidabo watershed and Sampling point of study

3.2.3 Sampling Techniques and Analysis

All water samples from sampling points were collected using clean and sterile polyethylene plastic bottles. The samples were stored in an ice box and transported to the laboratory of Hawassa University for analysis. The pH, TDS, Conductivity, Resistivity, Turbidity, DO and Temperature were measured on the field. Whereas, BOD, COD, Nitrate and Phosphate were analyzed according to standard method in laboratory.

Table 3. 1 parameters selected for the study site and apparatus used for methods of analysis

No.	Parameters	Method used	Unit
1.	pH	probes multi-parameter	-
2.	Turbidity	Turbidity meter	NTU
3.	Temperature	probes multi-parameter	°C
4.	TDS	probes multi-parameter	mg/L
5.	Electrical Conductivity	Probes multi parameter methods (EC meter)	µS/cm
6.	Dissolved Oxygen (DO)	Probes multi parameter methods (DO meter)	mg/L
7.	Biological Oxygen Demand	Standard method (Appendix)	mg/l
8.	Chemical Oxygen demand	Titration Method (Appendix)	mg/L
9.	Nitrate (NO_3^-)	Spectrophotometer	mg/L
10.	Phosphate	Spectrophotometer	mg/L
11.	Resistivity	probes multi-parameter	ohmmeter (Ω·m)
12.	Salinity	probes multi-parameter	parts per thousand (ppt)

3.2.4 Statistical analysis

The analysis for each parameters of sampled water was conducted using SPSS version 20. The spatial effect, seasonal effect and interaction effect of all surface water parameters were tested by using two-way ANOVA and for shallow well water samples were tested by one-way ANOVA, computed at 95% of confidence level. The seasonal homogeneity test was carried out by Tukey comparison test. The observed result from the three location (upstream, middle stream and downstream) were expressed as mean ± Standard deviation to show precision and the spatial variation. Finally the result was presented using tables, histograms and figures.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Impact of Wet Coffee Processing Effluent on Surface Water

The results presented below showed that the wastes (both solid and liquid) released from wet coffee processing industries are serious problems to the environment. For the reason that, the waste has high BOD/COD values during the peak coffee processing season with less water availability for dilution. The wastes are potential environmental problems and cause water pollution due to high organic and inorganic pollutants concentration. The means of the physicochemical parameters for all three sampling site with in two different seasons are given in (Table 4.1). Their seasonal variability is also presented in the same table.

Table 4. 1 Physicochemical water quality parameters (mean± SD) and their seasonal variability

		Location			
Parameters	Season	Upstream	Middle stream	Downstream	National Discharge Limit
pH	D	5.08 ±0.056*	5.0 ±0.56*	4.60 ±0.00*	6-9
	R	7.05±0.21	7.15±0.21	7.45±0.49	
Temperature (°C)	D	25.50 ±0.71	17.05 ±2.1	18.30 ±0.42	40
	R	22.1±0.14	23.85±0.21	24.5±0.707	
TDS (mg/l)	D	519.70 ±3.25	309.25±41.08	372.05 ±47.73	3000
	R	47.15±0.07	27.15±0.21	30.15±1.06	
Conductivity (μS/cm)	D	747.25 ±6.72	445.05±58.05	533.55 ±67.10	1000
	R	67±1.56	37.65±0.64	43.95±3.18	
DO (mg/l)	D	0.00 ± 0.00*	0.005±0.007*	0.005 ±0.007*	>4
	R	8.03±0.04	7.52±0.41	7.11±0.12	
Turbidity (NTU)	D	481.5 ±48.79*	70.3± 35.35*	168.15±103.*	50
	R	226±4.24*	56.9±2.69*	70.6±0.57*	
BOD (mg/l)	D	323.00 ±97.58*	374±39.59*	473.0±179.61*	80
	R	10.4±1.98	8.04±1.47	6.21±0.27	
COD (mg/l)	D	2664 ±1479.27*	172.5±38.89	3282.5±774.3*	250
	R	90.35±9.4	33.25±0.35	56.25±1.06	
Nitrate (mg/l)	D	172.5 ±38.88*	115.0±21.21	80.00 ±28.28*	20
	R	4.49±0.01	2.7±0.14	2.35±0	
Phosphate (mg/l)	D	31.25 ±13.08*	8.13 ±0.88*	4.38 ±4.42*	5
	R	0.52±0.00	0.41±0.01	0.28±0.1	

Where * shows the parameter is exceeding the discharge limit of National Standards (EEPA, 2003), D-Dry seasons, R-Rainy season

4.1.1 Temperature

The mean value of temperature of a river in the study area ranged between 14.80 ± 0.99 to 25.50 ±0.71 ^{0}C. The maximum value of temperature 25.50 ^{0}C was recorded at the upstream during wet coffee processing (dry season), whereas, minimum 17.05 ^{0}C was recorded at middle stream during the dry season. The Temperature was high due to other weather condition in the dry season. The coffee processing industries Temperature is one of the physical parameter important in river ecosystem due to its strong influence on many physical, chemical and biological characteristics. Increase in water temperature decreases the ability of dissolved oxygen to dissolve in water, thus its availability to aquatic organisms which may have an influence on their metabolic and other activities. The ANOVA result shows that the temperature is not significant both in spatial and seasonal variation at 95% confidence level.

4.1.2 pH

pH is a measure of acidity and alkalinity of water body. It is considered to be of especial parameters in water quality test as it influences most of the chemical and biochemical reactions takes place in the aquatic ecosystem. The mean value of pH of the study varied from 4.60 ±0.00 to 7.15±0.21 at the three sampling sites which revealed that the water is neither acidic nor basic during rainy season. The maximum pH was recorded at downstream during rainy (June to September) season and the minimum was recorded during dry season in downstream. Lower values of pH during dry could be due to high load of organic pollution from wet coffee processing industries thus, decomposition of organic matter and high respiration rate of aquatic flora and fauna, thus subsequent in production of CO_2 and decrease in pH. This finding is in line with the findings of Hue et al, (2006). Where they reported that the pH ranged from 3.5 to 4.5 in wet coffee processing wastewater . Within the two seasons the pH had a significant effect at 95% confidence level (Table 4.2). Moreover, the pH values of collected water samples in dry season were found below the given limit (6-9) by Ethiopian National Standards discharge limits to surface water (EEPA, 2003). Whereas, the rainy season samples were within the given limit.

This result was same with the findings of (Hassan et al, 2017), the maximum pH was recorded during rainy season and the minimum was recorded during summer (dry season) due to decomposition of organic matter and high respiration rate of aquatic organisms. However, this finding was in contradicting the findings of Islam et al, (2015) where the study shows the pH of the water was slightly high during the dry season (November to March) which shows the alkalinity of the water in the corresponding river and lower during the wet season due to a dilution effect.

