Addis Ababa University
School of Graduate Studies
College of Natural Science
Environmental Science Program

COMPARISON OF THE QUALITY OF WASTEWATER FROM CONVENTIONAL AND ADVANCED WET COFFEE PROCESSING PLANTS NEAR JIMMA, ETHIOPIA

By

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University College of Natural Science in Partial Fulfillment of the Requirements for the Degree of Master of Science in Environmental Science Program

Advisor: Fisseha Itanna (PhD)

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Examiners

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May 2011

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List of Abbreviations and Acronyms

a.s.l	Above Sea Level
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CTA	Coffee and Tea Authority
DO	Dissolved Oxygen
EIAR	Ethiopian Institute of Agricultural Research Center
ECIUT	Ethiopian Coffee Initiative Update Technoserve
EEPA	Ethiopian Environmental Protection Agency
ICO	International Coffee Organization
ITC	International Trade Center
JARC	Jimma Agricultural and Research Center
NMA	National Metrological Agency
NTU	Nephelometric Turbidity Unit
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
µS/Cm	micro Seimens per centimeter
WEF	Water Environment Federation

Abstract

The purpose of this study was to characterize and compare wastewater released from conventional and advanced wet coffee processing plants near Jimma. Sampling from raw water and wastewaters were done for both technologies. The water quality parameters used to investigate profiles of the raw water and wastewater from the conventional and advanced wet coffee processing plants were COD, BOD_5, DO, NH_3, PO_4^{3-}, NO_3^--N, pH, TSS, TDS, conductivity, and turbidity. The mean results obtained from conventional wet coffee processing plants were BOD_5 (1697 mg/L), COD (5682.5 mg/L), TSS (1975 mg/L), TDS (1800.75 mg/L),respectively and pH was 4.13. The conventional wet coffee wastewater BOD_5, COD, pH and TSS did not comply with Ethiopian permissible discharge limit standards whereas mean values of wastewater from advanced wet coffee processing plants for BOD_5, COD, pH, and TSS were 2687 mg/L, 3567 mg/L, 6.69, and 282.42 mg/L, respectively. Eventhough there was significant variation among conventional and advanced wet coffee processing plants; advanced wet coffee processing plants were also did not meet Ethiopian permissible discharge limit standards for BOD_5, COD and TSS. Therefore, establishment of wet coffee processing wastewater treatment system and regular monitoring is necessary to safeguard the environment from pollution.

Key words: Advanced, Comparison, Conventional, Wastewater, Wet Coffee Process,

1. Introduction

1.1 Background

Coffee is the most important agricultural commodity used for beverage enjoyed throughout the world. Coffee is cultivated and exported as raw, roasted or soluble product to more than 165 countries worldwide providing a livelihood for an estimate of some 100 million people in the world (ICO, 2004, Mekonen Hailemichael, 2009). Many countries are involved in coffee production, trade, communication and it is estimated that, about 125 countries export and re-export coffee products. In addition, about 50 developing countries are earning 25% of their foreign exchange from coffee (CTA, 1999; ITC, 2002; Mekonen Hailemichael, 2009).

Ethiopia is the largest country producing *Arabica coffee* and an original home of coffee along with the highest diversity in its genetic resource (ITC, 2002, Alemayehu Haddis and Rani, 2008) Coffee plant was originally found and cultivated in Kafa 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. Then it spread to the whole Europe (Adams, 1980, Alemayehu Haddis and Rani, 2008).

After harvesting, coffee can be processed in two ways; these are dry (natural) processing and wet (washed) processing. Wet processing is held with the help of water, especially to remove the outer red skin and the white fleshy pulp (Wintgens, 2009). In addition, the amorphous gel of mucilage around the beans is removed by fermentation. Previous studies have been conducted on conventional coffee processing plants and effluent characterization around Jimma Ethiopia. The results showed high biological oxygen demand (BOD_5), chemical oxygen demand (COD), phosphate, nitrate, suspended solids, dissolved solids and low pH (JARC and EIARC, 2007).

Wet coffee processing can be done in conventional system, as most of the processing plants do in Ethiopia. The advanced way is currently being practiced at some parts of the country. These technologies are expected to increase the quality of the product moreover, safeguard the environment from pollution (ECIUT, 2010). However, the potential of these advanced systems in achieving the required standard is to be evaluated.

1.2 Statement of the problem

After harvesting, coffee is processed in dry and wet system. The dry one is processed using solar energy whereas wet processing is held with the help of water to remove the outer red skin and the white fleshy pulp. Wet coffee processing plants may produce wastewaters that are not in compliance with the standards; then contributing to tremendous pollution (Wintgens, 2009).

Depending on previous studies recommendation, modern way of wet coffee processing is practiced in some parts of Jimma zone in order to produce wastewater that has no effect on the environment (ECIUT, 2010). However; no studies have been conducted regarding the evaluation of the modern wet coffee processing potential in terms of set standards. Previous studies have been conducted specific to conventional coffee processing plants. However, this study deals with the characteristics of both technologies wastewater effluent in order to examine the effluent wastewater quality by comparing with the available standards.

1.3 Scope of the study

A detailed characterization of conventional and advanced wet coffee processing raw and effluent wastewater samples were analyzed in order to determine their contribution in terms of pollution to receiving water body. In addition to wastewater characterization, raw water sampling and characterization was also done. Characterization of raw water attributed to examine the influent concentrations, which revealed to assess either the effluent level is reduced or increased from the raw water concentrations. This also provides understanding of conventional and advanced wet coffee processing units for determination of which one undertake more environmental friendly process

1.4 Significance of the study

The outcome of this study will provide data about conventional and modern coffee processing plants raw water and wastewater. Hence, the study also not only gives additional information on the characteristics of the effluents generated from advanced wet coffee processing system plants, but also to shed some light on the dilemma on the potential of the advanced plants in meeting the standards.

1.5 Objectives

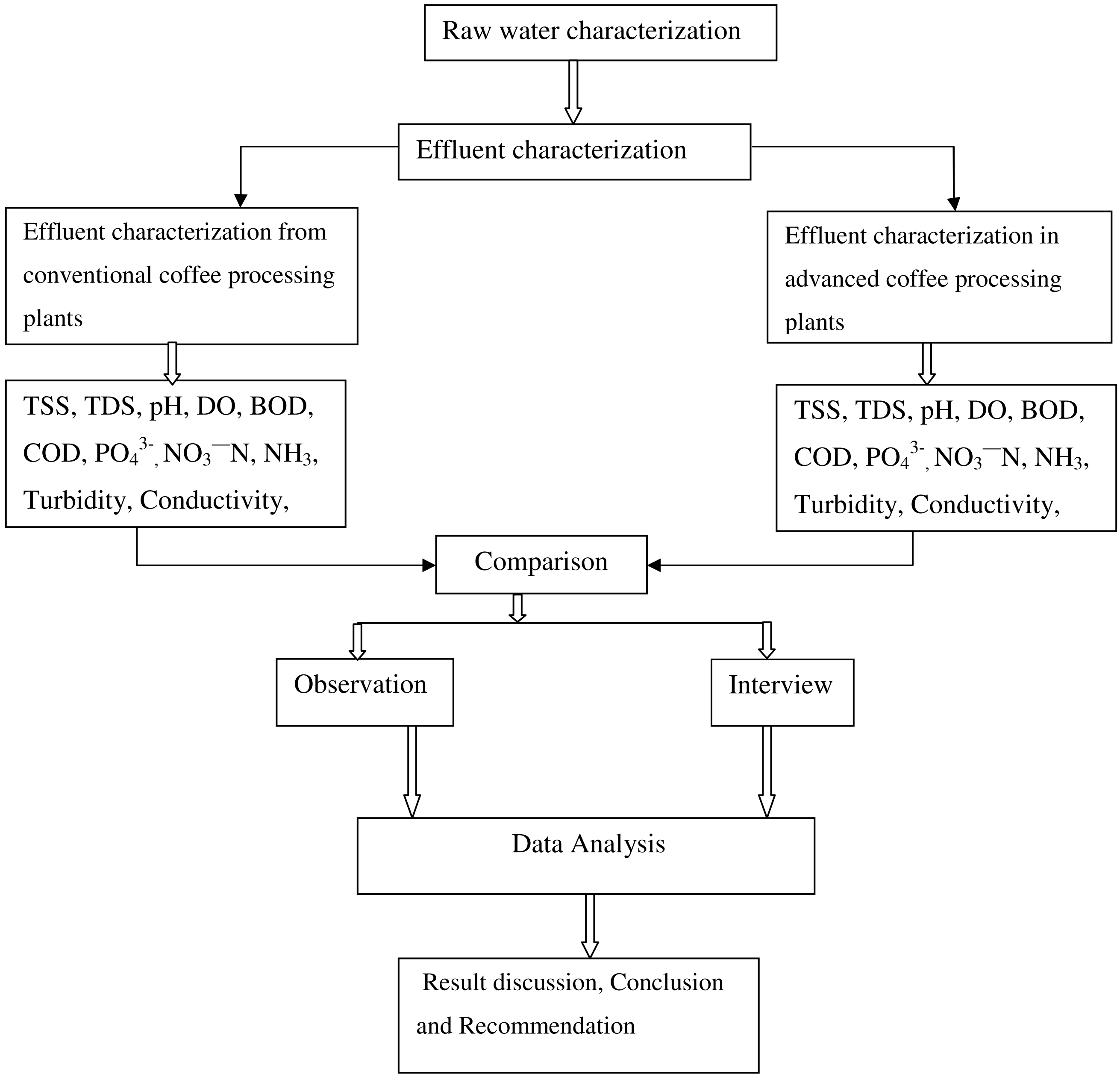
1.5.1 General objective

The overall purpose of this study is to characterize wastewater released from conventional and advanced coffee processing plants by analyzing physico-chemical parameters and examining existing situations through observation and interviews near Jimma.

