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ADDIS ABABA UNIVERSITY
DEPARTMENT OF EARTH SCIENCES
SCHOOL OF GRADUATE STUDIES

Water Pollution/Quality Assessment In Relation To Wet Coffee Processing Plants In Surface And Shallow Groundwater In Sidama And Gedeo Zones (SNNPR)

By

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Abstract

The study area located in Southern Nation and Nationality People Region (SNNPR) and encompass Sidama & Gedeo Zones that are among all the coffee growing region of Ethiopia, bounded between 37^0 54'N to $39^0$8 N latitude and 5^0 52'E to 7^0 13'E longitude in which most part of it situated in the rift valley lakes basin and the remaining part in Genale Dawa basin.

The study area has different land form characteristics varied from High Mountain up to low lands: its altitude varies from the highest peak (3000m) up to lowlands (1100 m)

High water usage, channeling residual water and the pulp together, in efficiency of the traditional waste disposal pits, absence of monitoring and lack of sustainable wet coffee production strategy and policy are some of the factors that aggravate the impact of the processing plants on the pollution of water bodies were discussed in problem identification and analysis.

Measured values of physical parameters such as turbidity and pH are out of the range of WHO guideline values and standards. From the Physical observation itself during coffee processing periods rivers and streams have objectionable color odor and taste so that the waters have evil or pungent small and test.

TDS and EC values of rivers and streams in particular spring and boreholes in general shows that the water is fresh.

Based on the measured value of the total hardness in terms of $CaCo_3$ the surface and groundwaters of the study area classified as moderately hard.

The limited water chemical analysis from previous representative sources indicated that the river and ground waters are Na HCO_3 type of water, the dominant cation being Na and anion bicarbonate.

The highest value BOD and COD in river water is 8750 and 3120mg/l that have a potential for decreasing greatly the level of dissolved oxygen in the rivers that reduces the diversity of

aquatic life. The maximum COD value of the effluent obtained from this analysis (24,600mg/l) is 98 times higher than the EPA standard fro effluent discharges to inland waters. The highest BOD value was 39 times higher than the EPA standard.

The bad, evil and pungent smell that can be sensed along the river courses during coffee processing periods were explained by the concentration of Ammonia (NH_3) that was ranged from 1.48to 90mg/l and was much higher than the recommended limits.

The highest nitrite (No_2-) concentration was 60mg/l in Melkadimtu Rivers. From the total analyzed samples about 50% of them had their values were nearly 1mg/l, which are far higher than levels in unpolluted waters (0.03mg/l). Rural communities that use river water as their source of water supply may expose to carcinogenic effect due to this level of nitrite.

Coffee pulp, which is one of the byproducts of coffee processing, have some economical applications that may become evident as their use is increased. Compost and fertilization, Pulp beverage, animal feed, fuel wood substitutes are some of the suggested measures to be taken to mitigate the effects.

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CHAPTER I

INTRODUCTION

1.1 Background

Water resources have been the most exploited natural system since man strode the earth. On the one hand rapid population growth, increasing living standards, wide spheres of human activities and industrialization have resulted in greater-demand of good quality water while on the other hand pollution of water resources is increasing steadily. Large quantity of wastes and effluents is generated from different activities and released in to nearest water bodies.

The introduction of modern water carriage systems transferred the sewage disposal from the streets and the surroundings of townships to neighboring stream and rivers. This was the beginning of the problem of water pollution. It is ironic that man from the earliest times, has tended to dispose of his wastes in the very streams and rivers from which most of his drinking water is drawn. Until quite recently this was not much of a problem, but with rapid urbanization and industrialization the problem of the pollution of natural waters is reaching alarming proportions.

The most disturbing feature of this mode of disposal is that those who cause water pollution are seldom the people who suffer from it. Cities and industries discharge their untreated or only partially treated sewage and industrial effluents into neighboring streams and their by remove waste matter from their own neighborhood. But in doing so they create intense pollution in streams and rivers and expose the downstream riparian population to dangerously unhygienic conditions. In addition to withdrawal of water for downstream towns and cities in many developing counties numerous villages and farmers generally rely on streams and rivers for drinking water for themselves and their cattle for cooking, bathing, washing and numerous other uses. It is this riparian population that especially needs protection from the growing menace of water pollution.

The term pollution may be defined as the deterioration in the chemical, physical and biological properties of water brought about mainly by human activities. Since surface waters is exposed directly to atmosphere as well as connected with several minor inlets as rivulets, seasonal streams and surface drains there is continues exchange of dissolved and atmospheric gases and addition of waste materials through water conveyances.

The problem of pollution in groundwater is much less than in surface water as the soil act as an adsorbent refining a large part of colloidal and soluble ions with a maximum of its cation exchange capacity. Still groundwaters are not absolutely free from the menace of pollution. The extent of groundwater pollution depends up on several factors: (i) soil properties, viz texture, structure and the infiltration rate (ii) depth of water table (iii) rainfall pattern (iv) distances from the source of contamination (CK VARSHNEY, 1983)

In Ethiopia as the impact of urbanization and industrialization on water quality has been a case for great concern in recent years, since more than 90% of industries discharge their effluent in to near by rivers, streams and open lands without treatment (EPA, 2001). It is also known that most of the industries in the country are food processing, beverages, textiles, chemicals, and metal processing and cement factories. The most polluting sources are sugar factories followed by textile and tannery factories that are characterized by high BOD wastes.