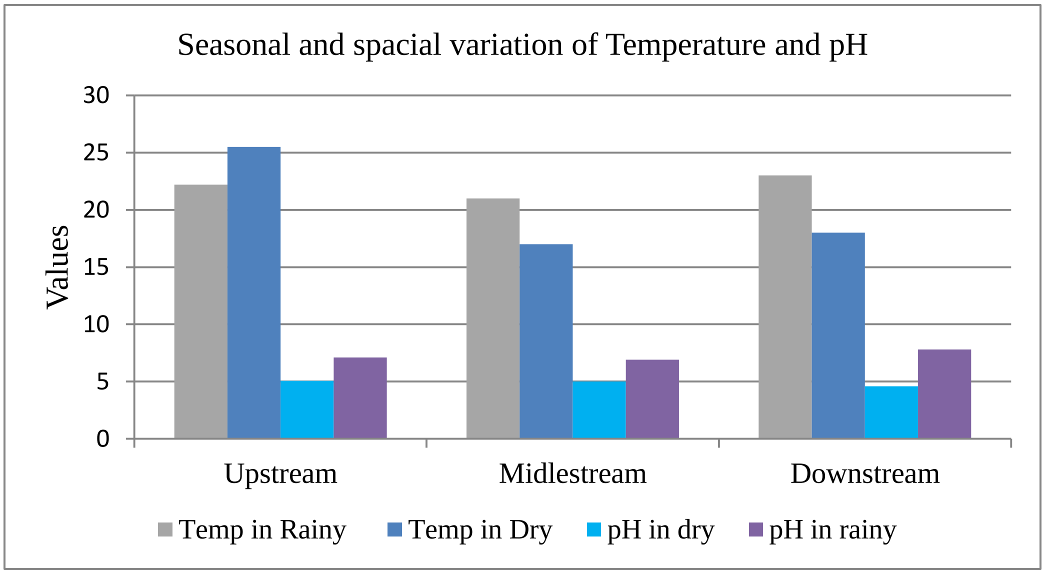


Fig 4. 1: Seasonal and spatial variation of Temperature and pH

4.1.3 Dissolved Oxygen (DO)

The maximum DO 8.03 ± 0.04 mg/l was recorded during rainy season due to high flow of water. Thus more amount of water that dilutes the organic pollutants, aeration and more dissolution of atmospheric oxygen with the river water area some of the constraints make the dissolved oxygen concentration to increases. Moreover, at this season there is no organic waste discharge from wet coffee processing activities in the area as the coffee harvesting time starts late October. The minimum was recorded during dry season, where it reaches zero in the catchment of possibly due to organic wastewaters discharged from wet coffee processing industries in the area. In dry season the industries are operating in maximum potential in the area. During dry season (Peak) coffee-processing time, the disposed untreated coffee waste and effluent consumed DO as result of high decomposition (Beyene et al, 2012).

Dissolved oxygen (DO) is a decisive parameter to indicate the degree of water quality and organic pollution load which shows the wellbeing of aquatic ecosystem. The major governing factors affecting the concentrations of DO are input sources such as: dissolution of atmospheric oxygen in water, photosynthesis by autotrophs and output sources such as respiration, decomposition of organic matters by microorganisms and evaporation due to high temperature (Panda et al, 2016). Additionally, oxygen concentrations vary with the volume and velocity of water flowing in a stream. The stream which is flowing high velocity creating white water areas tends to be rich in oxygen, because more oxygen enters the water from the atmosphere in those areas than in slower, stagnant areas and oxygen is also more easily dissolved into water with low levels of dissolved or suspended solids. Within, all those parameters human activities play an important role in lowering available oxygen concentration in the water bodies. Runoff from industries, sediments and other pollutants increases the amount of suspended and dissolved solids in stream water. As stated by Hassan et al, (2017) the concentration of oxygen in natural waters is largely influenced by physical factors like: temperature and salinity, i.e. dissolved oxygen solubility decreases as temperature and salinity increase. For example, as the temperature decreases the DO value increases.

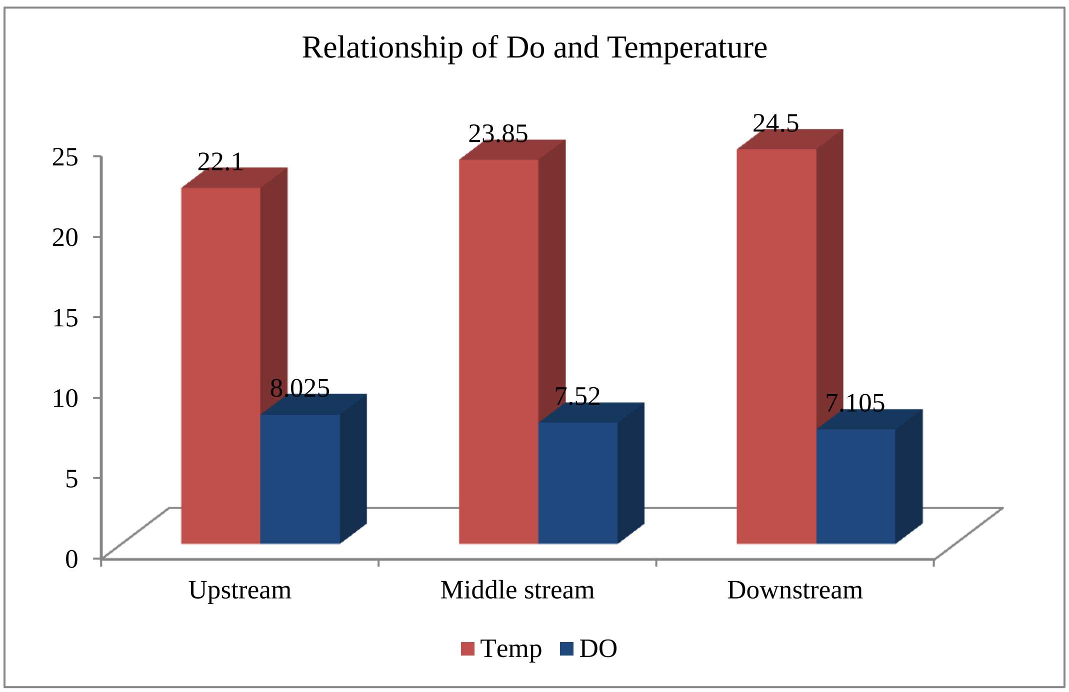


Fig 4. 2: Temperature effect on Dissolved Oxygen

The mean value of DO in the area varied from 0.00 ± 0.00* to 8.03 ± 0.04 mg/l in dry and rainy season, respectively. The maximum DO was recorded during rainy season at upstream and the minimum was recorded during dry season at upstream and middle stream. In this study, DO had a significant effect between the two seasons at (ά= 0.05). Hence, it is evident that the DO values are constantly influenced from wet coffee processing industries effluent. These findings were in line with Panda et al, (2016) results whereby the mean values of DO change shows a decreasing trend across the mining belt. The increasing trend is observed towards downstream due to dilution of pollution load from the upstream area. The amount of dissolved oxygen was lowest in downstream; the decomposition of organic matter from wet coffee processing industries and urban centers contributes to the low levels of dissolved oxygen in the water in the downstream. On the other side the value for BOD and COD were elevated in the downstream of the catchment. Additionally the finding of (Beyene, et al, 2011) indicate that high organic pollution during wet coffee processing season, depleted dissolved oxygen (DO) to a level less than 0.01 mg/l. In the peak coffee processing season DO values (Table 4.1) for all the sampling location ranged between 0.00 mg/l and 0.005 mg/l which are much lower than the recommended value by National Ethiopian Standards(≥4), where a DO value of less than 2 mg/l may pose serious threats to an aquatic ecosystem.

4.1.4 Biological Oxygen Demand (BOD_5)

The seasonal and spatial variation of BOD_5 in the study area was presented in (Table 4.2). The BOD_5 value was higher during the dry season (473 mg/l) as a result of higher concentrations of organic substances. BOD_5 is an approximate measure of the amount of oxygen required by the aerobic microorganisms to stabilize the biochemical degradable organic matter to a stable inorganic form present in any water sample, within five days of intervals therefore, it is taken as an approximate measure of the amount of biochemically degradable organic matter present in the aquatic systems, which adversely affects the river water quality and biodiversity (Hassan et al, 2017), Thus with lower DO values, the BOD levels were high due to high requirement of oxygen by microorganisms. The minimum value of biological oxygen demand was 6.210 mg/l during rainy season, as the dissolved oxygen amount available was more higher and low organic matter concentration due dilution and digestion. The result from ANOVA (Table 4.2) shows that biological oxygen demand is not significantly influenced by location difference in the study area where, it significantly influenced by season at 95% confidence level. Generally, the BOD values recorded in the entire sampling sites during wet coffee processing season (dry) crossed the standards limit prescribed by the national discharge limit of Ethiopia (80 mg/l).

Similar studies of (Beyene et al, 2011) revealed that mean concentration of biochemical measured as high as (1,900 mg/l) in impacted area and minimum as 0.5 mg/l in area free from effluent. According to (Haddis and Devi, 2008) concentration of BOD after entering of the wastewater from coffee processing plant in to the stream was 7800 mg/l. Thus in both scenarios the discharge limit is not respected.