1.5.2 Specific objectives

- To characterize raw water and effluent wastewater of the two processing plants.
- To compare and contrast the effluents generated from the conventional plants with that of the advanced ones.
- To compare the effluent wastewater of both technologies with available permissible discharge standards.

Fig 1.1 Conceptual frame work of study



2. Literature Review

2.1 Water pollution

Water is used for navigation; as a coolant, cleanser, and diluting; for recreational purposes; as a food resource; as a means of power; as a source of tranquil aesthetic enjoyment; as a transporter of disease; as a container for nuisances; and finally, as the once unlimited area for disposal of society's waste products. It is indeed a wonderful chemical medium which has unique properties of dissolving and carrying in suspension huge varieties of chemicals. Thus it can get contaminated easily. Much of water pollution is due to anthropogenic activities (Santra, 2001).

Generally, water pollution is caused by the presence of some organic, inorganic, biological, radiological or physical foreign substances in the water that tend to degrade its quality. The presence of undesirable and hazardous material and pathogens beyond certain limit will also cause water pollution (Narayanan, 2007).

2.2 Source of wastewater

Commercial, industries, agricultural and domestic activities are the main causes for water pollution. Nature and impact of wastewater to the receiving environment depends on its flow and quality characteristics. The volume of wastewater varies from country to country depending on standard of living and the availability of water supplies (Santra, 2001).

2.3 Characteristics of wastewater

Wastewater quality can be defined by physical, chemical, and biological characteristics. Physical parameters include color, odor, temperature, solids, turbidity, oil, and grease. Solids can be further classified into suspended and dissolved solids as well as organic (volatile) and inorganic (fixed) fractions. Chemical parameters associated with the organic content of wastewater include the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), and Total Oxygen Demand (TOD) (Manahan, 2001). BOD_5 is used to know the organics present in the water and determined by measuring the oxygen necessary to biostabilize. Inorganic chemical parameters include pH, acidity, nutrients and the like (Carl *et al.,* 1999).

2.3.1 Physical and Chemical Characteristics

2.3.1.1 Turbidity

Turbidity inhibits light transmissions in the water. In the sense that light transmission is inhibited, is known as turbid. Turbidity is undesirable for many reasons some are: aesthetic considerations, solids may contain, pathogens or other contaminants. Turbidity is the presence of suspended materials such as clay, silt, finely divided organic material, plankton, and other inorganic material. Turbidity, although not a hazard itself, may be an indication that pollution has been introduced into the water bodies (Nicholas, 2002). In wastewater turbidity is used as an indicator of the reduction of light due to haze, smoke and other particles (James and Edward, 2006).

2.3.1.2 Solids

Water pollution can occur by the dissolved and suspended materials it contains. Both dissolved and suspended materials are called solids.TSS includes any material left in a container after the water is removed by evaporation. Suspended solids are visible and in suspension in water (Ruth and Robin, 2003). Suspended solids include volatile and fixed solids. Suspension of suspended solid is governed by the upward components of turbulence, currents, or colloidal suspension. It can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment (Takash and Davi, 2002). Solids in the water that remain after filtration and evaporation as residue are called total dissolved solids (TDS) and used as indicator of water quality. TDS may be organic or inorganic and may cause physiological effects, as well as color, taste, and odor problems (Joanne, 2001).

2.3.1.3 pH

pH indicates the intensity of acidity or alkalinity in water, and affects biological and chemical reactions. Water's chemical balance (equilibrium relationships) is strongly influenced by pH (UFC, 2004). The pH of a solution is a measure of hydrogen (H^+) ion concentration, which is a measure of acidity. An excess of hydrogen ions makes a solution acidic (Roger, 1994).Low pH value inhibit biological wastewater treatment by hindering micro-organisms growth (Irene, 1999).

Acidity affects the population of aquatic life in several ways. As the pH of the water bodies decreases, it alters the delicately balanced working of the internal system of the organisms whose habitat is in and around water bodies. When the pH drops to 5.5, most species do not lay eggs at normal levels. By a pH drop to 4.5, most species are endangered because of reproductive failures (Herman and Michael, 2003).

2.3.1.4 Dissolved Oxygen (DO)

DO is the actual amount of oxygen available in dissolved form in the receiving water. 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. Oxygen, although poorly soluble in water, is fundamental to aquatic life. Without free dissolved oxygen, streams and lakes become uninhabitable to aerobic organisms, including fish and most invertebrates.

2.3.1.5 Nutrient

2.3.1.5.1 Nitrogen

Nitrogen occurs in five major forms in aquatic environments: organic nitrogen, ammonia, nitrite, nitrate, and dissolved nitrogen gas. Ammonia is one of the intermediate compounds formed during biological metabolism and, together with organic nitrogen, is considered an indicator of advanced pollution. Aerobic decomposition of organic nitrogen and ammonia eventually produces nitrite and finally nitrate (Joanne, 2001). High nitrate concentrations, therefore, may indicate that organic nitrogen pollution occurred far enough upstream that the organics have had time to oxidize completely. Ammonia converts to Nitrate under certain condition of excess oxygen. This process is known as Nitrification whereas the conversion of nitrate to nitrogen gas is known as denitrification, which requires the presence of denitrifying bacteria (Marcel, 2006). Both nitrification and denitrification require ideal conditions for the most favorable results, and may occur in the same tank, but at different times and in different environments. The principal ingredients required for nitrification and denitrification are sufficient oxygen levels and adequate bacterial concentrations (DAUSCE, 1999). As a result; ammonia creates additional DO, which further increases the BOD_5. Ammonia and organic nitrogen are pollution indicators.

2.3.1.5.2 Phosphorus

The sources of phosphorus are several: human excreta in water carried wastes; food residues from households, commercial and recreational establishments and restaurants; water treatment additives; detergents, both domestic and commercial; and from agricultural activities through sewer or manhole infiltration. The nutrient phosphorous mainly occurs in solution as particles or waste elements in microorganism, the most common forms are: orthophosphates ($PO4^{3-}$, $HPO4^{2-}$, H_2PO4^-, and H_3PO4^-); polyphosphates ($P_2\ O_7$) (DAUSCE, 1999). Phosphorus can be found in both plants and animals. As in the case of the nitrogen forms ammonia, nitrite and nitrate, orthophosphates can also cause eutrophication in receiving streams (Arcadio and Gregoria, 2003).

Though phosphorus is essential for life, it may become toxic when found in high level. Under natural conditions, nutrient input into a water body occurs slowly over a period of many years. This leads to its eutrophication, a process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears. After nutrients reach a certain concentration, the water becomes choked with plant life. Algal “blooms” may form a scum on the water surface, produce offensive smells, give the water a bad taste, and uncomfortable for human use. Human activities can put eutrophication on fast forward by rapidly discharging large amounts of nutrients (especially nitrate and phosphorus) into water (Marquita, 2010). A final step results when the water DO becomes greatly depleted or eliminated. At that point, it becomes a dead zone. Thus, concentrations of orthophosphates should be controlled through removal before discharging the wastewater into receiving bodies of water.

2.3.1.6 Biological Oxygen Demand

Wastewater quality can be defined by physical, chemical, and biological characteristics. Chemical parameters associated with the organic content of wastewater include the biochemical oxygen demand (Jan, 2008). BOD_5 is a measurement that allows comparing the relative polluting strength of different organic substances. This method attempts to replicate the oxidation condition found in the natural environment (Roger, 1994).

According to (Ronaldo *et al.*, 2006), oxygen demand is the measurement of amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter. That part of oxygen demand associated with biochemical oxidation of carbonaceous, as distinct from nitrogenous, material. Biological oxygen demand could be determined by allowing biochemical oxidation to proceed, under conditions specified in standard methods, for 5 days (DAUSCE, 1999). Biochemical Oxygen Demand (BOD_5) is amount of oxygen required to decompose a given amount of organic material. Water ordinarily contains some natural BOD_5 such as plant debris and wildlife feces. High BOD_5 reduces or depletes the DO in water (Marquita, 2010).

2.3.1.7 Chemical Oxygen Demand

The chemical oxygen demand (COD) test has been used to measure the oxygen equivalent content of a given waste by using a chemical to oxidize the organic content of the waste. The higher the equivalent oxygen content of a given waste, the higher is its COD and the higher is its polluting potential. The COD test normally yields higher oxygen equivalent values than those derived using the standard BOD_5 test, because more oxygen equivalents can always be oxidized by the chemical than can be oxidized by the microorganisms (Arcadio and Gregoria, 2003).

BOD_5 and COD are widely used as measures of oxygen demand. 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).

COD is usually higher than the BOD_5 of the water. Testing the amount of oxygen by chemical oxygen demand is relatively rapid than Biological Oxygen Demand. The test does not oxidize some organic pollutants like toluene. However; the system oxidizes inorganic compounds that are not measured in the BOD_5 analysis (Nelson *et al.,* 2009). Chemical oxygen demand used to measure pollutants causing oxygen demand. These pollutants deplete the DO in the water bodies. Loss of dissolved oxygen creates difficulties in the stream (Herman and Michael, 2003) .

2.4 The effect of agricultural activities on water pollution

Pollution of environment and its component may occur because of different activities. Coffee processing plants are one of the major agro-based industries which are responsible for water pollution. Agricultural wastes are typically high in nutrients (phosphorus and nitrogen), biodegradable organic matter, suspended solids and the like (Marquita, 2010). Nutrients, mainly nitrogen and phosphorus, can promote accelerated eutrophication, or the rapid biological "aging" of lakes, streams, and estuaries (Narayanan, 2007). Phosphorus adheres to inorganic sediments and is transported with sediments in storm runoff. Nitrogen tends to move with organic matter or is leached from soils and moves with groundwater (Ruth and Robin, 2003).