Similarly following the investment proclamation no -30/1996 there was a rapid and still expanding increase in the establishment of wet coffee processing plants in the study area of Southern Nation, Nationality & Peoples Region (SNNPR) particularly in Sidama and Gedeo zones. There is increasing evidence of s surface water-pollution by effluents from coffee processing plants. It is perhaps the most wide spread river pollution in the region. Unlike the above mentioned industries the impact of coffee processing industries on surface and groundwater quality has received relatively little or no attention. This initiates the author to make a research on a trend, extent and effect of the pollution and measures to be taken related mainly to coffee processing industries.

Biodegradable carbonaceous materials derived from domestic, agricultural and agro-industries can often cause marked changes in the amenity values of a watercourse, largely as a consequence of alteration in the O_2 balance of the water environment. The most wide spread watercourse pollutions in rural Ethiopia at present time are discharges of effluents arising from the wet coffee processing plants. There are now 600 wet processing plants, all of them are situated in rural areas, and almost all are designed to process at least 2.8

tons of parchment coffee per day. The by-product of wet coffee processing plants are mainly coffee pulps, solids from the mucilage and residual water. Pollution arises when raw waters used in coffee processing operation is discharged in to water bodies. Similarly effects have been observed from drainage and seepage of raw effluent from decomposing coffee heaps. Since coffee is produced in rural areas where treatment facilities are absent, the water pollution consequently can have adverse effects on domestic water use and in coffee processing itself. Since coffee processing requires clean water and as there are often as many as six or more processing plants closer to each other along a stream, the use of polluted water is likely to give undesirable off –flavors resulting in the possible loss of quality standards. Watercourse pollution by wet processed coffee by products is therefore a central issue in the development of the Ethiopian coffee industry.

Ethiopia regards itself as the motherland of coffee, it is being widely accepted that coffee tree is indigenous to the Ethiopian highlands. Undoubtedly the economy of Ethiopia is coffee economy, expressing the decisive roles that coffee plays in the economical development of the country. Economically it accounts for more than 60% of the countries foreign exchange earrings. Several million rural Ethiopians survive on coffee as one dependable and only cash crop, while in the towns and cities it means employment for many processors, sorters, collectors and sellers.

Ethiopia is the third leading producer of coffee in Africa after Cot ed voire and Uganda and the continents number one producer of the most heavily demanded coffee qualities that attain high premium prices in the world market. Thus it is the nature of the Ethiopian coffees themselves that excite global specialty interests. However the way coffee is picked and processed also plays a vital role in quality determinations. Coffee is processed by either the wet or dry method. The former being more advantageous on attaining high prices while securing high preferences and dependable demands by the majority of the consuming nations. Export volumes are gradually building up. Fifteen years ago Ethiopia Exported 50,967 tons of coffee of which washed coffee was about 22%, by 1996 export increased to 111,206 tons of which 17% was washed coffee and in the year 2000, export increased to 120,303 of which 27% was washed coffee. Washed coffee export reached 32,961 ton in the year 2000, up was 17,397 tons in 1996 and 11,168 tons in 1990. The figure below shows the increase in the export of washed coffee at a national level. Conversely the value earned from washed coffee increased by 986% in year 2000 & 549%

in year 1996 compared to the base year value of 30.5 million USD, in 1990. Thus a steep growth of washed coffee has been especially in momentum in the past decades with immense potential for further growth. Currently there are over 600 wet processing plants, which function at 60% efficiency and produce about 38,000 ton clean coffee annually (CTA, 2000). The prospects of Ethiopia are therefore to increase its wet processed coffee production capacity in order to boost cash income at all levels (farm gate, individual processor, regional and national levels)

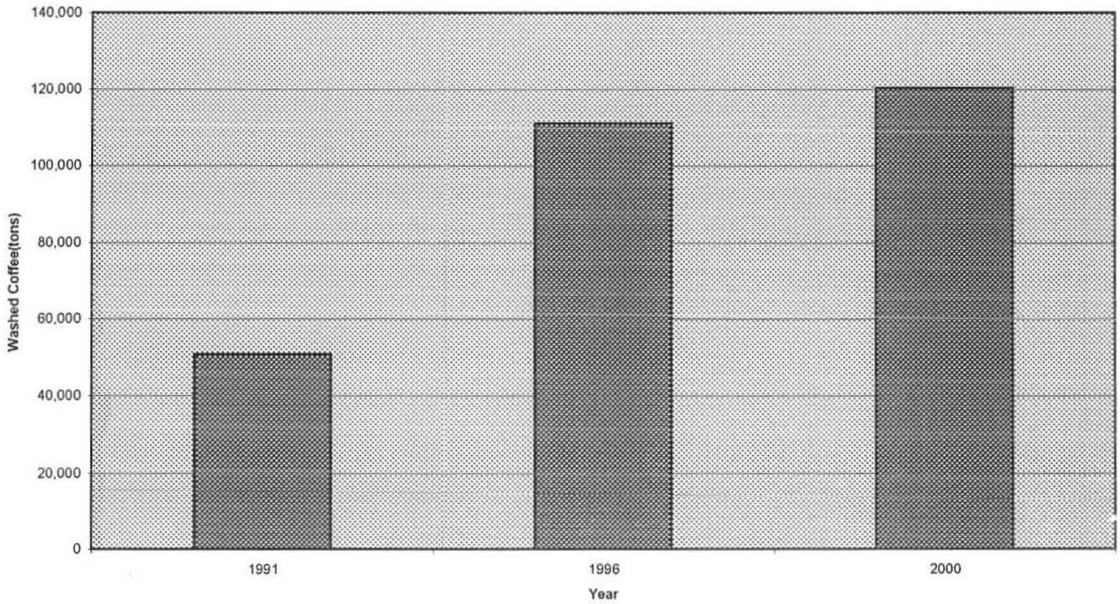

Fig 1.1 Increase in washed coffee exported at a national level vs. year

The geographical location of the coffee zones endowment favorable climates that provides a higher amount of rainfall and much of this water flows to rivers and streams. Although it cannot be definite due to lack of systematic studies, professional guess indicates that there are high potentials to utilize rivers and stream waters for further expansion of wet coffee processing plants across the coffee zones in the study area. However even without further expansion phases watercourse pollution caused by the existing wet processing plants has become a concern.