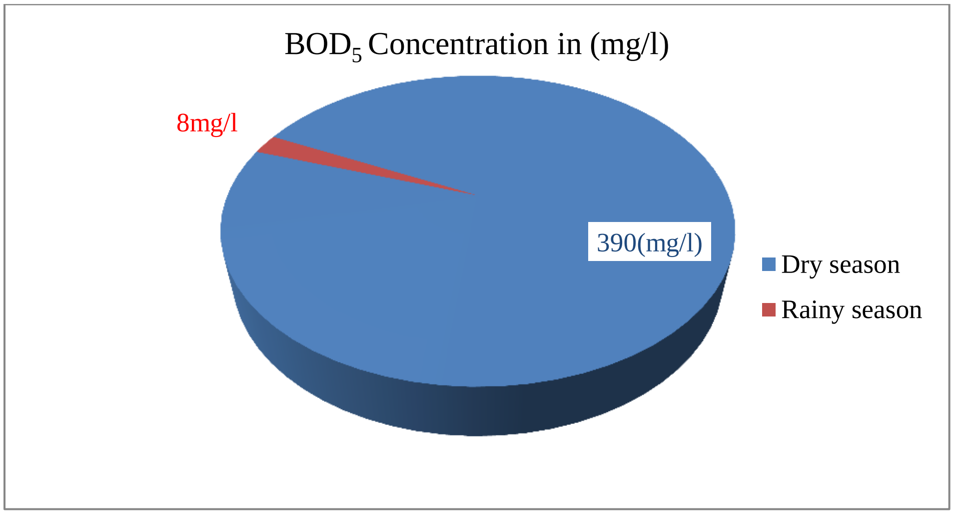


Fig 4. 3: Biological oxygen demand in different season

4.1.5 Chemical Oxygen Demand

Chemical oxygen demand (COD) is one of the most important parameters of water quality assessment employed for estimating the organic pollution of water. Mainly it is a useful parameter in the determination of industrial wastes, and very practical in the determination of organic pollution in domestic waste and polluted waters. The COD is widely used as a measure of the Oxygen needed for oxidation of the organic and inorganic materials present in the water bodies. The mean concentration of COD in dry season was 3567 mg/l (Table 4.1), which was above the Ethiopian permissible discharge limit (EEPA, 2003).

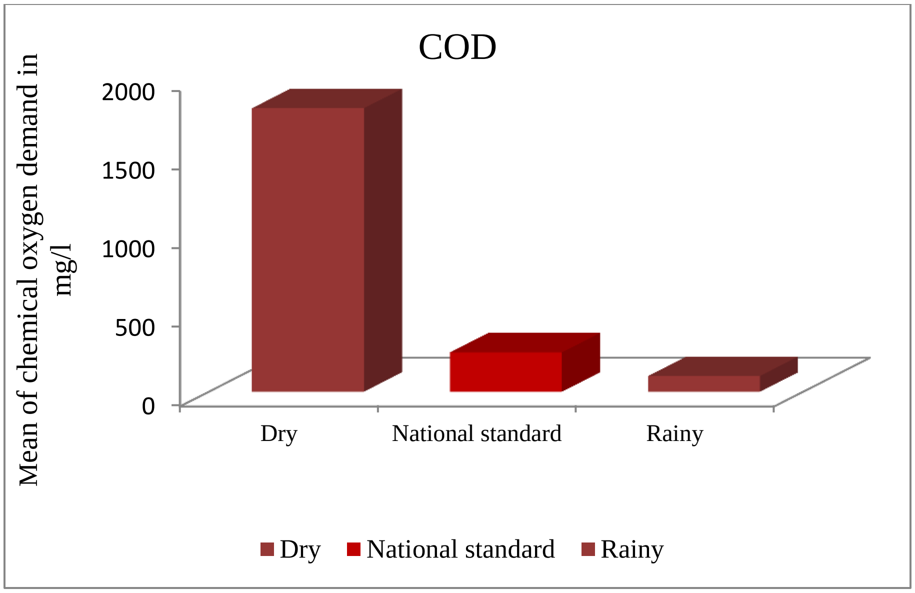


Fig 4. 4: Mean Variation of COD in different seasons

As a result, COD values are greater than BOD_5 values. COD values may be much greater when significant amounts of biologically resistant organic matter are present in the water body (Sawyer and McCarty, 1978). Also COD values are always higher than BOD values because, COD includes both biodegradable and non-biodegradable organic and inorganic compounds while BOD value only indicate biodegradable organic compound by microorganisms. The result from ANOVA table revealed that the COD concentration was significantly influenced by seasonal variation at (ά= 0.05). This indicates that the variation in concentration was due to difference in organic load with in the two seasons.

Table 4. 2 Two-way ANOVA test result showing spatial variations at 95% confidence level

Source	Dependent Variable	Sum of Squares	Mean Square	F	Sig.
Season	pH	16.194	16.194*	147.617	0.000
	Temp	1.021	1.021	1.002	0.356
	TDS	400807.301	400807.301*	604.584	0.000
	EC	829239.187	829239.187*	627.318	0.000
	DO	170.857	170.857*	5571.409	0.000
	Turbidity	44761.868	44761.868*	18.820	0.005
	BOD	437275.541	437275.541*	60.517	0.000
	COD	19687176.84	19687176.84*	28.662	0.002
	Nitrate	42709.401	42709.401*	92.762	0.000
	Phosphate	603.359	603.359*	18.909	0.005
Location	pH	0.006	0.003	0.026	0.975
	Temp	62.415	31.208*	30.621	0.001
	TDS	28182.155	14091.077*	21.255	0.002
	EC	58321.002	29160.501*	22.060	0.002
	DO	0.42	0.210*	6.845	0.028
	Turbid	189639.352	94819.676*	39.867	0.000
	BOD	11022.805	5511.402	0.763	0.507
	COD	969819.707	484909.853	0.706	0.530
	Nitrate	4548.526	2274.263	4.940	0.054
	Phosphate	430.112	215.056*	6.740	0.029
Season *Location	pH	0.432	0.216	1.970	0.220
	Temp	27.312	13.656*	13.399	0.006
	TDS	18972.222	9486.11*	14.309	0.005
	EC	39183.795	19591.898*	14.821	0.005
Season *Location	DO	0.429	0.215*	7.000	0.027
	Turbid	30213.945	15106.97*	6.352	0.033
	BOD	12262.845	6131.422	0.849	0.474
	COD	899354.107	449677.053	0.655	0.553
	N	4156.4	2078.2	4.5	0.064
	P	417.341	208.671*	6.540	0.031

Where values within rows having '' superscripts shows there is a significant difference (ά= 0.05).

4.1.6 Electrical Conductivity (EC)

The mean value of Electrical conductivity of the area ranges 37.65 ± 0.64 to 747.25 ± 6.72 µS/cm, during rainy and dry seasons respectively. The maximum electrical conductivity was recorded during peak coffee processing season attributed to the presence of organic matter in water due to an increase in the ionic concentration and the minimum was recorded during rainy season. Elevated levels of EC can have certain physiological effects on the habitat of aquatic system. Nevertheless, these values indicate that the Rivers could be receiving wastewater (industrial and sewage effluent) that contains high ionic concentrations, which is ultimately harmful for aquatic biodiversity. The result from analysis of variance shows that there is a significant difference on water quality in different seasons. Due to organic effluents from coffee processing dominate dry season. Additionally the rainy season have dilution effect on concentration. Despite the fact the Electrical conductivity water samples were found within the given limit (1000 µS/cm) prescribed by (EEPA, 2003).

4.1.7 Total dissolved Solids (TDS)

The mean value of TDS varied from 27.15 ± 0.21 to 519.7 ± 3.25 mg/l at different sampling sites. The result indicating that the surface water samples lie within the permissible limits. The maximum TDS were recorded during dry season almost in all location and the minimum during rainy season. The result from the ANOVA (Table 4.2) illustrate, that TDS shows significant difference in different season and location in the area at (ά =0.05). The concentration of total dissolved solids was high in the dry season from (October to December) was from the impact of wet coffee industries waste. These wastes highly contain solid particles like: pulp, dust, husk and others that affect the clarity of water. In the rainy season from (June to September) the erosion from the high land of the area was high, thus the turbidity of the rivers still recognizable. The upstream community in the watershed is practicing the agricultural activities which mostly contribute to the soil erosion.

TDS includes anything present in water other than pure water molecules and suspended solids. As reported by Hassan et al, (2017), the increase in TDS value reflects the pollutant load in the aquatic ecosystem originating from both natural as well as anthropogenic sources like: sewage, industrial wastewater and hence, adversely affect the quality of water. As the finding of Islam et al, (2015), sated also the highest maximum TDS value (1560 mg/L) of examined rivers were during the dry season, the average value was higher than monsoon season due to the dilution effect as this river is the recipient of many sources of pollution.