In many coffee processing countries the wastewater is disposed from pulping, fermentation and washing of coffee beans and presents series of problem on receiving environment especially on water bodies (Braham and Bressani, 1979).

2.4.1 Coffee Processing

After harvesting, coffee berries are taken to where coffee processing plants are found. There are two fundamental processing methods, Wet and Dry coffee processing. Waste products are generated from both methods (Braham and Bressani, 1979).

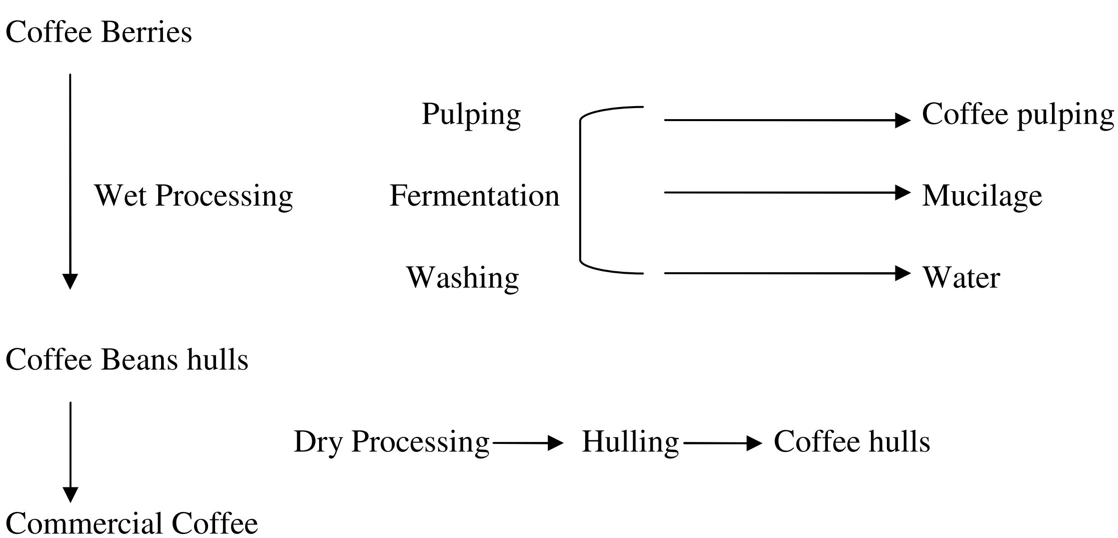


Fig 2. 1. Steps involved in coffee-berry processing and their by-products

2.4. 1.1 Wet coffee processing

Wet Coffee processing is widely accepted for selection of ripe coffee fruit which is essential for producing good quality coffee beans (Rodrigo, 2003). Wet processing step yields coffee pulp, mucilage, and waste waters on the one hand, and coffee beans with hulls on the other (Antonio *et al.,* 1999). There are conventional and advanced wet coffee processing methods. In the case of conventional wet coffee processing system, the coffee beans once separated from the pulp are transported by water to fermentation tanks for mucilage breakdown and removal. Fermentation time is varied depending on the altitude and temperature of processing sites. This process is almost anaerobic in nature, and carried out for 36-72 hr (Braham and Bressani, 1979).

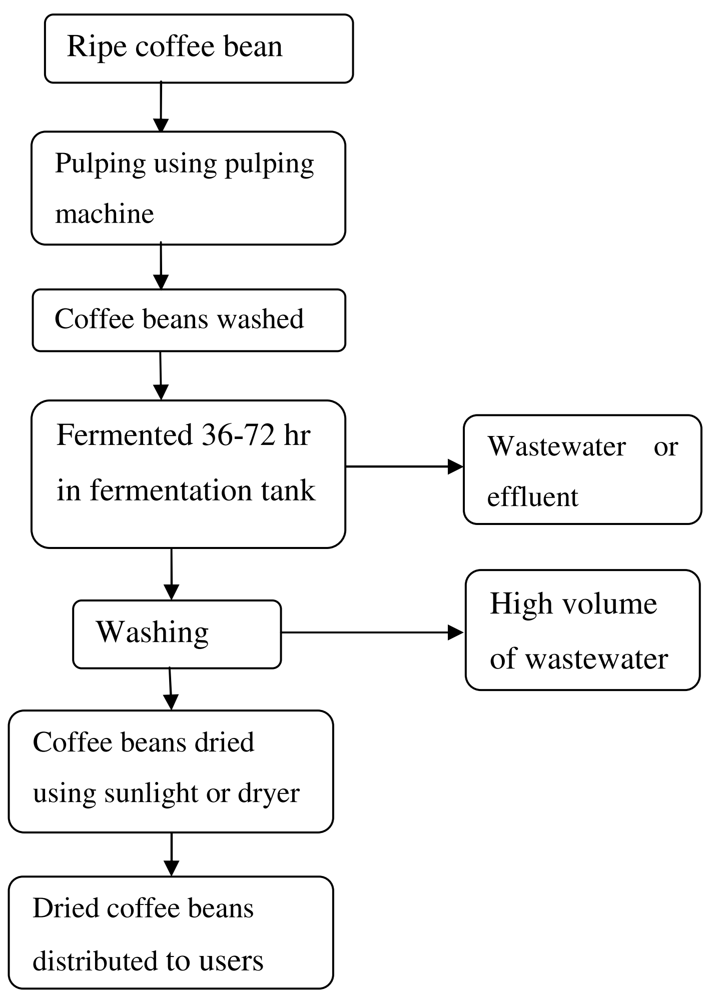


Fig 2. 2**.**Schematic representation of conventional wet coffee processing

Organic and acetic acids are formed from coffee mucilage as the result of fermentation of the sugars. This will make the wastewater very acidic (with pH as low as 3.8), a condition in which higher plants and animals can hardly survive (Antonio *et al*., 1999)

Advanced wet coffee processing plants follow the same procedure for pulping (removal of the outer skin from coffee bean). However; mucilage is removed by friction as the beans pass between a revolving perforated drum and an inner perforated tube with a counter flow of water. The products of this hydrolysis remain in the water.

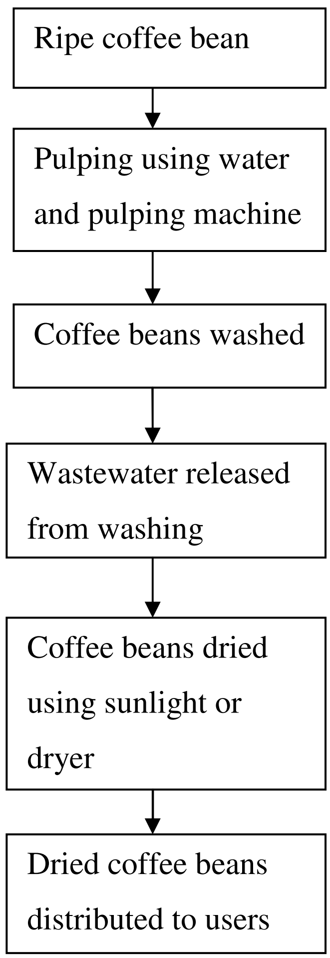


Fig 2. 3**.**Schematic representation of advanced wet coffee processing

2.4. 1.2 The Nature of Wastewater from coffee processing plants

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

Table 2.1 Effluent characteristics from conventional wet coffee processing plants in case of Jimma zone, Ethiopia**.**

Parameter	Mean value
Temperature (^{o}C)	25
pH	3.57
BOD_5	14,200
COD	25,600
TSS	5870
Phosphate	7.3
Nitrate	23

Source: (Alemayehu Haddis and Rani, 2008) All units are in mg/L unless indicated otherwise except pH

Wet coffee processing effluents are complex mixtures of chemicals, varying in composition over time and from system to system as well as on coffee diversity .Alemayehu Haddis and Rani, (2008) noted that, effluent from wet coffee processing plants are highly colored and acidic and contain non-biodegradable compounds, and are high in Biological and Chemical Oxygen Demand. Coffee wastewater had high concentrations of suspended solids, dissolved solids and elevated nutrient. Moreover, wet coffee processing usually has high amount of conductivity, lower dissolved oxygen and elevated amount of turbidity to nearby water bodies or receiving environment (JARC and EIARC, 2007).

Pollutants in coffee wastewater emerge from the organic matter set free during pulping especially due to the difficulty in degrading the mucilage layer surrounding the beans. Wastewater generated from coffee processing plants is acidic and plants and animals hardily survive when exposed to it. The sugars contained in the mucilage undergo fermentation process. The organic and acetic acids from the fermentation of sugars make the wastewater very acidic. The digested mucilage in the wastewater builds a crust on the surface, clogging up waterways and further contributing to anaerobic conditions. Mucilage and coffee pulp are made of different components.

Mucilage is composed of water, protein, sugar, pectic acid and ash (Vossen, 2005). Coffee pulp components are responsible for pollution of nearby water bodies and receiving environment. These components are, ether extract, crude fiber, crude protein, ash, nitrogen fiber extract, tannin, pectic substances, reducing sugars, and caffeine. In addition to coffee pulp mucilage it also plays a great role in water pollution.