Discharges from wet processing plants represent major source of watercourse pollution especially in the south and west coffee zones of Ethiopia. The process of separating the parchment coffee from cherries generates enormous volumes of waste material in the form of pulp solid effluents and residual water. According to Kenyan experiences the pollution discharging from factory producing one tone per day of parchment coffee and corresponding 20,000 liters of effluent produces has equivalent biological oxygen demand (BOD) comparable to that caused by about 2000 people per day (J.K Mburu and P.K Mwaura, 1996).

Although coffee processing effluents are produced only seasonally (August to December) the by products of the wet processed coffee particularly coffee processing effluents and discharge from the composting pulp can cause considerable pollution of water courses. For example in 1999/2000 about 47,000 parchment coffee was delivered to the central action assuming 10% processing wastage (floaters, machine damage, human mismanagement) it is estimated that over a four month period the processing of 51700 ton of parchment coffee could have generated 206,800 tons of pulp and could pollute 21,000 cubic meters of water per day resulting in discharges to the different water courses in the coffee zones. This could be equivalent to raw sewage damping from a city of 764,000 people.

When we come to specific problems of the study area, the study areas i.e. (Sidama and Gedeo zones) are among all the coffee growing region of Ethiopia. Activities related to coffee washing process caused substantial contamination on drinking water.

Prior to this study, although no full account of the problem is available, drinking water contamination has been reported in communities such as those in Yirgalem and Dilla town and the load on drinking water treatment plants considerably increases especially during coffee harvesting season. The Problem is also highly magnified in many rural settlements downstream of the plant in such away that the rural communities even with out scientific approval they are complaining of the polluted surface water which has unpleasant smell and unfit for drinking and washing purposes.. There are about 283 pulping and 57 hulling coffee industries that are distributed in different woredas in the study area (SZFEDCMD, 2004). Out of 13 coffee producing woredas in the study area,Wonago woreda in Gedeo zone have a large number of pulping industries. The following figure shows coffee producing woredas and the level of their production in the study area.

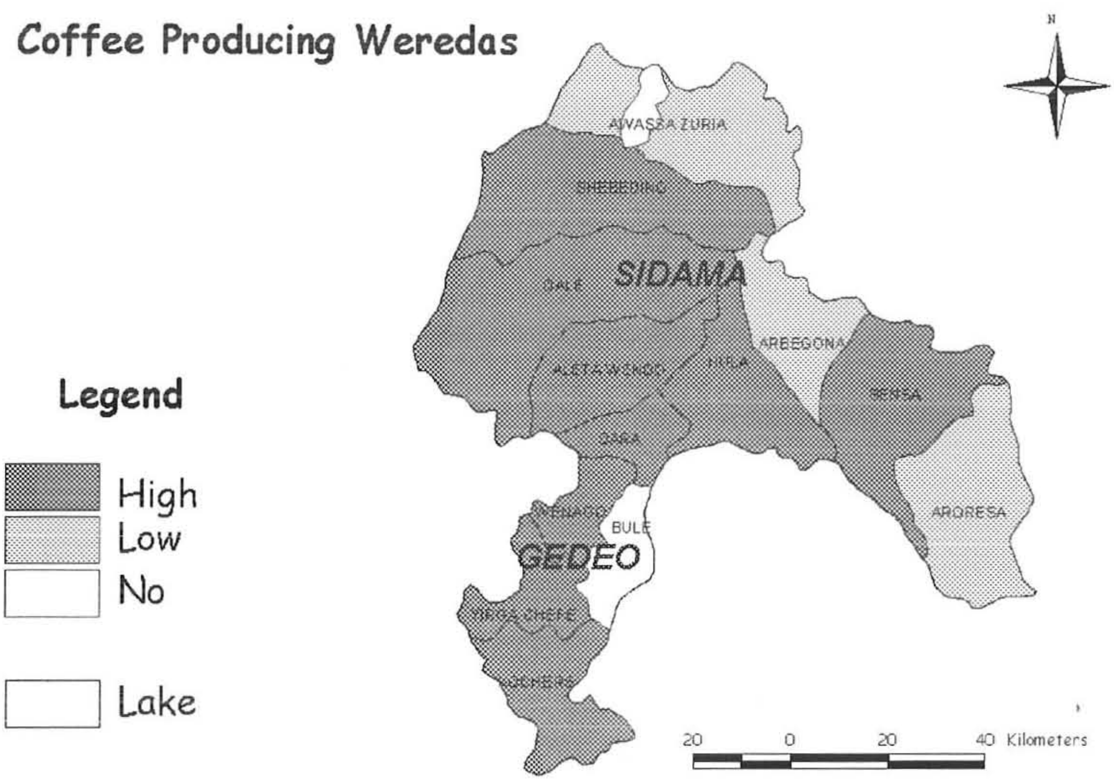

Fig 1.2 Coffee producing Woredas (Source: SNNPR Statistics and Population Bureou, 1997)

From the figure, we can see that out of thirteen Woredas in the study area,only one Woreda(Bule Woreda in Gedeo zone) doesn't produce coffee. Nine Woredas (70% of the whole) are grouped under high coffee producer and the rest as low coffee producer.