4.1.8 Turbidity

Turbidity ranged from 70.3 ± 35.35 NTU to 481.50 ± 48.79 NTU during the dry season and from 56.9 ± 2.69 NTU to 226 ± 4.24 NTU during the rainy season. During the dry season the effluent from the wet coffee processing and other anthropogenic activities enhance the turbidity level in the river. Where, in the rainy season the upstream had high turbid value due to, high soil erosion in the highland area.

The result from analysis of variances (Table 4.2) indicated that the spatial variation of turbidity were significant for both seasons at 95% confidence interval.

Turbidity blocks out the light needed by submerged aquatic flora. The suspended particles near the surface of water facilitate the absorption of heat from sunlight, which can raise surface water temperatures above normal. Moderate turbidity levels may indicate a healthy, well-functioning ecosystem.

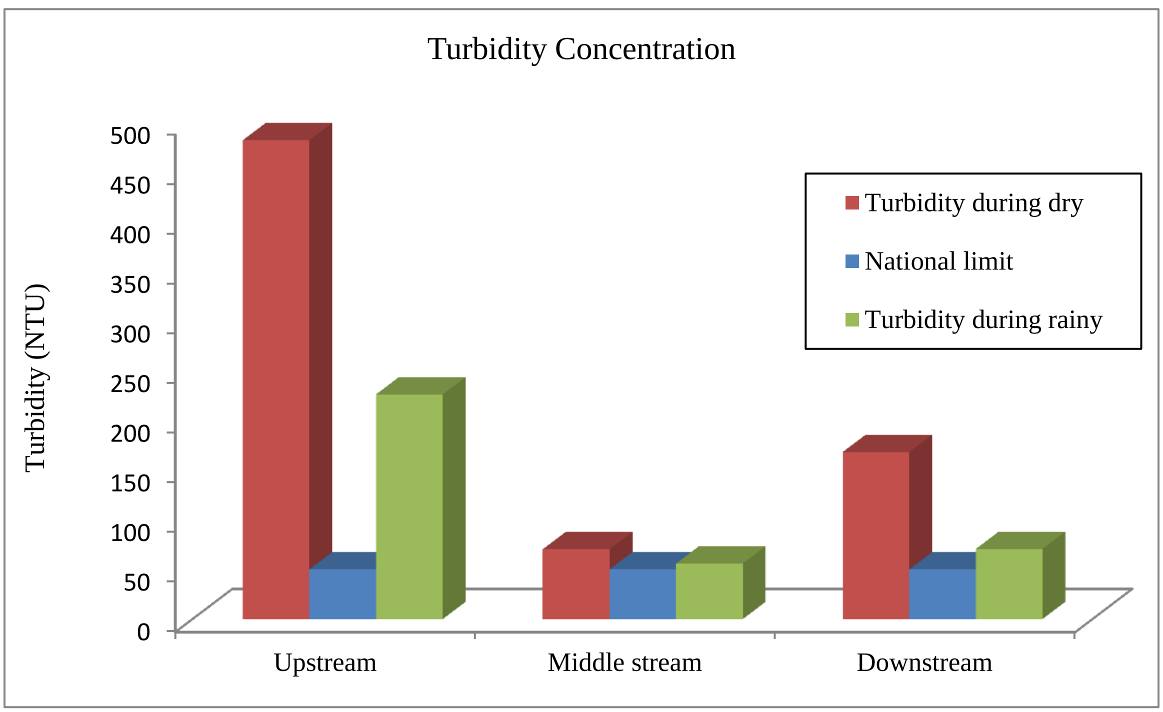


Fig 4. 5 : Seasonal Variation of Turbidity Level

4.1.9 Nitrates (NO_3^{-}) and Phosphate (PO_4^{3-})

The range of nitrate and phosphate was between, 2.35 ± 0 mg/l to 172.5 ± 38.88 mg/l and 0.28 ± 0.1 mg/l to 8.13 ± 0.88 mg/l during the rainy and peak coffee processing season respectively. The seasonal variations for nitrate and phosphate were found to be statistically significant (at 95 % confidence level) indicating that there is more nitrate being added to the river during the dry season than during the rainy season due to the organic matter load. All samples apart from the rainy season sample were above the National Standard Limit value of 20 mg/l and 5mg/l for Nitrate and phosphate respectively. While all point rainy seasons were below the given standard limit. Foremost source of phosphate in water is effluent discharge from industries, sewage treatment plants, domestic wastewater and runoff from agricultural additives. ANOVA results also indicate that Phosphate has significant variation along the location of the sampling; by the time carried by water the chance of uptake by plant in different place increases.

The finding of Hassan et al, (2017), was indicate that high phosphate recorded during rainy season could be correlated to inflow of rain water from catchment area, which brought with it various salts and fertilizers including phosphates into the Chania river (Kenya). Phosphate is rarely found in high concentrations in natural waters and as it is actively taken up by plants.

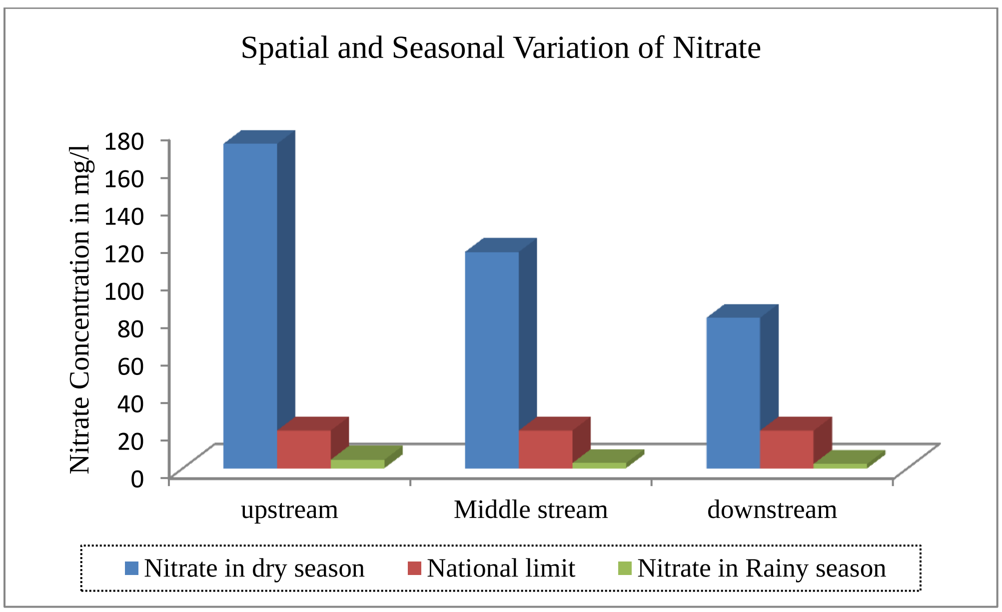


Fig 4. 6: Spatial Variation of Nitrate Concentration

The amount of nutrients in the upstream was also found to be higher than in lower stream in both seasons may be indicate that the nutrient like nitrate and hosphate the sources of nutrient may lead to the agricultural land in the upstream area. Moreover the nutrients, natural available in trace quantity and actively taken by plant or react in the ecosystem. In general, the comparison between upstream and downstream sites clearly demonstrated that the deterioration of water quality were concern the whole catchment. These indicate that the hypothesis of the study is accepted. Additionally the parameters of the study were significantly affected by the seasons as, the peak coffee processing season alter the water physicochemical property in general.

4.2 Physicochemical parameters of shallow well water in the study area

There was a significant spatial variation of DO values of the study sites at 95% confidence level (Table 4.3). The mean value of DO ranges from 1.655 ± 0.22 mg/l to 5.325 ± 0.53 mg/l. Thus results the BOD levels extend from 1.46 ± 0.18 mg/l to 2.59 ± 0.34 mg/l at the upstream site and downstream site of the catchment respectively. The pH levels of the Shallow well water ranged between 5.25 ± 0.354 and 5.95 ± 0.071 (Table 4.3) almost the same for the three locations. The spatial variations of pH, Temperature, TDS, COD and Phosphate were not significant at 95% confidence level. However, the pH indicates that the water is slightly acidic.