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

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

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

Parameters	Water characteristics	
	Before	After
Temperature(^{o}C)	15	18
pH	6.5	5.15
BOD_5	120	7800
COD	176	9780
TSS	520	2880
Phosphate	2.3	4.1
Nitrate	4.0	7.5

Source: (Alemayehu Haddis and Rani 2008) All units are in mg/L unless indicated otherwise except pH

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

2.4.4 Application of Wastewater generated from wet coffee processing plants

If wastewater emanating from wet coffee processing plants is discharged into the natural water bodies without treatment, it will pollute (Salvamurugan *et al*., 2010). Wastewater generated from wet coffee processing plants composed of organic and inorganic compounds, nutrients like phosphorous and nitrogen (JARC & EIARC, 2007). However the amounts of these components are found to be above the permissible discharge limit. Well treated wastewater from these processing plants could be used for irrigation (Alemayehu Haddis and Ran, 2008).

2.5 Conventional vs. Advanced Wet Coffee processing plants

In the study sites there were two types of wet coffee processing plants. These are conventional and modern coffee processing plants. Depending on their processing system, wastewater generated varies in quality and quantity. Some of the two systems variation measures were wastewater quantity, organic load, pH and the like.

Depending on the processing technology applied, quantities of coffee wastewater are varying. Modern mechanical mucilage removal machines producing semi-washed coffee use about one m^3 per tonne fresh cherry (without finish fermentation and washing) whereas the conventional uses up to 20 m^3 per tonne cherry. According to (Selvamurugan 2010), about 80,000-93,000 liter water is required to process one tonne coffee using conventional system wet coffee processing pulper and washer.

As demand for raw water is increased, the amount of wastewater to be discharged also increases. This implies that pollution potential of the conventional wet coffee processing plants is higher comparing with advanced ones (Jan *et al*., 2002).

Conventional wet coffee processing system is sometimes called fully washed process while the advanced wet processing is known as semi-washed wet coffee processing. There are several steps in both systems. In case of traditional wet processing depulping removes the outer red part, but leaves a slimy coating of mucilage surrounding the bean. Fermentation allows microbial decomposition of this layer, after which it can be washed away. The time required for fermentation depends on ambient temperature, which is often determined by altitude in coffee growing areas (Noah, 2009).

According to coffee experts familiar with processing in Jimma zone Ethiopia, the time required may range from as little as twenty four hours in the hot lowlands to fourty eight hours in the cool highlands. Advanced wet coffee processing plants follow similar procedure as traditional wet coffee processing plants. The variation among the systems is fermentation. In this case mucilage separation from coffee bean is done mechanically. As the beans pass between a revolving perforated drum and an inner perforated tube, the mucilage is removed by friction with a counter flow of water (Braham and Bressani, 1979).

Wastewater from conventional system wet coffee processing plants is acidic when compared with advanced technology for several reasons. During the fermentation process in the effluents from pulpers, fermentation tanks and mechanical mucilage removers, sugars will ferment in the presence of yeasts to alcohol and CO_2. However, in this situation the alcohol is quickly converted to vinegar or acetic acid in the fermented pulping water. The other means that make wastewater from conventional wet coffee processing acidic are, long chain pectins split by enzymes (pectinase, pectase) into short chain pectin oligosaccharides. Oligosaccharides are soluble in alkaline and neutral solutions, but in acid conditions they are thrown out of solution as pectic acid (Jan *et al*., 2002).

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

3. Materials and Methods

3.1 Study area description

The study was conducted in Doyo, Seka, Geruke and Haro districts found in Jimma zone, around 12 km west of, 20 km south west, 25 km to east direction and around 15 km to south east of Jimma, respectively. Doyo and Seka are study areas where advanced coffee processing is practiced while Geruke and Haro are other study areas where conventional coffee processing plants exited. Jimma is located at 352 km away from Addis Ababa in south-west Ethiopia. Jimma lies between $7^{o}20' 0''$ N and $8^{o}55' 0''$ N latitude and $35^{o}45' 0'$E and 37^{o} $35' 0'$E Longitude Maximum annual temperature of Jimma zone is 27.5 ^{o}C whereas minimum annual temperature was 10.47 ^{o}C and annual rainfall was 495.6 mm (NMA, 2009).

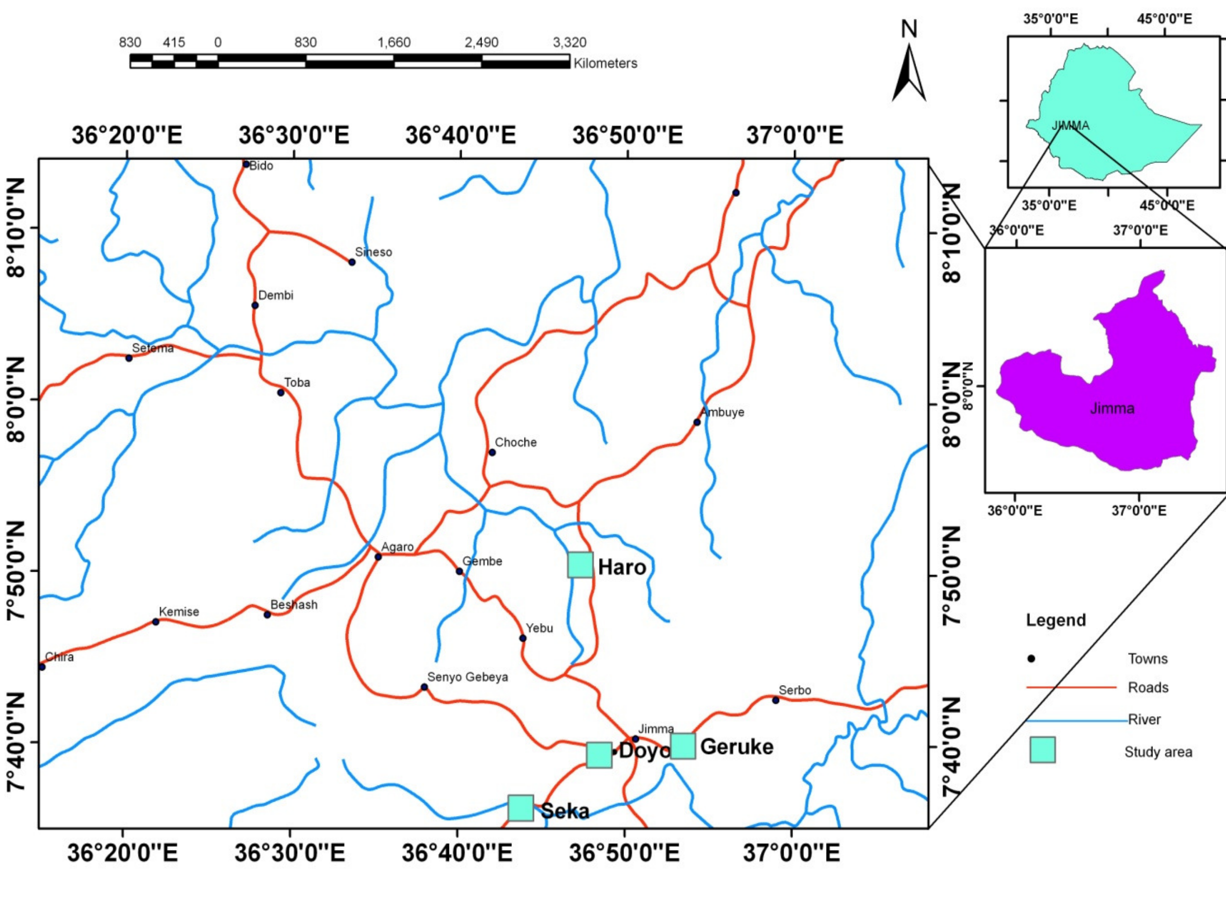
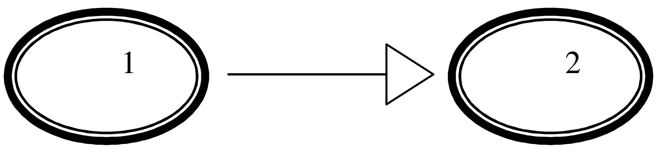


Fig 3. 1. location of the study areas

3.2 Study Design

A descriptive study was conducted in order to characterize and compare the effluent wastewater and influent water of conventional and advanced wet coffee processing plants in Jimma zone. In addition interview and observation was performed one for data gathering.

3.2.1 Sampling site for both conventional and advanced wet coffee processing plants



1 - raw water used for the processing

2 - effluent wastewater released from the processing plants**.**

3.2.2 Sampling Techniques

Samples were collected using polyethylene bottels (1000 ml) from each sampling sites for all four sampling areas for triplicate bassed on four days interval. Four day is determined for analyzing one day for each four sampling areas.Samples were analyzed for pH, TSS, TDS NH_3, NO_3^--N $^-$, PO_4^{3-} DO, BOD_5 COD, conductivity and turbidity

3.2.3 Interview

Twelve key informants were selected by purposive sampling techniques in order to gather detailed information through informal discussion. The criteria of selection for key informants were more approaching people for wet coffee processing and three people from each site. Questions during interviewing key informants:

- What is the major difference between advanced and conventional wet coffee processing?
- What is feasibility of recent technology in terms of economy, environment, and health?
- What are the impacts of wastewater released from wet coffee processing plants on water bodies?
- What is effect of polluted water bodies on local people when used for domestic purpose?