1.2 General Information on Wet Coffee Processing

The way coffee is grown and processed has profound environmental importance both locally and internationally. The ripe fruits of coffee which are normally processed in the production area they go through certain number of operations, the objective of which are to extract the beans from their covering of pulp, mucilage, parchment and film and to improve their appearance. Although the beans could be removed from the fresh cherry easily enough, the parchment coffee was covered with mucilage, which is rich in sugars, particularly glucose making it a good medium for the growth of bacteria, yeasts and fungi.

The general flow chart of this wet processing is shown in Figure1. 3 (Gordon Wrigley, 1988) .As the whole process is carried out in the presence of clean water, the construction of the plant is of necessarily near river or stream, which can provide a good supply of water at picking time. This is usually at the lower part of an estate or holding so that the transport of the heavy cherry is downhill and if possible it should be located centrally. Ripe cherry starts to ferment very soon after it is picked so it is important to keep it in the shade and process it as soon as possible, certainly on the day it is picked. If cherry can't be pulped straight away it should be held under water. Fermentation at this stage causes to pick up off flavors similar to over fermented coffee and the beans become brown.

. Generally the following techniques are used to obtain clean coffee beans. (Rene Coste, 1992).

a/ Removal of the pulp (pulping) and mucilage (mucilage removal), washing,

b/ Drying of parchment coffee

c/ Removal of the inner coverings, parchment, and film (hulling)

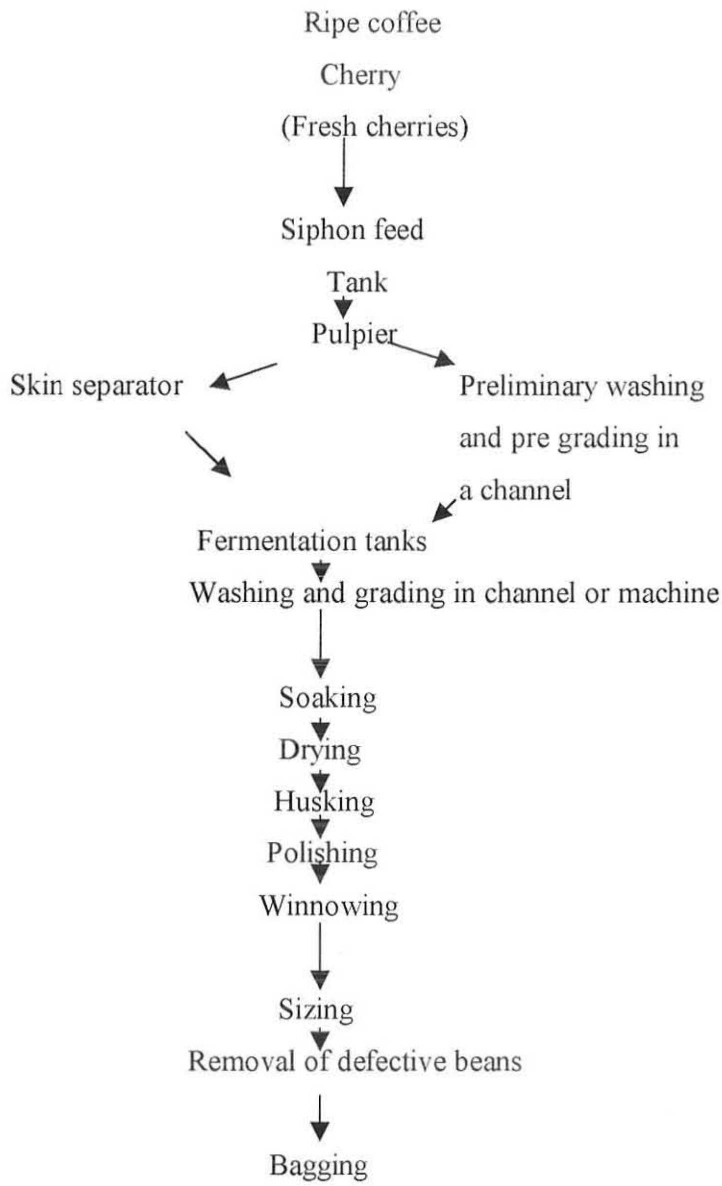

Fig 1.3. The general flow chart of wet processing

The first operation, pulping is often preceded by sorting a basic cleaning the objective of which is to eliminate plant debris such as leaves and pieces of branches and foreign particles such as stones and soil fragments that have been collected during harvesting .A considerable amount of water is required to operate the pulpier properly particularly the cylinder coffee pulpier. A minimum flow of one liter per kg of fruit is judged to be necessary. It is estimated that 40m^3 of water per tone of clean coffee is the required amount for receiving the cherries transporting them hydraulically in the pulping machine via the water current removing the pulp and sorting and repassing any cherries with residual pulp adhering to them.

Mucilage Removal

When the coffee emerges from the pulpers, it is still coated with mucilage that sticks to the parchment. This material is rich in pectin and is very hygroscopic, which renders it an obstacle to the rapid drying of the beans. It is eliminated by using different techniques.

One of these is biochemical removal or fermentation involves placing the pulped coffee in appropriate environmental conditions, so that the pectin of the mucilaginous coating of the beans decomposes due to lactic fermentation. The pectinolysis is accelerated by the presence of different microorganisms such as yeast and bacteria.