Table 4. 3 One-way ANOVA test result showing spatial variations at confidence level of 95%

Source	Dependent Variable	Sum of Squares	Mean Square	F	Sig.
Spatial Variation	pH	0.573	0.287	2.293	0.249
	Temperature	7.263	3.632	6.524	0.081
	TDS	36521.33	18260.67	2.943	0.196
	EC	44617.33	22308.67*	12.017	0.037
	Turbidity	42.946	21.473*	102.545	0.002
	Resistivity	7.784	3.892*	10.019	0.047
	BOD	1.289	0.644	12.175	0.036
	COD	6.086	3.043	3.037	0.19
	Nitrate	2.085	1.042	12.338	0.036
	Phosphate	0.013	0.007*	5.841	0.092
	Salinity	0.299	0.149*	67.361	0.003
	DO	13.981	6.991*	20.451	0.018

*The mean values under the respective season given different superscript letters are significantly different

Turbidity values ranged between 7 ± 0.7 NTU and 2.06 ± 0.35 NTU. The upstream and middle stream was more turbid than the downstream even if the effect was not considerable. The relatively high turbidity at the upper course of Gidabo catchment might be related to seasonal condition in the environment, high soil erosion in the sloppy area of the catchment. Nitrate from the results, water samples from the three sites have nitrate content below the recommended value of (50 mg/l) by Ethiopian National Standards for drinking water and it is not the concern for the area. Similar studies by Isah, (2015) in Nigeria shows that water samples from hand dug wells have nitrate concentration below the permitted limit of 50 mg/l recommended by the country.

Table 4. 4 Physicochemical parameters concentrations of well water (Mean± SD)

Location	Upstream Mean	Middle stream Mean	Downstream Mean
pH	5.95 ±.071	5.25 ±.354	5.35 ±.495
Temperature	24.75±1.061	23.85 ±.21	26.5 ±.71
TDS	361.5±48.79	340.5 ±75.66	186.5 ±102.53
EC	580.5±9.193	483.5 ±72.83	369.5±13.435
Turbidity	7.7±.70711	7.77 ±.05657	2.06 ±.354
Resistivity	8.65±.92	8.74 ±.127	6.28 ±.55
BOD	1.46±.18	1.93 ±.099	2.59 ±.34
COD	7.75 ±.78	7.75 ±.78	10.1 ±1.27
Nitrate	2.58±.32	2.3 ±.29	1.21 ±.27
Phosphate	.255 ±.0071	.21 ±.014	.14 ±.057
Salinity	.68 ±.029	.17 ±.04	.255 ±.064
DO	5.325 ±.53	4.11 ±.83	1.655 ±.22

4.3. Seasonal variability of river water quality parameters

The water samples were analyzed for seasonal variations of selected physicochemical parameters during the peak coffee processing seasons (October to December) and wet months (June to August). The mean value of the parameters is higher during the coffee processing season. The pH value in dry season indicates that the water has acidic property. Higher value of BOD and COD was also due to high load of organic pollution in this season. Moreover, nutrient concentration like: nitrate and phosphate were also have same properties. As the result of the ANOVA shows in (Table 4.2) all tested parameters except temperature all have significant difference in seasonal variation at 95% confidence level. The concentration of DO, BOD, COD, pH, turbidity, nitrate and phosphate all the studied physicochemical parameters, except temperature, TDS and conductivity all were higher than the prescribed limits of the national standard.

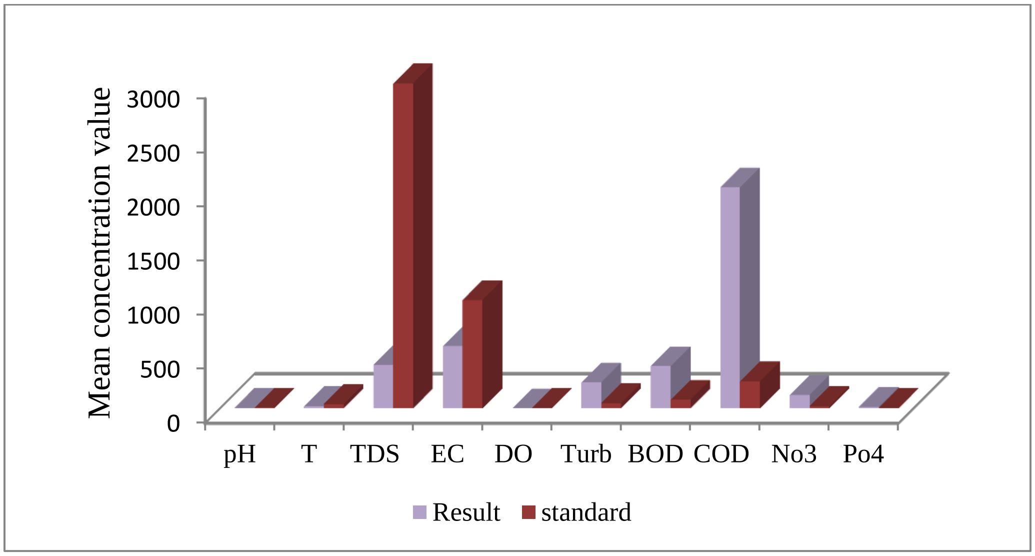


Fig 4. 7: physicochemical parameters during dry season

All studied parameters show significant difference in seasonal variation due to high organic matter load in this season. This finding is in agreement with a study conducted on the effects of coffee waste on water quality of nearby rivers in Ethiopia (Beyene, et al, 2011).

Sources: Ulsido 2015

Fig 4. 8: Wet mills releasing untreated to the near-by streams

The coffee washing plants have neither adequate number of lagoons nor have sufficient capacity to accommodate wastewater for extended retention time. Most of the plants incorporate two lagoons with average depth of 1.5 m. For example 73% of coffee washing plants in Dara district have two lagoons, 18% one lagoon and the rest 9% have three lagoons. Nearly all Lagoons are not lined, not systematically arranged or interconnected in such a way that wastewater can be oxygenated through recirculation and transfer from one to another as well as sufficient retention time is allowed for microbial degradation of the BOD_5 load within. The effluent from the machine has the maximum of two days retention period in the ponds not only that, for above 80% of the machine, the gap between the river and the ponds are below 20 m. In special case there are also some sites have a ditch that allow the effluent directly to the river. All this contributes for the seasonal variability of pollutants concentration as presented in (Table 4.1) above.

In aquatic ecosystems a diverse relations of physical and biochemical parameters exists. Human activities, predominantly, the introduction of either organic or inorganic chemicals into water, may adversely affect many species of aquatic flora and fauna. Water quality guide line for the protection of aquatic life may take into account only physicochemical parameters before which tend to define a water quality that protects and maintains aquatic life. Mainly DO is the concern as it may cause fish death at low concentrations, as well as phosphates and nitrate causes significant changes in community structure if released into aquatic ecosystems in excessive amounts. Some additive to water molecules as pollutants can also cause reproductive, carcinogenic and developmental effects on aquatic life. Recently the concept of the ecosystem approach in water management focuses on healthy aquatic ecosystem conditions. This describes the state of inhabitant species and the organization and function of ecosystems as a whole.

It was noted that in river where there is directly discharged of wet coffee processing waste, DO was not available in required amount to support the ecosystem functions (Beyene et al, 2012). High BOD to COD ratio loading from the coffee discharge had rendered that area of the river toxic. It was also indicated that most small water ways receiving coffee effluent directly had been rendered toxic during the processing season had a detrimental effect on flora and fauna of water bodies (Adams, 2006). During wet coffee processing the organic and acetic acids from the fermentation of the sugars in the mucilage make the wastewater very acid, pH down to 5 (Table

4.1). Under these acid conditions, many of plants and animals will be affected. After the first fermentation of sugars in the waste water took place, the organic substances diluted in the waste water, break down only very slowly by microbiological processes using up oxygen from the water. This process causes problems as the demand for oxygen to break down organic material in the waste water exceeds the supply, dissolved in the water, thus creating anaerobic conditions (GTZ –PPP Project, 2002).

As an effect of the high values of COD and BOD anaerobic conditions ("rotting") set in quickly causing bad smells and speed up the death of aquatic life due to the quick use up of oxygen dissolved in the water. Bacteria living in anaerobic conditions can also cause health problems for humans when found in drinking water. In addition to the bad smell, coffee waste water will turn dark green to black after a while. This staining is caused by the chemical components of the red color of the coffee cherry (flavonoids) and is also well known in other food processing industries, like the wine and olive industries. These fruit colors are actually the precursors of the brown humus color of swamp water, which is completely innocuous to aquatic species. So, although they do not look nice, the intermediate black colors by themselves do not do any harm to the environment nor add much to the BOD or COD (GTZ –PPP Project, 2002).