3.2.4 Observation

Observation was used during data collection period. Its main purpose was to observe the different environmental characteristics of the study area, some practice of the people with polluted rivers around coffee processing plants and existing condition of the environment around coffee processing. What people feel about the role of advanced wet coffee process and conventional one was also observed. During observation field notes were taken. This method was used for generating question during employing other tools. Observation points were:

- Source of raw water
- Impact of wastewater from conventional and advanced wet coffee processing plants effect on nearby environment
- Waste management systems of the two processing plants

3.3 Physical and Chemical properties measurements

3.3.1 pH, DO, Conductivity and Turbidity

pH ,DO, Conductivity and Turbidity were measured onsite during sampling using portable thermometer, pH meter ,DO meter , Conductivity and Turbidity meters , respectively from the raw water and wastewater effluent of conventional and advanced wet coffee processing plants

3.3.2 BOD_5

Preparation of dilution water was done. Two liters volume of water in a suitable bottle and add 1 mL each of phosphate buffer, $MgSO_4$, $CaCl_2$, and $FeCl_3$ solutions/L of water. From the prepared solution 299 mL of samples were sampled with1 mL sample added in incubation bottles having capacity of 300-mL and initial dissolved oxygen was measured using dissolved oxygen meter. Incubation for five days at 20 C^o was done that 300-mL whose initial dissolved oxygen measured. After five days final dissolved oxygen was measured.

Calculation

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

Where;

DOi = initial dissolved oxygen

DOf = final dissolved oxygen

Df = dilution factor

3.3.3 COD

COD was determined using reactor digestion method as follows

100 mL of the sample was homogenized using a blender for 30 seconds in order to mix settled solids then, 2 mL homogenized samples were added into K2Cr2O7 containing vials and blank was prepared by adding 2 mL of de-iodized water into another K2Cr2O7 contained. Vials of the sample and the blank were heated for 2 h in COD reactor at 150 ^{o}C and then the result (mg/L, COD) was read using a spectrophotometer after the vials were cooled at room temperature, while the blank was used as a reference for result reading.

3.3.4 TSS

TSS was measured using gravimetric method and described as follows;

First insert disk with wrinkled side up in filtration apparatus and apply vacuum and wash disk with three successive 20-mL portions of distilled water continue suction to remove all traces of water, and discard washing then remove filter from filtration apparatus along with the Gooch crucible, and dry in an oven at 103 to 105 ^{o}C for 1 hour.

Assemble filtering apparatus and filter and begin suction and wet filter with a small volume of distilled water to seat it then filter a measured volume of well mixed sample through the glass fiber filter and wash with three successive 10-mL volumes of distilled water, allowing complete drainage between washings and continue suction for about 3 minutes after filtration is complete Remove the crucible and filter combination from the crucible adapter if a Gooch crucible is used and dry for at least one hour at 103 to 105 ^{o}C in an oven, Cool in a desiccators to balance temperature, and weigh.

Calculation

$$\text{Mg suspended solids/L} = \frac{(A\text{-}B) \times 1000}{\text{ML sample}}$$

Where;

A= Weight of filter + dried residue, mg

B= Weight of filter, mg

3.3. 5 TDS

Filter measured 20 mL volume of well-mixed sample through glass-fiber-filter, wash with three successive 10-mL volumes of distilled water, allowing complete drainage between washings, and continue suction for about 3 minutes after filtration is complete. Transfer filtrate to a weighed evaporating dish and evaporate to dryness on a steam bath if filtrate volume exceeds dish capacity successive portions to the same dish after evaporation. Dry for at least 1 hours in an oven at 103-1050C, cool in a desiccators to balance temperature, and weigh

Calculation

$$\text{mg total solids/l} = \frac{(A\text{-}B) \times 1000}{\text{ML sample}}$$

Where:

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

3.3.6 NO_3^-–N

NO_3--N was analyzed using cadmium reduction method. Selection of program 353 was done Touching Hach Programs and around sample cell was filled with 10 mL of sample then one NitraVer 5 Nitrate Reagent Powder Pillow was added (this is the prepared sample) and one minute was allowed for reaction. A five-minute reaction period will begin and an amber color will develop if nitrate is present. Blank was also prepared. Wipe the sample and place it into the cell holder and touch Read then results will appear in mg/L NO_3^-–N

3.3.7 NH_3

Analysis of NH_3 was done using ammonia Salicylate Method. Selection of 343 N program was done touching Hach Programs. 0.1 mL of sample was added to one AmVer™ Diluent Reagent Test ‘N Tube for High Range Ammonia Nitrogen (this is the prepared sample) and 0.1 mL of ammonia-free water was added to one AmVer™ Diluent Reagent Test ‘N Tube Ammonia Nitrogen (this is the blank). One Ammonia Salicylate Reagent Powder Pillow was added for 5 mL sample to each vial. The solution should shakes well waited for 20 minute reaction period. First zero was touched to display 0.0 mg/L NH3–N then Results was appeared in mg/L NH_3–N when read touched.

3.3.8 PO_4^{3-}

PO_4^{3-} was analyzed using Amino Acid Method as follows;

25-mL of sample was added in to cylinder and then 1 mL of Molybdate reagent was dropped using a 1mL calibrated dropper and Add 1 mL of Amino Acid Reagent Solution was added and inverted several times to mix. A blue color will form if phosphate is present. 25 mL of sample was poured into a round sample cell which used as the blank). Finally selection of program from hatch procedures and touch read results will appear in mg/L PO_4^{3-}.

3.4 Data Analysis

Statistical analyses were performed using SPSS version 16 in order to setup mean, standard deviation and range of the lab result. The effluents from both conventional and modern wet coffee processing plants were compared manually with Ethiopia standards discharged to surface water. Observation and interview results were also analyzed. Finally the results were displayed using tables and figures.

4. Result and Discussion

4.1 Raw water characteristics of conventional and advanced wet coffee processing plants

The raw water intended to use for advanced and conventional wet coffee processing system was characterized and their means are indicated in Table 4.1 and Table 4.2 respectively. Raw water used for advanced and conventional wet coffee processing was from nearby streams.

Table 4. 1. Characteristics of raw water used in advanced coffee processing plants

Parameter	Mean + SD	Range
pH	6.92 ± 0.637	6.87 - 7.01
BOD_5	96.25 ± 17.36	81.8 - 120.2
COD	130 ± 14.8	110 – 146
NH_3	0.94 ± 0.42	0.34 - 1.24
NO_3^-N	1.41 ± 0.43	1 – 2
$PO4^{3-}$	0.27 ± 0.11	0.18 - 0.42
TSS	238.25 ± 53.1	198 – 312
TDS	190.75 ± 20.9	178 -222
Conductivity (µs/cm)	70.25 ± 10.24	58 - 83
Turbidity (NTU)	22.6 3 ± 8.51	16 - 35
DO	7.48 ± 1.07	6.2 - 8.7

All units are in mg/L unless indicated otherwise except pH

BOD_5 that was used as raw water in advanced wet coffee processing plants was above discharge limit of EEPA (Table 2.3).

Table 4. 2. Physico- chemical characteristics of raw water was used in conventional Coffee Processing Plants

Parameter	Means ± SD	Range
pH	7.01 ± 0.55	6.19 - 7.35
BOD_5	214.25 ± 81.33	113 – 312
COD	233.5 ± 79.4	155 – 324
NH_3	0.78 ± 0.28	0.37 - 0.96
NO_3^{-}–N	0.98 ± 0.22	0.66 - 1.13
PO_4^{3-}	0.34 ± 0.16	0.18 - 0.54
TSS	259.5 ± 65.3	170 – 322
TDS	189.5 ± 46.5	143 – 254
Conductivity (µs/cm)	65.8 ± 4.24	61 – 71
Turbidity (NTU)	32.28 ± 9.64	23 – 45
DO	6.34 ± 0.6	5.74-7.02

All units are in mg/L unless indicated otherwise except pH

Result of BOD_5 that was used in raw water of conventional wet coffee processing plants was above discharge limit of EEPA (2003) (Table 4.3).

4.2 Effluent wastewater characteristics of conventional wet coffee processing plants

Mean concentrations of conventional effluent wastewater indicated in Table 4.3. The study revealed the concentrations of conventional wastewater effluent did not comply with Ethiopian standards except NH_3, NO_3^{-}–N, and PO_4^{3}. Conventional coffee processing plants effluent had mean concentration value of COD 5682 mg/L (Table 4.3) which is higher than the acceptable ranges of the provisional discharge limits (EEPA, 2003) (Table 4.3). The mean pH value was 4.13 (Table 4.3) which did not meet acceptable ranges of the provisional discharge limits to be discharged on surface water (EEPA, 2003) (Table 4.3). Wet Coffee Processing plants wastewater characterization studies near Jimma by (Alemayehu Haddis and Rani, 2008) showed COD had value of 25,600 (Table 2.1).

Table 4.3. Physico-chemical characteristics of conventional wet coffee processing Plants wastewater

Parameter	Mean ± SD	Range	Permissible Limit(EEPA,2003)
pH	4.13 ± 0.23	3.9 - 4.4	6-9
BOD_5	1697 ± 390.67	1210-2130	80
COD	5682.5 ± 304.45	5470-6120	250
NH_3	4.51 ± 1.62	3.15- 6.65	5
$NO_3^{-}N$	3.39 ± 0.65	2.70 - 4.12	20
$PO4^{3-}$	3.32 ± 0.5	2.71 - 3.45	5
TSS	1975 ± 322	1564 – 2310	100
TDS	1800.75 ± 244.8	1580 – 2133	3000
Conductivity (µs/cm)	747 ± 64	663 – 821	-
Turbidity (NTU)	271 ± 128.5	185 – 458	-
DO	2.14 ± 0.72	1.09 - 2.7	-

All units are in mg/L unless indicated otherwise except pH

In this study, the recorded mean concentration pH value from conventional wet coffee processing plant was 4.13 and it is almost similar with study conducted by (Alemayehu Haddis and Rani 2008) which was a pH of 3.57. According to (Tamrat Alemayehu *et al*., 2006) findings, untreated conventional wet coffee processing plants effluents have extremes of pH depending on fermentation length.