The operation is marked by a slight rise in the temperature of the mass of beans due to various fermentations among which lactic fermentation predominates a very slight increase in the acidity (PH) also occurs from 6.5 to 6.8 at the beginning to between 4.5 and 4.8 at the end of the operation. The rise in temperatures is favorable to the effects of the fermentation, which includes the activity of the enzyme diastase on the pectin's. It is equally important to prevent harmful pathogenic species, such as moulds from appearing.

Washing

The objective of washing is to remove products formed during the course of fermentation, such as the debris from the pulp, which remains adhered to the parchment, etc. Washing is generally carried out in large tanks, called washers, or by slowly moving the coffee through open-topped channels.

Washing is completed when the water is as clear on leaving the channel or washtub as when it entered. Water requirements are high about 10 liters per kilogram of coffee.

Composition of coffee fruits and clean coffee yields (Rene Coste, 1992)
Arabica coffee:

100 kg of ripe fruit decompose into about

39 kg of fresh pulp

22 kg of mucilage

39 kg of moist parchment coffee

100 kg of moist parchment coffee provides about:

79 kg of dry parchment coffee

54 kg of dry clean coffee

Spiller based on results presented by vitzthum published the components of green coffee. These results include the large classes of compounds proteins, carbohydrates, lipids, also volatile and non-volatile acids, alkaloids, water and partially identified compounds (Rene Coste et al, 1992). Let us see a brief review of these main components.

Minerals: Green coffee contains an average of 3 to 4 percent chemical constituents. This comprises mostly potassium, sodium, calcium, magnesium, phosphorus and Sulphur. Numerous trace elements have also been found including iron, aluminum, copper, iodine, fluoride, boron and magnesium.

Proteins: Green coffee contains a total of 1 to 3 percent Nitrogen, which is present in various combinations. The main ones being proteins and alkaloids. Several amino acids and certain Sulphuric amino acids play a major role in the formation of the aroma of roasted coffee.

Lipids: Coffee beans also contain fat, which is rich in unsaponified substances that are not eliminated during the common refining process. Arabicas are considered to be rich in oil (12 to 18 percent).

Carbohydrates: Represent more than half of the dry matter of green coffee beans. Among these, the polysaccharides are the most largely represented (over 45%), where as the content of oligosaccharide and monosaccharide is only 5 and 1 percent. Green coffee containing small quantities of free reducing sugars (especially glucose and sucrose 5 to 8 percents).

Aliphatic and polyphenolic acids: Includes different organic aliphatic acids but especially phenolic acids that have the characteristics of tannis. The usual non-volatile and volatile organic aliphatic acids have also been identified including oxalic, malice, citric, tatric, and acetic acidic.

1.3 Statements of the Problems

1.3.1. Problem Identification:

In general all the wet processing plants are situated on small stream but drains to rivers such as Gidabo, Gelans, Dawa, and Gibe. Although these rivers have adequate water flows for self-purification, the byproducts could pollute the streams until the coffee effluents are delivered to the main rivers. As discussed earlier coffee pulp, processing effluent are the major byproducts of coffee processing. Currently the actual individual processing plant capacity utilization is production of 2.8 tons parchment coffee per day; this yield is associated with byproduct of 106 ton of pulp and 216 cubic meter residual water per day. In almost all sites visited the pulp and the residual water are channeled together either to traditional pits or directly to watercourses while very few have constructed ponds with poor performances. In general the current wet coffee processing system discharges 100% of its organic pollutant to surface watercourses directly and the causes are schematically explained in a problem tree as follows.