Fig 4. 9: Solid Waste management on one of the wet mills in the basin

Summarizing, the combination of high acidity, and high BOD, depleting life supporting oxygen from the water, are causing the problems in coffee waste water treatment and need to be overcome.

4.4. Possible interventions to mitigate these problems

4.4.1 Policy Enforcement Options

Before discussing about technological interventions as an option, it is logical to discuss about environmental audit and environmental impact assessment (EIA) as a proactive tool for environmentally friendly management of the sector. It is very important to undertake environmental audit for the exiting industries in the region before they start production particularly on June and July to monitor their commitment on waste management.

The other equally important point is that, Regional Investment Agency, Marketing and cooperative Bureau, finance sources like bank and Natural and Environmental protection Authority should work hand in hand to implement Environmental Impact Assessment (EIA) study for a newly coming investor in the wet coffee processing plant. Thus, leaders should harmonize their plan on the sector, since the condition is environmentally shocking.

4.4.2 Technology options

Currently there exist recent technologies which are water intensive and cost effective. Adoption or adaptation of such technologies can mitigate and facilitates environmentally friendly production of the coffee beans. Moreover, introduction of a decentralized household level wet coffee processing with hand technologies can guarantee material recycling and optimizes resources utilization efficiency.

4.4.2.1 Lagoons Standardization

Lagoons are a very effective treatment method and relatively easy to maintain. Determination of size of lagoons depends on the estimated water usage, rainfall amount and evaporation. Areas with high rainfall require relatively large sized lagoons. They should be constructed in such a way that they can have sufficient exposure to sunlight and oxygen; and enable aerobic bacteria to digest organic matter in the effluent. So, Lagoons should be built in locations where trees will not restrict sunlight exposure or air movement. To prevent out flow or discharge of wastewater from inside and inflow of surface water from surrounding area, protective system is constructed on all sides of lagoons. There should not be any discharge to environment. If lagoons are properly designed, operated and maintained there is no undesirable odor coming out from them. It is necessary to include lining structure in order to avoid leakages.

Sources (WRDB, 2014)

Fig 4. 10: the disposal system of the influent at the coffee processing sites

Nearly all lagoons in the study area have neither lining nor any protective dike on the sides to avoid outflow or discharge of wastewater from inside and inflow of runoff from surrounding area. They are situated very close to streams and rivers at average distance of not more than 20 m (Table 4.5). Pond and lagoons can be effective if properly maintained, for reduction of 70 to 90% BOD with a retention time of 10 days (Admas, 2006).

Table 4. 5. Lagoon conditions and their average distance from a stream

Woreda	Number of lined	Distance(M)
Dale	Nil	15
Chuko	Nil	10
Dara	Nil	20
Aleta	Nil	25
Dilla zuria	Nil	20
Average		**21**

Sources: (WRDB, 2014)

4.4.2.2 Recycling of water

The sources of water consumed for washing in majority of the plants are either Gidabo River or its tributaries. All wet coffee processing industries are constructed by the side of streams or rivers in order to easily exploit the water. Electric power or fuel driven generators are used to pump the washing water from foot of the site to reservoirs positioned at higher elevation. There are no attempts to incorporate water recycling systems despite its remarkable economic advantage in reducing the amount of water resource consumed during the entire process. Water recycling is not practiced in the area of the study even though, coffee industries in some countries, including Kenya, are reported to practice waste minimization and reuse of wastewater. Pulping alone consumed 6 to 7m^3 of water per ton of fresh coffee cherries processed in Kenya, whereas reuse of water reduced this volume up to 50% (Mwaura and Mburu1998). Though, this does not minimize the total load of BOD, COD or suspended solids discharged to the ecosystem. The best treatment option is anaerobic digestion of this effluent followed by aerobic treatment. Limiting the consumption of water through recycling system is also advantageous in reducing contamination and cost of treatment.

Table 4. 6 Water recycling system in wet mills of Gidabo watershed

District	No. of coffee washing plants in the Watershed	Plants with water recycling	Functional water recycling system	Percent (%)
Dale	56	Nil	Nil	Nil
Chuko	32	Nil	Nil	Nil
Dara	32	Nil	Nil	Nil
Aleta wendo	55	Nil	Nil	Nil
Dilla zuria	28	Nil	Nil	Nil

Sources: (WRDB, 2014)

4.4.2.3 Stabilizing Wetland

Different investigations have been made on the use of constructed wetland for the treatment of wastewater from different sources, but very few have examined their performance in coffee wastewater treatment. In constructed wetlands (CWs) with a horizontal sub-surface flow, nutrient removal, especially phosphorus adsorption, is limited for many reasons. Efficient nutrient removal including root zone oxidation, adsorption, and plant uptake require sufficient interaction of wastewater with the treatment media shall be studied and used for the treatment of pollutants from wet coffee processing industries. This treatment method have to be used with other treatment options as the system is slow and take long time to break all organic matter in the effluent.

4.4.2.4 Adsorption based Technologies

Adsorption based innovative technology (Devi et al., 2002), developed with low cost carbonaceous materials showed good potential, more so for COD removal from such wastewater. Such adsorption approach can offer an easy and economical solution to these environmental challenges. Moreover, activated carbon is considered very effective in reduction of color, absorbable organic halides (AO_X) and non-biodegradable pollutants of such wastewater (Mall and

Prasad, 1998 and Mall and Upadhyay, 1998) but this process has some additional costs associated with the production of activated carbon (Shawwa et al, 2001).

4.4.2.5 Composting

Almost all the coffee washing plants incorporated compost tanks. But none of the tanks is properly built or lined. The cherry skin is accumulated over open land in uncontrolled manner, and in extreme cases they are dumped directly down to the nearby streams. In few sites the cherry skin and liquid coffee waste are not completely separated. Coffee pulp solids contain only one fifth of the nutrients taken out of the soil by export of the green bean. However, it is a good source of humus and organic soil carbon. The study carried out by (Mihret and Li 2016), in Ethiopia indicates that the coffee pulp compost amended topsoil gave a significantly higher above ground and below ground fresh and dry weight compared with the topsoil that is not mixed with any fertilizer and top soil mixed with sawdust compost. As the mature stayed for three months under cover, it will reduce further to become very nice dry earthy compost which is a good soil improver and conditioning agent (Adams, 2006).

4.4.2.6 Biogas and fuel

Coffee husk is normally burnt in crude furnaces to dry our coffee parchment and for other uses. The process of burn the husk in a gas producer and run an engine on that producer gas generates electricity. The waste heat from the gas producer and the engine can be used to heat and can be used for drying in coffee processing industries. Co-digestion of waste coffee-pulp with cow-dung can also yield biogas high content of methane when digested at least for 8 months. As Corro et al, 2013, demonstrate that the collected coffee-pulp mixed with cow-dung in appropriate proportion can act as a valuable biomass for the production of biogas containing high amounts of valuable combustion gases such as methane and propane. Averagely, the coffee husk yield 56.6 ml of biogas and 30.85 ml of methane every day from 10 grams of the substrate for 40 days showing the potential of the husk for gas production. The study stated biogas production as a possible option for energy generation concurrently resolving environmental problems. Coffee waste can be utilized as a feed for biogas reactors that can serve for different purposes in the industry and the community as well (Ulsido et al, 2016).

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Water quality parameters analyzed and examined from the three sampling sites in the watershed were showed unsuitability of the water for different uses; domestic use and aquatic life especially, during peak coffee processing season (dry seasons). High levels of TDS, conductivity, BOD, COD and turbidity were observed in the peak coffee processing season as compared to the rainy season in Gidabo River these, could be attributed from wet coffee industrial practices.