Similar study was done by JARC and EIARC (2007) revealed pH 2.1 from water bodies found near conventional wet coffee processing plants after receiving effluent wastewater from these systems.

The mean concentrations of COD (5682.5 ± 304.45 mg/ L), BOD_5 (1697 ± 390.67 mg/L) and TSS (1975 ± 322 mg/L) were about 22, 21 and 2 fold, respectively (Table 4.3), higher than the acceptable ranges of the provisional discharge limits set by (EEPA, 2003) (Table 4.3). Similar studies in characterization of conventional wet coffee processing wastewater, showed that measured BOD_5, COD and TSS levels were (14,200 mg/L), (25,600 mg/L,) and (5,870 mg/L) respectively (Alemayehu Haddis and Rani, 2008) . According to (Salvamurugan *et al*., 2010), BOD_5 (3800 - 4780 mg/L) and COD (6420 - 8480 mg/L) were found by characterizing wastewater released from conventional wet coffee processing plants.

Different countries set standards to protect environment and its component from pollution. For example France and Germany set the standard for BOD_5 (25 mg/L) and (40 mg/L) mean and COD (125 mg/L) and (150 mg/L), respectively. These values are set for any effluent discharge to surface water. In addition; Taiwan set mean concentration value BOD_5 (80 mg/L) and COD (250 mg/L) standard for the effluent to be discharged to any surface water (Jacobsen and Warn, 1999, Ismail *et al*., 2008).

According to (Tamrat Alemayehu *et al* 2006) the maximum COD and BOD_5 value recorded in the polluted river downstream from conventional wet coffee processing industries were 24,600 mg/L and 10,604 mg/L, respectively. These values were recorded at a point where wet conventional coffee processing effluents discharge into traditional wastewater lagoon or pools (Alemayehu haddis and Rani 2008), explained that wet coffee processing effluents are complex furthermore; have several effects on water bodies and human health.

Untreated wet coffee processing effluents are known to have high BOD_5, COD and TSS (Tamrat Alemayehu *et al*., 2006; JARC & EIARC (2007). High levels of BOD_5 are indications of the pollution strength of the wastewaters and also indicate that there could be low oxygen available for living organisms in the wastewater when utilizing the organic matter present. High COD levels imply toxic condition and the presence of biologically resistant organic substances (Joo *et al*., 2006).

In the same way, mean concentration of TDS (1800.75 ± 244.8), and conductivity (747 ± 64) (Table 4.3) were obtained. Similar studies by (Salvamurugan *et al*., 2010) revealed TDS in the ranges of 1130 - 1380 mg/L.

The mean concentration of Ammonia, Nitrate and Phosphate at conventional wet coffee processing plants effluent were also found to be (4.51 ±1 .62 mg/L), (3.39 ± 0.65 mg/L), (3.32 ± 0.5 mg/L), respectively (Table 4.3) and these values were lower than Ethiopian discharge limits to surface water (EEPA, 2003).

Similar studies of (Tamrat Alemayehu *et al*., 2006) explained mean concentration of Ammonia (90 mg/L). However, another study by (JARC & EIARC 2007) found ammonia concentrations in the range of 1.35 – 8.02 mg/L. The study also revealed mean concentration of Nitrate (17.8. mg/L). According to (Alemayehu Haddis and Rani, 2008), mean concentration of nitrate and phosphate from the conventional system wet coffee processing plants was 23 mg/L and 7.3 mg/L, respectively. According to (Salvamurugan *et al.,* 2010) found mean concentration of nitrate in the range of 125.8 - 173.2mg/L. Nitrate is an oxidized, inorganic form of nitrogen in water. Nitrogen is a necessary nutrient for plant growth. Too much phosphorus and nitrogen in surface waters contributes to nutrient enrichment, increasing aquatic plant growth and challenge plants and animals that live in water bodies (Joanne, 2001).

The mean concentration value of conductivity (747 ± 64 µs/cm), turbidity (271 ± 128.5 NTU) and dissolved oxygen (2.14 ± 0.72 mg/L) were recorded in conventional wet coffee processing plants (Table 4.3). Similar studies of (JARC & EIARC, 2007) revealed that mean concentration of conductivity (800µs/m) and mean concentration of DO (4.49 mg/L). According to (Salvamurugan *et al*. 2010), concentration of conductivity from wet coffee processing effluent was in the range of 0.96 -1.20 ds/m.

The study of (James and Edward, 2006) revealed that to specify a water quality standard, a minimum DO content should be 5.0 mg/L for trout waters, 5.0 or 4.0 mg/L for non-trout waters and a minimum 2.0 or 3.0 mg/L for any other waters. An excess of biodegradable organic matter leads to an accelerated growth of the microbial population. They are aerobic and require DO in the water for respiration. As result; a large population could deplete the dissolved oxygen supply (Ruth and Robin, 2003). In addition anaerobic fauna and flora will flourish producing reduced gaseous substances, such as ammonia gases that are toxic and unpleasantly odiferous (Marquita, 2010).

Mean concentration turbidity recorded from conventional wet coffee processing plants wastewater was 271 NTU. Turbidity of wastewater indicates the quantity of suspended and colloidal material in the effluent while conductivity measures the ability of an aqueous solution to carry an electrical current. In other word conductivity of wastewater is defined as an indicator of the quantity of dissolved inorganic material present in the water (WEF, 2008).

4.3 Effluent wastewater characteristics of advanced wet coffee processing plants

In addition to conventional system wet coffee processing plants wastewater, effluent from the outlet of advanced wet coffee processing plants were also analyzed. Laboratory analysis of both system effluents were needed to compare the contribution to pollution and to examine how the processing plants produce environmentally sound products. Moreover, it is easier to know the system efficiency by comparing with set standard.

Average characteristics of wastewater from advanced wet coffee processing plants are illustrated in Table 4.4. An average effluent from advanced coffee processing plants had 3576 ± 667.7 mg/L COD. Furthermore, the mean concentration of BOD_5 was 2687 ± 518.04 mg/L. The mean concentration value of Ammonia, Nitrate and Phosphate were 11.85 ± 4.13 mg/L, 2.04 ± 0.34 mg/L and 2.26 ± 0.68 mg/L, respectively. Mean value of ammonia was above the discharge limit set by EEPA, 2003 (Table 2.3). An average value of TSS was 282 ± 44.75 mg/L. TDS and DO had mean concentration of 789.25 ± 72.3 mg/L and 4.38 ± 0.63 mg/L, respectively.

Both TSS and TDS were lower than discharge limit set by (EEPA 2003) (Table, 2.3), the mean value for conductity and turbidity were 350 ± 68.66 µs/cm and 91.25 ±31.4 NTU. pH value of the system was found to be 6.69 ± 0.12 which show that the wastewater released from advanced system wet coffee processing was almost neutral.

4.4. Physico-chemical characteristics of wastewater from advanced coffee processing Plants

Parameter	Mean ± SD	Range	Permissible Limit (EEPA,2003)
pH	6.69 ± 0.12	6.54 - 6.82	6-9
BOD_5	2687 ± 518.04	2220 – 3356	80
COD	3567 ± 667.7	2580 – 3990	250
NH_3	11.85 ± 4.13	8.44 - 17.08	5
$NO3^{2-}$	2.04 ± 0.34	1.67 - 2.51	20
$PO4^{3-}$	2.26 ± 0.68	1.75 - 3.27	5
TSS	282.42 ± 44.75	216 – 312	100
TDS	789.25 ± 72.3	698 – 854	3000
Conductivity µs/cm	350 ± 68.66	315 – 453	-
Turbidity NTU	91.25 ± 31.4	57 – 126	-
DO	4.38 ± 0.63	3.70 - 5.20	-

All units are in mg/L unless indicated otherwise except pH

4.4 Comparisons of wastewater from advanced and conventional wet coffee processing plants

The objective of the study was comparing wastewater generated from advanced and conventional system wet coffee processing plants. Consequently; effluent from advanced wet coffee processing plants were sampled and characterized. Samplings from both conventional and advanced wet coffee processing plants were used to compare the result with each other and with available standard.

Table 4.5. Comparison of wastewater between advanced and conventional wet coffee processing plants

Parameter	Advanced (Mean ±SD)	Raw water of advanced wet coffee process	Conventional (Mean ±SD)	Raw water used in conventional wet coffee process	Permissible Limit (EEPA,2003)
pH	6.69	6.92	4.13	7.01	6-9
BOD_5	2687	96.25	1697	214.25	80
COD	3567	130	5682.5	233.5	250
NH_3	11.85	0.94	4.51	0.78	5
$NO3^{2-}$	2.04	1.41	3.39	0.98	20
$PO4^{3-}$	2.26	0.27	3.32	0.34	5
TSS	282.42	238.25	1975	259.5	100
TDS	789.25	190.75	1800.75	189.5	3000
Conductivity µs/cm	350	70.25	747	65.8	-
Turbidity NTU	91.25	22.6 3	271	32.28	-
DO	4.38	7.48	2.14	6.34	-

All units are in mg/L unless indicated otherwise except pH

The analyses indicated high variation between conventional and advanced wet coffee processing plants (Table 4.5). The mean concentrations of COD of advanced wet coffee processing plants were (3567 mg/L) (Table 4.5). The result was around 1.5 fold less than the mean concentration value of effluent released from conventional wet coffee processing plants (Table 4.5). However; the mean concentration from the outlet of advanced wet coffee processing plant was above the Ethiopian permissible discharge limit (EEPA, 2003) (Table 4.5).