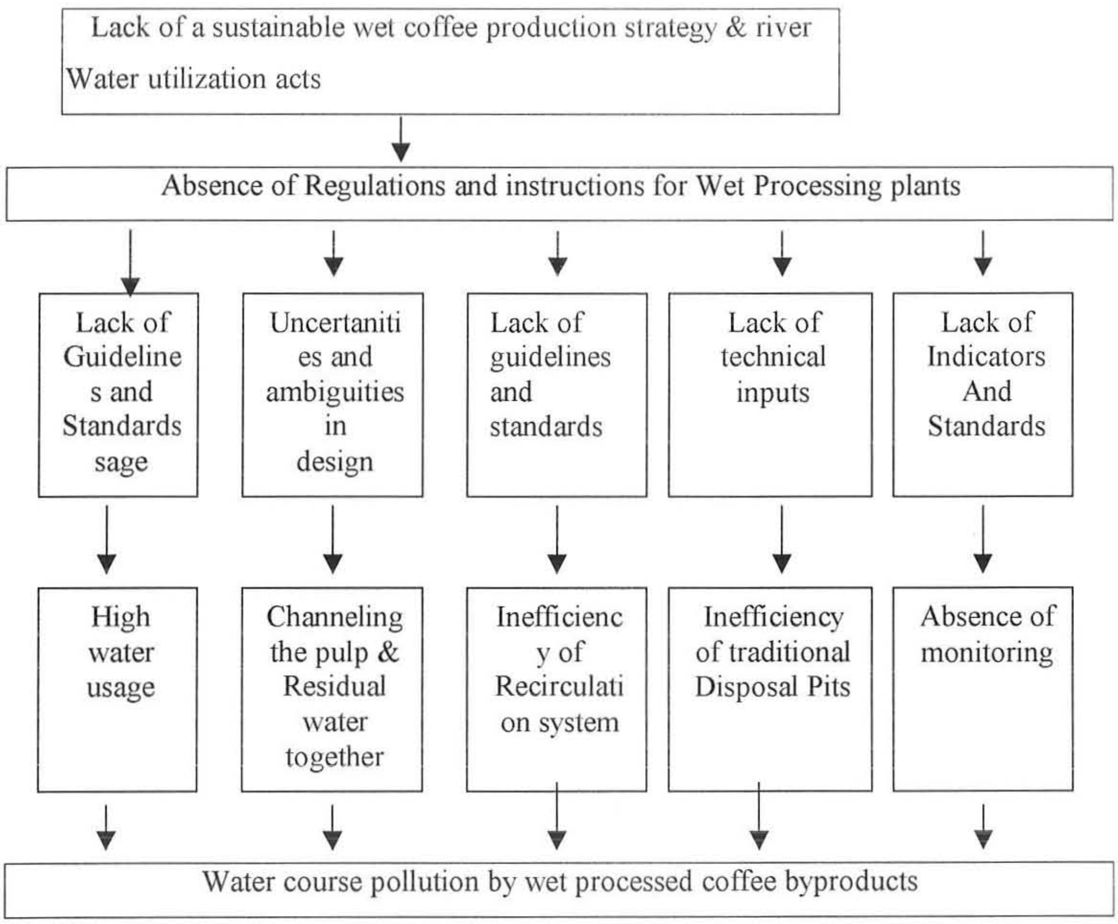

Fig.1.4. Problem tree

1.3.2. Problem Analysis

Quality coffee production being important, the environmental impact of the wet processing plants has definitely lower impact than the pollution from municipal and industrial, such as leather, textile, pints, effluents. However, the present problem has arisen due to the rapid and still expanding increase in the production of coffee during the past decade and the survey result have indications that watercourse pollution by coffee effluents would be critical. Attempts were, therefore, made to identify the causative agents of watercourse pollution and the core causative agents that need immediate interventions are discussed as follows.

High Water Usage

To achieve top quality coffee standards, coffee processing plants require clean and adequate amount of water. However, currently including allowances of water for cleaning the industry, total water consumption is about 160cubic meter for processing 2.8 tons of parchment coffee. This high water usage is attributable that most of the wet processing plants do not incorporate re-circulation system in their operations and/ or in those which have incorporated re-circulation system, in some cases the skin pumps do not function properly and on other cases the responsible personnel are reluctant to operate the re-circulation system at fulltime basis, which could be again attributed to poor cost benefit analysis of minimizing fuel costs. Generally if effectively the re-circulation system is in operation the high water usage may be reduced by more than 50% or even by 70%. While this reduces the volume of water in the system, it also concentrates the effluents from subsequent treatments.

Channeling Residual Water and The pulp Together

In theory the pulp was supposed to be damped separately form the residual water. However, the current system of the wet processing plants encourages discharging the residual water and the pulp together towards down slopes, in which gradually both drains to watercourses. Furthermore, nearly all the wet processing plants are situated on small streams and the effluent solids that are originated from mucilage removal are causing marked impact in the amenity values of theses watercourses, largely as a consequence of alteration of O_2 balance of the water environment. It was observed that some watercourse characteristically has turned in to an evil-smelling and black in color.

It is possible to predict the loading of biodegradable material that a particular watercourse is capable of accommodating, if the flow rate, dilution factor, temperature etc are known and also the strength of the inflow of the waster material. This problem is therefore, attributed to lack of comprehensive studies of the water resources during the planning sage of the wet processing plants. It may also be attributed to poor design parameters or lack of know-how in interpreting the design into the ground. All these together could be associated with lack of integrated strategies, guiding principle, regulations and policy on water use, waster discharges and treatments in the development programs of the Ethiopian Coffee Industry.

Inefficiency of the Re-Circulation system

According to the ideal design and construction, the skins and water from pulping and pre-grading are conveyed to the skin pump and pumped to up to a screen. The screen is set at an angle of 45^0 which have a mesh size of 1 by 1 mm square, and in order to prevent the adhesion of water to the underside of the screen, a buffer plate of 5 to 7 cm strips at 20 cm intervals are fixed on its underside, perpendicular to the screen. The skin will fall down on to a ramp. The water draining through the screen is used over and over again for pulping and pregrading 3to 5 times, that is until the viscosity of the water increases to such a level that can no longer be used for efficient pulping and pre-grading. The water, which has been used for pulping and pre-grading, can then be disposed into safe disposal. Compared to this analogy the efficiency and effectiveness of the re-circulation systems of those, which are operational, are very low based on visual observation and informal information, the efficiency and effectiveness of the re-circulation systems is less than 10%. These poor efficiency and effectiveness are associated with inappropriate setting of the skin (re-circulation) pump and the skin separation tower and/or due to inappropriate pumping heads. These in turn could be attributed to inappropriate design or inappropriate interpretation of the design of ground. In general the incorporation of the re-circulation systems in most of the wet processing plant lack professional compatibility.

In efficiency of the Traditional waster Disposal pits

Recent years have witnessed important progress in the development of pollution control measures in various wet coffee processing plants. A small but growing number of wet processing plants are attempting to reduce direct discharge of effluents to watercourses. Of which, it includes the limited exercise of composting coffee pulps as well as discharging residual water from pulping, pre-grading and fermentation tanks in to traditional pits. However success has not yet been demonstrated with these measures, in the case of compositing even 1% of the total pulp that is produced is not being converted to organic fertilizer, while the efficiency of the Traditional pit system is less than 10%.There size is vary small and filled within few days of processing and definitely the over flow drains to watercourses. Because of lack of proper designs the effluent after anaerobic fermentation seep to the watercourses too.