Even though, both point and non-point sources of pollution beside the natural factors affect the quality, the river quality is mainly influenced by effluents from wet coffee processing industries which are located at the source of the river and its tributaries. The results of this study revealed significant environmental impact of study sites due to the effluent of processing industries. Thus, the measurements of physicochemical parameters indicated that the wet coffee processing can be considered as one of the main anthropogenic activities mainly affect the water quality of the study area. However, the intensity of these effects is rather seasonal. It was observed that the concentrations of pH, TDS, BOD, Turbidity, COD, EC, DO, NO_3^- and PO_4^{3-} in water samples showed statistically significant seasonal variations in 95% confidence level which shows, that the hypothesis of the study was accepted with acceptable 5% acceptable error. The physicochemical parameter analysis of shallow well water indicates that the parameters like: turbidity, salinity and DO have significantly different on spatial variation. Whereas, the rest of the parameters were not, significantly influenced by the location. These revealed that the well water was not significantly affected by waste effluent in this season. While, the parameters concentration remained high during the dry season for surface water due to low river flow and high pollutant load in peak processing time as compared to the rainy season. It is absolute that the seasonal analysis of the water bodies around that all the parameters like: pH, BOD, COD, TDS, Turbidity, phosphate and nitrate were much more than the prescribed the threshold limits by National standards.

Consequently, river pollution is largely dependent on the industrial activities in the area which indicates that the management of effluent discharge from those industries indirectly controls the river pollution in Gidabo watershed. The seasonal effect may affect the self-purification capacity of receiving rivers and the recovery this may alter its ecology in general.

5.2 Recommendations

The acidity of untreated water needs to be lifted to at least pH 6 or 7, before discharge into natural water ways without threatening aquatic life. Considering the low cost and ease of supply of natural limestone, $CaCO_3$, it seems the best solution to neutralize coffee waste water. After good mixing of limestone and acid water, the pH of the coffee waste water will automatically stabilize at a pH of 6.1 leaving any excess limestone unchanged. Burnt lime, (Calcium Oxide, CaO) and slaked limestone or Calcium hydroxide ($Ca(OH)_2$,) are not appropriate as they are not automatically buffering, and the danger to create excessively alkali conditions with too high pH values is too great. Even though, the water under the crust of mucilage in pond appears clear, the water is still acidic and has high COD and COD values. Later the remaining organic materials in the water have to be broken down after neutralizing the water. The concentration of BOD value in wastewater effluent have be reduced to less than 200 mg/L before let into natural waterway (Von Enden et al, 2002).

To prevent out flow of wastewater to surrounding area and the reverse process, separation of solid waste and liquid was necessary in addition to well-structured and constructed lagoons are need for all stations.

Moreover the following recommendations shall be implemented to mitigate the observed environmental problems and sustain the service and goods provided by the catchment:

- Create awareness of the people on the effect and create motivation to control, it is better to give opportunity to solve the problem by themselves by showing possible options
- Stake holder involvement in environmental safe guarding project
- Cooperation between expert, researcher and community in all especially in application of new technologies.

- Change the waste product of coffee to use full product mainly by creating pilot of biogas, organic fertilizer, animal feed and others
- By far there must be legal enforcement of laws to treat wastewater from the industry by itself.

There need monitoring mechanisms for organic load, total dissolved solids, pH, phosphorus, nitrate, and ammonia (nitrogenous compounds) downstream in Gidabo River both in the dry and wet season. To investigate the seasonal effect and direct effect of coffee effluent on well water in the area the peak season parameters have to be studied.

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APPENDIX

Biochemical Oxygen Demand (BOD)

Standard method Apparatus:

1. 300 ml BOD bottles
2. 20 ^{o}C incubator
3. DO meter
4. Burette

Preparation of dilution water was done. Two liters volume of water in a suitable bottle and add 1 mL each of phosphate buffer, MgSO4, $CaCl_2$, and $FeCl_3$ solutions/L of water. pH should be 7.2 stored in refrigerator

a. the sampled water is cheeked from free of chlorine.

b. Needs to be in the pH range of 6.5 - 7.5

Procedures

1. The BOD bottles designed to allow full filling with no air space and provide an airtight seal are used.

2. The bottles are filled with the sample to be tested or dilution (distilled or deionized) water and various amounts of the wastewater sample are added to reflect different dilutions.

3. At least one bottle is filled only with dilution water as a control or "blank."

4. A DO meter is used to measure the initial dissolved oxygen concentration (mg/L) in each bottle

5. Each bottle in then placed into a dark incubator at 20°C for five days.

6. After five days of incubation the DO meter is used again to measure a final dissolved oxygen concentration (mg/L)

7. The final DO reading is then subtracted from the initial DO reading and the result is the BOD concentration (mg/L).

If the wastewater sample required dilution, the BOD concentration reading is multiplied by the dilution factor.

BOD_5 (in mg/L) = (DO_i - DO_f) D_f

Where: $BOD_{5=}$ biochemical oxygen demand after five days

DO_i= initial dissolved oxygen concentration of the prepared solution (mg/l)

DO_f = dissolved oxygen concentration of the prepared solution after five days of Incubation (mg/l)

$$Df = \text{dilution factor} = \frac{\text{Bottle volume (300mL)}}{\text{Sample Volume}}$$

Chemical Oxygen Demand (COD) Determination

The Chemical Oxygen Demand (COD) is defined as the oxygen required for the water sample for the oxidation of organic and inorganic matter with a strong oxidizing agent in acidic medium. It is an indication of total oxidizable material present in water. It determines the quantity of oxygen required to oxidize the organic matter in a waste sample, under specific conditions of oxidizing agent, temperature, and time. The organic matter present in waste water is often assessed in terms of oxygen required to completely oxidize the organic matter to CO_2, H_2O and other oxidized species. If the organic compounds and their concentration are known the oxygen demand of the sample can be accurately computed but it is impossible to know the details of organic compounds Present in raw water or waste water. Since the test utilizes a specific chemical oxidation the result has no definite relationship to the Biochemical Oxygen Demand (BOD) of the waste or to the Total Organic Carbon (TOC) level. The test result should be considered as an independent measurement of organic matter in the sample.

Principle

Water sample is refluxed in strong acidic solution with a known excess amount of potassium dichromate.

After digestion, the remaining unreduced $K_2Cr_2O_7$ is titrated with Ferrous Ammonium Sulfate (FAS) to determine $K_2Cr_2O_7$ consumed.

This gives us the oxidizable organic matter in terms of oxygen equivalent.

Apparatus

- Clean 500 mL standard burrete
- Volumetric(Refluxing) flask 250 mL
- Conical flask 250 mL
- Funnel
- Test tube holder
- Pipette

Reagents

- Distilled water: Special precautions should be taken to insure that distilled water used in this test be low in organic matter.
- Standard potassium dichromate solution (0.250 N): Dissolve 12.25 g $K_2Cr_2O_7$, primary standard grade, previously dried at 103 °C for two hours, in distilled water and dilute to 1000 mL
- Sulfuric acid reagent: Conc. H_2SO_4 containing 23.5 g silver sulfate, Ag_2SO_4, per 4.09 kg bottle. With continuous stirring, the silver sulfate may be dissolved in about 30 minutes.
- Standard ferrous ammonium sulfate (0.25 N): Dissolve 98 g of Fe $(NH_4)_2(SO_4)_2$ $6H_2O$ in distilled water. Add 20 mL of conc. H_2SO_4 cool and dilute to 1 liter. This solution must be standardized daily against standard $K_2Cr_2O_7$ solution
- Standardization: To approximately 200 mL of distilled water add 25.0 mL of 0.25 N $K_2Cr_2O_7$ solutions. Add 20 mL of H_2SO_4 and cool.
- Mercuric sulfate: Powdered $HgSO_4$ or Silver sulfate: Powdered Ag_2SO_4

- Phenanthroline ferrous sulfate (ferroin) indicator solution
- Titrate with ferrous ammonium sulfate using 3 drops of ferroin indicator .The color change is sharp, going from blue-green to reddish-brown.

Calculation

Calculate the COD in the sample in mg/L as follows:

$$\text{COD mg/l} = \frac{(A-B)*N*8000}{\text{ml sample taken}}$$

Where:

A = milliliters of Fe $(NH_4)_2(SO4)_2$ solution required for titration of the blank,

B = milliliters of Fe $(NH_4)_2(SO4)_2$ solution required for of the sample,

N = normality of the Fe $(NH_4)_2(SO4)_2$ solution, and

$$\text{Normality} = \frac{(\text{mL of } K_2Cr_2O_7)\ (0.25)}{\text{mL of Fe } (NH_4)_2\ (SO4)_2}$$

Summary of Method

Organic and oxidizable inorganic substances in the sample are oxidized by potassium dichromate in 50% sulfuric acid solution at reflux temperature. Silver sulfate is used as a catalyst and mercuric sulfate is added to remove chloride interference. The excess dichromate is titrated with standard ferrous ammonium sulfate, using ferroin indicator solution. The result is expressed in milligrams per litre (mg/L) also referred to as ppm (parts per million), which indicates the mass of oxygen consumed per litre of solution (EPA, 1974).