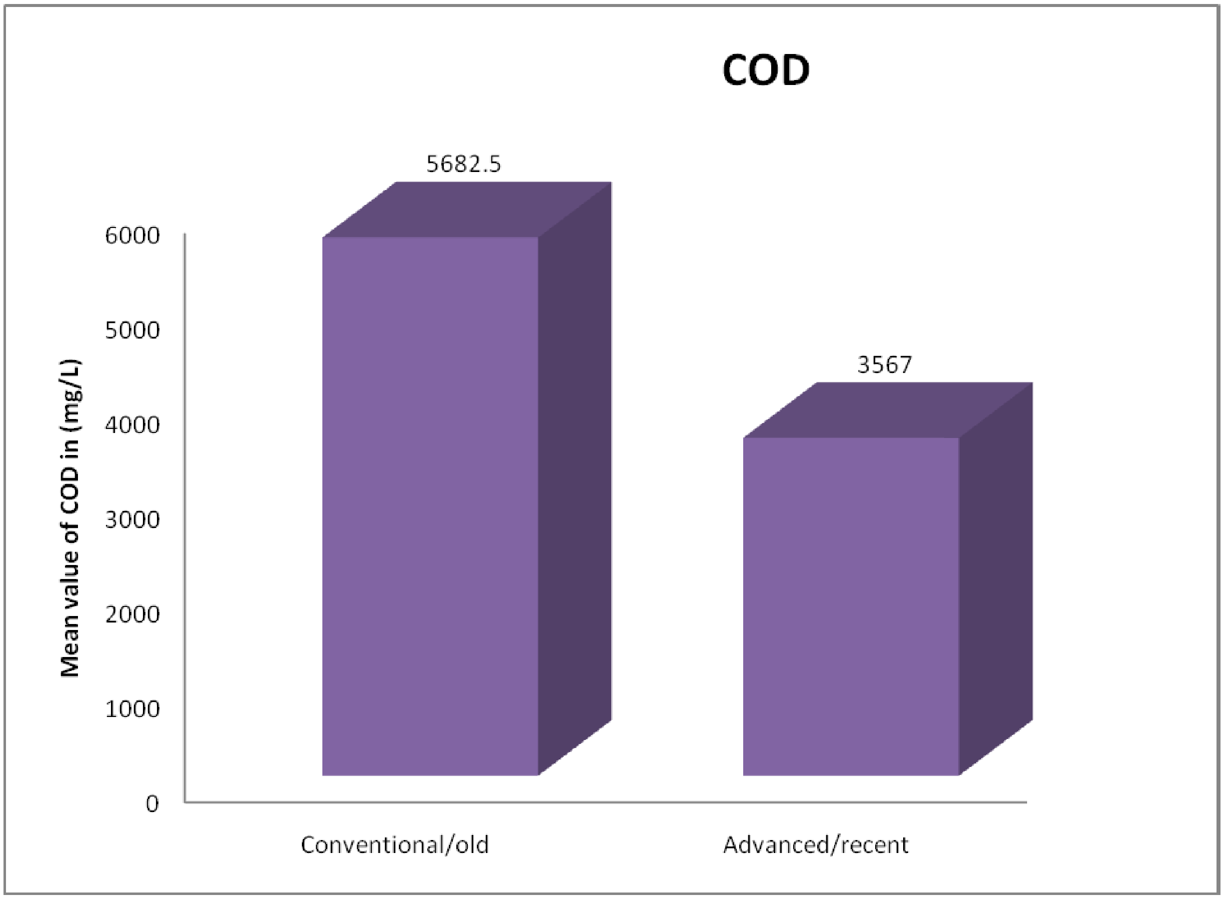


Fig 4. 1**.**Comparison of COD in wastewater of conventional and advanced wet coffee processing plants

BOD_5 of the conventional and advanced wet coffee processing plants indicated in Table 4.5. The result from advanced wet coffee processing plant was greater than that of conventional wet coffee processing plants effluent. This may due to; fermentation process was not practiced in modern wet coffee processing. As the result; organic matter had lower chance than conventional processing to decompose by micro-organisms. BOD_5 measures organic matter decomposed by micro-organisms (Noah, 2009).

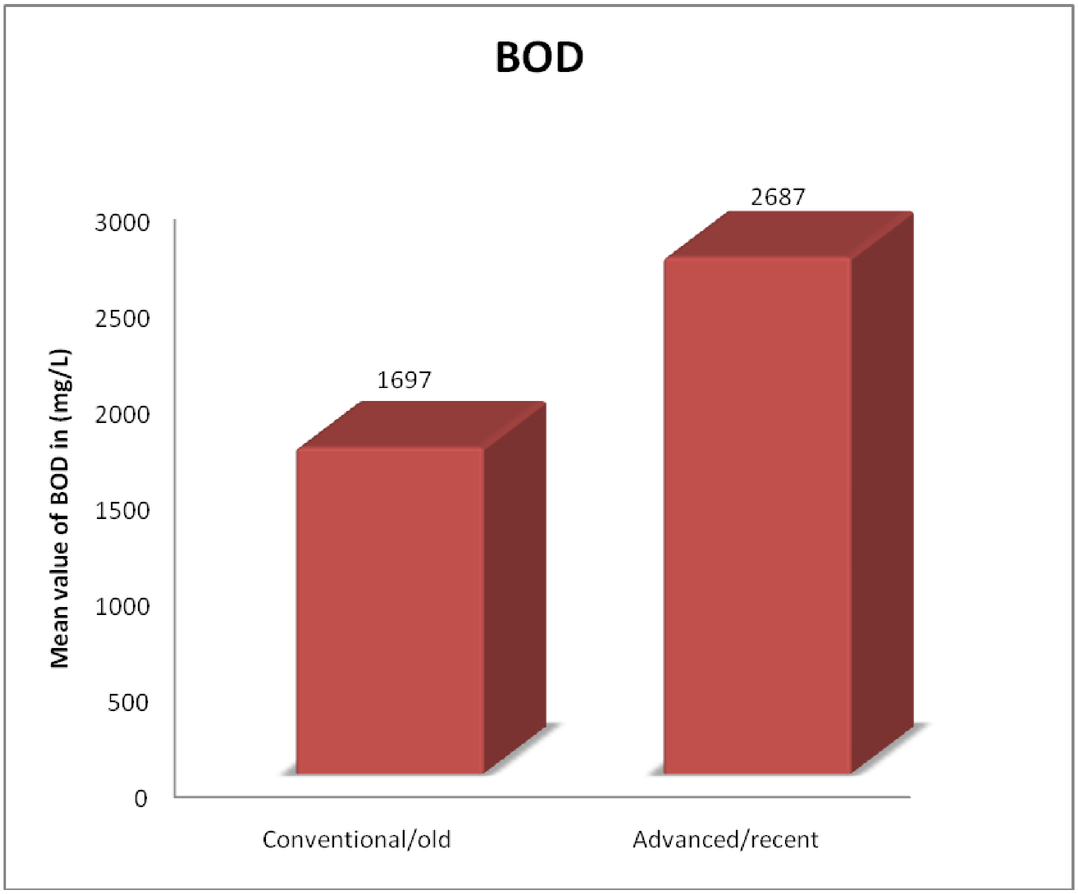


Fig 4.2. Mean BOD_5 comparison in wastewater of conventional and advanced wet coffee processing plants

To measure the difference in wastewater between conventional and advanced wet coffee processing plants, TSS and DO were also analyzed. Mean concentration of TSS in advanced wet coffee processing effluent was (282.42 ± 44.75 mg/L) (Table 4.4). The recorded result was about eight fold lower than conventional wet coffee processing plants wastewater (Table 4.5). On the other hand mean concentration of TDS in advanced technology was (789.25 ±72.3 mg/L). The variation might have occurred due to, conventional wet coffee processing plants, once coffee beans separated from the pulp in the conventional wet coffee processing then they are transported by water to fermentation tanks for mucilage breakdown and removal. The products of this hydrolysis remain in the wastewater of the systems. In the case of advanced wet coffee processing plants, mucilage separation is done mechanically by friction as beans pass between revolving perforated drum and inner perforated tube with a counter flow of water (Braham and Bressani, 1979).

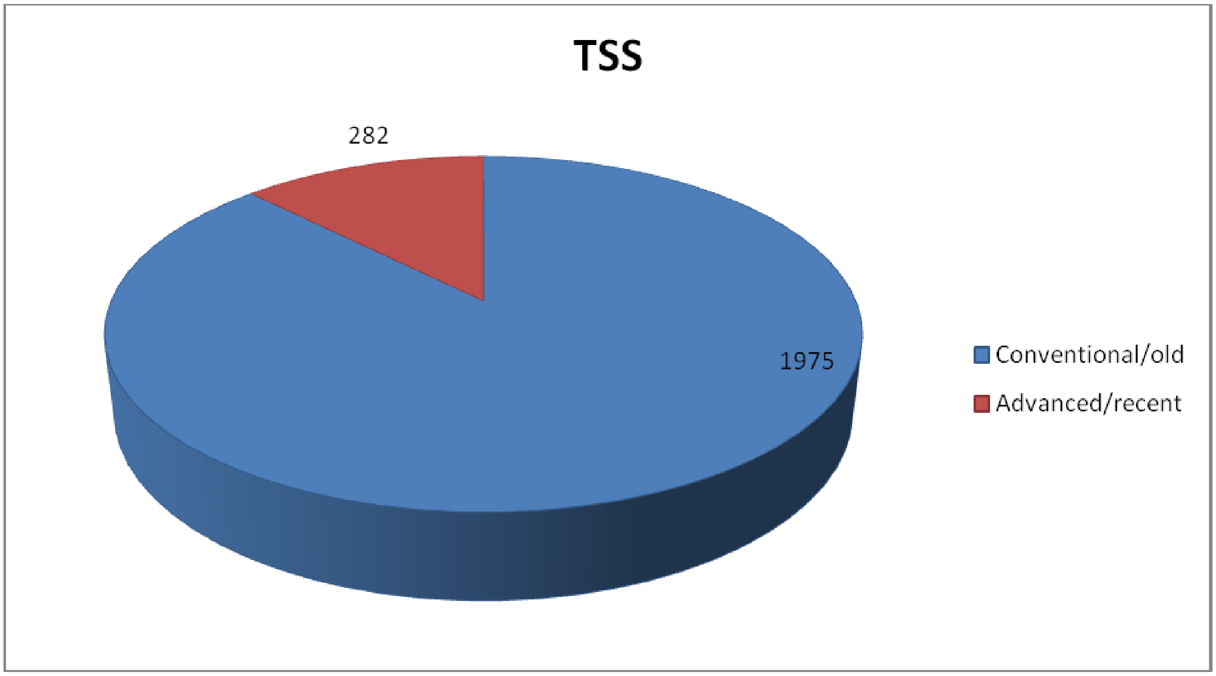


Fig 4.3. TSS (in mg/L) in wastewater of advanced and conventional wet coffee processing plants