Although the local agricultural officers have suggested constructing traditional pits 25 meters faraway from stream banks, the pits require large area of flatland for their constructions sites and sufficient size, which are scarce in most of the coffee zones and suggestion was not put into practice. Conversely to minimize the impact of pollutants from the traditional pits river banks and down side of the pits could be vegetated with filter plants that can absorb or filter toxic elements such as, Vetiver Grass, Reed grass (Shenbeko), napire grass, Sugarcane, etc.

Absences of Monitoring

Actually there are standards for sitting, construction, performance and management of wet processing plants, which was developed in 1986 by ULG consultants Limited for the EX-Ministry of coffee & Tea development. These standards were developed to replace the traditional innovative designs of wet coffee processing plants of the 1950's by proven designs. As project, the beneficiaries of the project were the farmers' cooperatives and the project was implemented by PIU (project Implementation Unit) under the auspicious of MCTD and financed by the World Bank. After the market liberalization of 1994 and following the Investment proclamation of 1996, many companies jumped into wet coffee processing business to take the advantage or the stronger prices given to wet processed coffee. However many of these newly constructed wet processing plants are more or less duplicated the ULG's 1986's technical drawing. Although the design has no technical limitations' it lacks site-verification with the landscape conditions of each individual plant and with the discharges of the streams in use. Thus almost all recently constructed wet processing plants have the same capacity regardless of the size of streams they are using, regardless the size of the land they occupied or even with out taking in to account the area extents of red cherry supplies. These drawbacks could be attributed to lack of pre-feasibility studies, lack of updating the 1986's technical drawing and lack of accountable or responsible offices to monitor and inspect the feasibility and compatibility of the processing plants with localized resource basis (land, water, coffee). Thus, one can conclude that the "Universally employed" wet processing design or Technical drawing is no man's property; where as, those who had invested used it just to get official permits and licenses. Conversely, once the wet processing plat construction is officially permitted, there were no follow-ups or monitoring, whether the plant has incorporated technologies that are required to prevent negative environmental impacts or whether the plant is functioning as planned.

Additionally, suitable evaluation mechanisms are not yet established to monitor the progress of adoption of waste treatment technologies and there are no regulatory instruments to promote the adherence to technical standards. However, at Federal level, three governmental institutions directly or indirectly share responsibilities to promote environmentally sound wet processed coffee productions. The Coffee and Tea Authority is mandated to promote the quality of Ethiopian coffees (proclamation No.116/1995), while the Environmental protection Authority is mandated to prepare standards that help in the protection of water resources as well as the biological system they support (proclamation No 91/1995), on the other hand the Ministry of Water Resources Development is mandated to ensure that water resources are not polluted and hazardous to health and environment (proclamation No.197/2000), however, non of these institutions attempted to play advocacy roles to promote public awareness and /or to promote policy changes for a sustainable and environmentally sound wet processed coffee production. In view of the above facts it is high time to establish generally accepted regulations and Rules which can make the competent agency or agencies to monitor water use for the pulping hulling and washing of coffees and environmentally sound effluent disposals to water bodies.

Lack of sustainable wet coffee production strategy& policy

Despite the absence of a sustainable and environmentally sound wet processed coffee production strategies the premium quality washed coffee can sometimes command price 30% above unwashed. Thus, the portion of foreign exchange washed coffee has generated and the number of people it has employed places wet processed coffee in a distinctive role in this counter economic growth. In the future efforts to provide more washed coffee and more money, many new wet processing plants has grown up by over 1000%. It is also believed that this increase will continue and will be a giant step in the near future. Conversely, if the growth of wet processed coffee is allowed without a sustainable and environmentally sound strategies, the adverse environmental impact will be more serious. One valuable approach to address the threats of watercourse pollution by coffee effluents are to think of environmental issues on the basis of water shades, micro water shades and ecological zoning. Generally, integrated strategies for enhancing wet coffee processing, reducing water use and antipollution on a national basis have to be developed in consultations with local communities, farmers' service cooperatives, private entrepreneurs and international organizations.

1.4 Existing water resources and usage

Knowing the existing water resources and usage for the community helps to know the effects, degree and extent of the pollution. So water resources in the study area for rural drinking purposes are limited. Traditional drinking water suppliers are shallow hand dug wells with bucket systems and also from unprotected springs. In both zones (Sidama and Gedeo) rivers, which possess high contamination during coffee harvesting period, are widely used as a source of drinking water for domestic use. About 30% of the total populations have an access to safe drinking water form protected well and spring as their sources of water; while 32% used ponds and the rest (38%) used ponds, undeveloped springs & local HDW as their source of water supply. So only a small number of the rural households have access to pure drinking water and they are still subjected to the use of unclean Polluted water.

Up to a few years back the social assessment in each village reveals that drinking water supply system did not correspond with the community needs. An issue of sanitation was not an important preoccupation for most people. But as the Ethiopian government has given a top priority for the development of water resources with the immediate objective of providing clean water to the people which is also true for the SNNPR and due to the increase in the awareness the rural community about hygiene and sanitation now they are complaining about the water course pollution by the effluents from coffee processing. The table in annex-3a and annex 3b shows the water coverage and the number of water supply schemes in the study area:

1.5 Objectives

The general objective of the study is to evaluate the level of pollution of surface and shallow groundwater based on physical, chemical and bacteriological analysis of water samples.