Test for Nitrate – Nitrogen

Total oxidized nitrogen is the sum of nitrate & nitrite nitrogen. Nitrate generally occurs in trace quantities in surface water but may obtain high levels in some groundwater. The range of concentration of nitrate determines the method used for measurement nitrate – nitrogen. Nitrates are normally present in natural, drinking and wastewaters. Nitrates enter water supplies from the breakdown of natural vegetation, the use of chemical fertilizers in modern agriculture and from the oxidation of nitrogen compounds in sewage effluents and industrial wastes.

Apparatus:

- Palintest Nitratset Tube
- 20 ml (PT 508)
- Palintest Photometer
- Round Test Tubes
- 10 ml (PT 515) and watch

Reagents:

- Palintest Nitratest Powder
- Palintest Nitratest Tablets,
- Palintest Nitricol Tablets

Procedure:

1. Fill the Nitratest tube with sample to the 20 ml mark.

2. Add one level spoonful of Nitratest powder and one Nitratest tablet.

Do not crush the tablet. Replace screw cap and shake tube well for one minute.

3. Allow tube to stand for about one minute, then gently invert three or four times to aid flocculation. Allow tube to stand for two minutes or longer to ensure complete settlement.

4. Remove screw cap and wipe around the top the tube with a clean tissue. Carefully decant the clear solution in around test tube, filling to the 10 ml mark.

5. Add Nitricol tablet, crush and mix to dissolve.

6. Stand for 10 minutes to allow full color development.

7. Select wavelength 570 nm on photometer.

8. Take photometer reading in usual manner.

Low rage Phosphate Determination (EPA, 1975)

Apparatus: - Palintest Photometer, Round test tubes, 10 ml glass (PT 515), watch

Reagents: - Palintest Phosphate No 1 and 2 LR Tablets.

Procedure:

1. Fill the test tube with the sample to the 10ml mark.

2. Add one phosphate no 1 LR tablet, crush and mix to dissolve.

3. Add one phosphate no 2 LR tablet, crush and mix to dissolve.

4. Stand for 10 minutes to allow full color development.

5. Select wavelength 640nm on the photometer.

6. Take photometer reading in the usual manner.

7. Consult phosphate LR calibration chart.

Table 4. 3 Location and seasonal interaction effect on physicochemical parameters

Dependent Variable	location	Season	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
pH	Upstream	Rainy	7.050[b]	.234	6.477	7.623
		Dry	5.080**a**	.234	4.507	5.653
	Middle stream	Rainy	7.150[b]	.234	6.577	7.723
		Dry	5.000[a]	.234	4.427	5.573
	Downstream	Rainy	7.450[b]	.234	6.877	8.023
		Dry	4.600[a]	.234	4.027	5.173
Temperature	Upstream	Rainy	22.100[a]	.714	20.353	23.847
		Dry	25.500[b]	.714	23.753	27.247
	Middle stream	Rainy	20.950 [b]	.714	19.203	22.697
		Dry	17.050 [a]	.714	15.303	18.797
	Downstream	Rainy	19.550 [a]	.714	17.803	21.297
		Dry	18.300 [a]	.714	16.553	20.047
TDS	Upstream	Rainy	47.150 [a]	18.206	2.600	91.700
		Dry	519.700 [b]	18.206	475.150	564.250
	Middle stream	Rainy	27.150 [a]	18.206	-17.400	71.700
		Dry	309.250 [b]	18.206	264.700	353.800
	Downstream	Rainy	30.150 [a]	18.206	-14.400	74.700
		Dry	372.050 [b]	18.206	327.500	416.600

EC	Upstream	Rainy Dry	67.000 [a] 747.250 [b]	25.709 25.709	4.093 684.343	129.907 810.157
	Middle stream	Rainy Dry	37.650 [a] 445.050 [b]	25.709 25.709	-25.257 382.143	100.557 507.957
	Downstream	Rainy Dry	43.950 [a] 533.550 [b]	25.709 25.709	-18.957 470.643	106.857 596.457
DO	Upstream	Rainy Dry	8.025 [b] -9.7E-016 [a]	.124 .124	7.722 -.303	8.328 .303
	Middle stream	Rainy Dry	7.520 [b] .005 [a]	.124 .124	7.217 -.298	7.823 .308
	Downstream	Rainy Dry	7.105 [b] .005 [a]	.124 .124	6.802 -.298	7.408 .308
Turbidity	Upstream	Rainy Dry	226.000 [a] 481.500 [b]	34.485 34.485	141.619 397.119	310.381 565.881
	Middle stream	Rainy Dry	56.900 [a] 70.300 [a]	34.485 34.485	-27.481 -14.081	141.281 154.681
	Downstream	Rainy Dry	70.600 [a] 168.150 [b]	34.485 34.485	-13.781 83.769	154.981 252.531
BOD	Upstream	Rainy Dry	10.400 [a] 323.000 [b]	60.107 60.107	-136.676 175.924	157.476 470.076
	Middle stream	Rainy Dry	8.040 [a] 374.000 [b]	60.107 60.107	-139.036 226.924	155.116 521.076
	Downstream	Rainy	6.210 [a]	60.107	-140.866	153.286
		Dry	473.0 [b]	60.107	325.924	620.076
COD	Upstream	Rainy Dry	90.350 [a] 2664.000 [b]	586.030 586.030	-1343.615 1230.035	1524.315 4097.965
	Middle stream	Rainy Dry	33.250 [a] 1918.500 [b]	586.030 586.030	-1400.715 484.535	1467.215 3352.465
	Downstream	Rainy Dry	56.250 [a] 3282.500 [b]	586.030 586.030	-1377.715 1848.535	1490.215 4716.465
Nitrate	Upstream	Rainy Dry	4.490 [a] 172.500 [b]	15.173 15.173	-32.636 135.374	41.616 209.626
	Middle stream	Rainy Dry	2.700 [a] 115.000 [b]	15.173 15.173	-34.426 77.874	39.826 152.126
	Downstream	Rainy Dry	2.350 [a] 80.000 [b]	15.173 15.173	-34.776 42.874	39.476 117.126
Phosphate	Upstream	Rainy Dry	.520 [a] 31.250 [b]	3.994 3.994	-9.254 21.476	10.294 41.024
	Middle stream	Rainy Dry	.405 [a] 8.125 [a]	3.994 3.994	-9.369 -1.649	10.179 17.899
	Downstream	Rainy Dry	.280 [a] 4.375 [a]	3.994 3.994	-9.494 -5.399	10.054 14.149

*Seasonal mean values under the respective location given different superscript are significantly different

Existing situation, observed

It is observed that the turbidity of river water is high due to erosion in rainy season.

Fig 4. 11: high turbidity due Erosion in rainy season and the a waste water

Table 4. 4 Two-way ANOVA table showing significant seasonal difference

Dependent Variable	season	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
pH	Rainy	7.217[b]	.135	6.886	7.548
	dry	4.893[a]	.135	4.562	5.224
Temperature	Rainy	20.867[a]	.412	19.858	21.875
	dry	20.283[a]	.412	19.275	21.292
TDS	Rainy	34.817[a]	10.511	9.096	60.537
	dry	400.333[b]	10.511	374.613	426.054
EC	Rainy	49.533[a]	14.843	13.214	85.853
	dry	575.283[b]	14.843	538.964	611.603
DO	Rainy	7.550[b]	.071	7.375	7.725
	dry	.003[a]	.071	-.172	.178
Turbid	Rainy	117.833[a]	19.910	69.116	166.551
	dry	239.983[b]	19.910	191.266	288.701
BOD	Rainy	8.217[a]	34.703	-76.698	93.131
	dry	390.000[b]	34.703	305.085	474.915
COD	Rainy	59.950[a]	338.345	-767.950	887.850
	dry	2621.667[b]	338.345	1793.767	3449.567
N	Rainy	3.180[a]	8.760	-18.255	24.615
	dry	122.500[b]	8.760	101.065	143.935
P	Rainy	.402[a]	2.306	-5.241	6.044
	dry	14.583[b]	2.306	8.941	20.226

*The mean values under the respective season given different superscript letters are significantly different