In this study, the pH of conventional and advanced wet coffee processing plants was also compared. Wastewater from conventional wet coffee processing plants was acidic when compared with effluent from advanced wet coffee processing plants as indicated in Table 4.5

The pH value of wastewater from conventional wet coffee processing plants did not also comply with the discharge limit set by (EEPA, 2003) (Table 4.5). Effluent wastewater from advanced wet coffee processing plants fullfil the discharge limit set by EEPA (Table 4.5). According to WEF (2008) micro-organisms remain sufficiently active only within a narrow range, generally between pH 6.5 and 8. Outside this range, pH can inhibit or completely stop biological activity

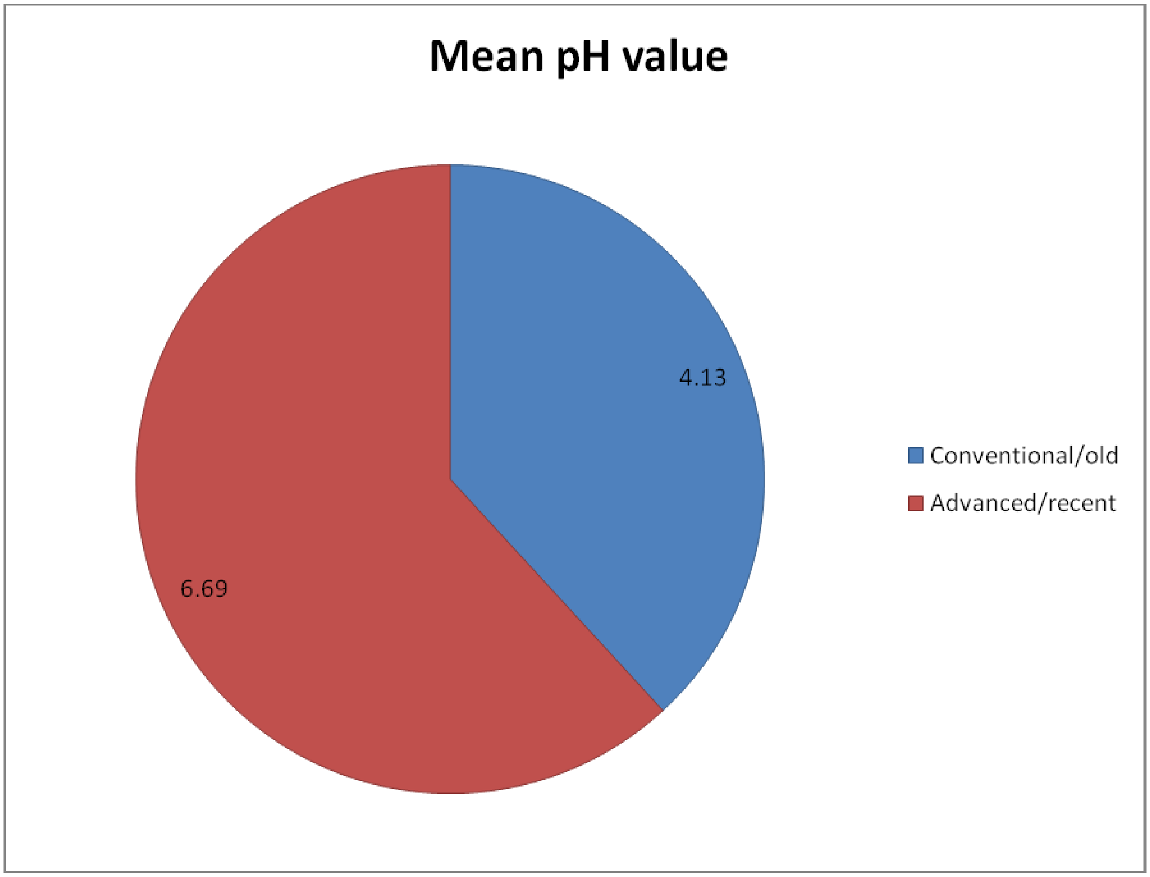


Fig 4. 4.Mean concentration value of pH difference between Conventional and advanced wet coffee processing effluents.

Wastewaters from conventional and advanced wet coffee processing were lower than Ethiopian permissible discharge limit in Nitrate, Phosphate and Total Dissolved Solids measurements.

4.5. Existing situation, Interview

The key informants explained that, the development of advanced wet coffee processing plants in the area protect the environment especially water bodies from pollution. The key informants' confirmed also advanced wet coffee processing much better than the conventional in terms of quality and of wastewater released from the processing. However, wastes released from the processing plants were not giving economic importance like fertilizer and biogas.

The key informants of local people in the study area point out that, water bodies polluted by wastewater from conventional wet coffee processing plants have health impact on their cattle and themselves. They also explained that advanced wet coffee processing plants have great contribution in maintaining the stability of the environmental condition. They think that the existence of modern wet coffee processing plants made them enjoy regarding protecting their environment. These systems also conserve water resource and protect their environment from pollution. Furthermore; they reflect the fact that environmentally sound production of wet coffee processing plants should take over conventional wet coffee processing plants.

4.6 Existing situation, observed

It is observed that raw water used in processing was unclean (plate 4.1). Using unclean water contributes high impact on quality of effluent wastewater. As observed, processing plants whose location is at lower catchments' use more unclean raw water. This is because almost all of the wet coffee processing plants are planted nearby rivers. As a result, they release their wastewater to those water bodies.

Plate 4. 1 Raw water used in wet coffee processing plants

Raw water water tank

During data collection it was observed that at some places of wet coffee processing plants vetiver grass was planted for remediation or cleaning purpose. However; the mentioned plant did not grow as expected under effluent wastewater from conventional wet coffee processing plants as shown in plate (4.2). Wastewater released from conventional wet coffee processing plants was acidic when compared with that of advanced wet coffee processing. Under the effluent wastewater from advanced wet coffee processing vetiver grass was grown well (plate 4.3). However; it was observed that frequently exposed grass face the same problem as observed in conventional wet coffee processing plants. Bad smell is common around the environment where coffee processing existed.

Plate 4.2 vetiver grass grow under wastewater from conventional wet coffee processing plants

Plat

e 4.3 vetiver grass grow under wastewater from advanced wet coffee processing plants

5. Conclusion and Recommendations

5.1 Conclusion

Raw water used in conventional wet coffee processing plants had BOD_5 (214 mg/L), COD (233 mg/L),TSS (259 mg/L) and TDS (189 mg/L) and raw water used for advanced wet coffee processing plants revealed BOD_5,COD,TSS and TDS were 96, 130, 238, 190.7 mg/L values respectively.BOD_5 of conventional and advanced wet coffee processing plants raw water used was above Ethiopian permissible discharge limit.

Wastewater of conventional wet coffee processing plants revealed that BOD_5 (1697 mg/L), COD (5682 mg/L), TSS (1975 mg/L) and pH (4.13) were not complying with Ethiopian discharge standards. Advanced wet coffee processing plants were better than conventional wet coffee processing plants by producing low effluent wastewater concentrations even though it did not meet the discharge standards such as BOD_5 (2687 mg/L),COD (3567 mg/L) and TSS (282 mg/L).

It was observed that plants grown under wastewater effluent from advanced wet coffee processing plants were greenish. However; plants grown around waste water of conventional wet coffee processing couldn't resist and grow properly. This may be due to wastewater released from conventional wet coffee processing plants was acidic, whereas effluent from conventional wet coffee processing was neutral. The waste management systems of wet coffee processing plants also were not good.

5.2 Recommendation

- Using clean water for the processing purpose could minimize the pollution potential of effluent wastewater released from wet coffee processing plants.
- Establishment of wastewater treatment systems is necessary to produce better wastewater comply with standards and safeguard environment
- It is necessary to monitor continuously the coffee effluent wastewater before discharging it into nearby water bodies and further studies are essential for local community view about cattle death by coffee wastewater.
- Wise use of waste from wet coffee processing for different purpose like biogas and fertilizer should be encouraged; these methods are promising actions for environmental protection and sustainable development.

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Declaration

I hereby declare that I am the sole author of this thesis and have not been presented for any degree in any higher institution and all the resource of material used for the thesis have been duly acknowledged.

I authorized the Addis Ababa University, Environmental Science Program to lend or distribute this thesis to other institutions or individuals for the purpose of research.

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This thesis has been submitted for examination with my approval as university advisor.

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Advisor	**Signature**	**Date of approval**