The specific objectives include:

- A pollution source assessment with special emphasis on coffee processing industries.
- To identify pollutants of particular significance in the water environment and their origin.
- To evaluate the concentration of major pollutants;

- To identify physical&chemical parameters those have potential effects on the quality of surface and shallow groundwater in the study area.
- To indicate the degree and extent of the pollution.
- A review of possible effects on human, animal, and aquatic habitat.
- The formulation of recommendation to improve the effects.

The finding of this study is expected to assist the government by giving some suggestion and it will also act as a stepping-stone for further study. It also improves awareness of society (public), the industry managers, and the labor union to solve their problems related to coffee processing industries.

1.6 Methodologies and materials used

To accomplish the objectives of the research work the following methodologies and material has been employed after identification of the water quality problem in the area. Extensive review of available literature on different aspects of the studied area relevant to the research, including reviewing of topographic, geologic, and hydro geological maps in the area and the surrounding have been done. Other data were obtained through questionnaires, interview with rural (local) people in the study area across which a polluted surface water possess, relevant professional especially from agricultural offices governmental authorities (regional zonal as well as Woreda's) who play a vital role in decision making process, Industries owners and finally through direct personal observation (field survey).

Field equipments during the fieldwork:-

- GPS 310 model was used to get the location (longitude/ latitude) and elevation of coffee processing industries as well as the sampling point.
- PH meter, calibrated with standard solutions was used to measure the PH and temperature of the samples.
- A kit to measure total dissolved solids (TDS), Electrical conductivity (EC) and temperature of the water samples in situ.

The field survey was conducted in two periods. First season (July-September): since severity of watercourse pollution is directly correlated to the density of wet processing plants along a length of a river, from the two zones, Woreda,s that have significant numbers of wet processing plants have been identified and to get their location and elevation of the selected industries GPS was used. In each Woreda's sample wet processing plants were selected systematically with the consultation of concerned staff of Woredas and Zonal Agricultural offices.

It is during this part of the survey that in-situ measurements of physical parameters such as PH, Temperature, Electrical Conductivity and Total Dissolved Solids of water samples collected from river up stream & down stream of the coffee processing plants and from wastewater lagoon were collected. This period is selected because it is the time in which there was no any activity related to coffee processing.

Second seasons (November-January): In this period detailed geological, hydrogeolgical, land use land cover, soil, relief, rain fall mapping, in-situ field measurement of water quality parameters (EC, ph and temperature) and water samples for laboratory analysis was done.

This survey methodology also followed three parallel approaches. The first was to conduct Survey on coffee cherry in water usage, parchment coffee-out and discharge sold-out. The second was to investigate current practices of wastewater treatment and evaluate alternatives, which would be more cost effective and technically efficient. The third was discussion and interviewing wet processing plant managers and technical workers using a checklist covering a wider range of topics. Additionally relevant documents were referred and also informal discussions with professionals were carried out.

A total of 34 water samples collected during the two field seasons and samples from the 1'st field period were analyzed at the laboratory of southern Region water Resource Bureau (WRB). To identify pollutants of significant important with respect to coffee processing industries samples collected during the 2nd field trip were analyzed at the Laboratory of Addis Ababa University and Addis Ababa water and sewerage Authority.

Additional chemical, physical and Biological analysis data were taken from other sources (southern Region water Resource Bureau, Kedir Yassin (2002) and other published reports) was collected to interpret the result.

1.7 Survey Area

The assessment study covers or the survey was conducted in Dale, Dara, Wonago, Yirgacheffe and Kochore Woredess. Out of a total of 283 coffee processing plants only some of them (57 or 20% of the total) were investigated and their location with respect to latitude and longitude was taken using GPS (Annex 4).

Since the study area was vast and then due to logistical problems including shortage of finance and vehicle it was not possible to reach the whole area and investigate each of the coffee processing plants. However in all the study area i.e. in both Sidama and Gedeo zones all processing plants were follow the same trend in every aspect starting from the design, construction, the amount of water they used, also their waste disposal methods and sometimes waste minimization mechanisms. So observing this uniformity the author tried to select representative coffee processing plants and took different water samples and analyzed the results believing that the result in these representative sample area would serve for also the remaining and then the strategies or the recommendations or integrated approaches given to one area can serve for the other.

A total of 34 water samples were collected from different localities during different seasons and were analyzed in different laboratories.

The average distance between the sampling stations was ---km. Out of the 4 sub basins in the area samples were taking from wastewater lagoons, boreholes, springs and rivers drains to Gidabo and Gelana basins.

1.8 Previous works

Except one report on "Protecting water courses pollution from coffee processing industries in Southern region"(Tessema Chekun, 2000), no work has been done in a regional as well as at a national level in relation to the effect of coffee processing plants on water bodies. This imposes limitation on the preparation of this research paper.

Surprisingly the Ethiopian Environmental Protection Agency on his preparation of provisional standards for industrial pollution control in Ethiopia for different industries, they forgot or give no attention to coffee processing industries that rapidly expanding since 1996 following the investment proclamation no.30/1996 and that have a potential impact on the quality of the environment particularly water bodies.

But the most relevant works for this study includes:

- The report of Tessema Chekun in Southern region on watercourse pollution from coffee processing processing plant (2001)

- Socioeconomic and demographic profile of Sidama zone by Finance and
- Economic development Coordination Department (2004)

- Hydrogeology of upper Gidabo catchments by Kedir Yassin (2002)

- Report on hydro geological mapping of Yirgalenm and Kilsa sheet (2004)

- Preliminary survey of groundwater potential of Southern region by Kedir Yassin (2004)

CHAPTERE II

GENERAL OVERVIEW OF THE STUDY AREA

2.1. Location and Accessibility

The study area belongs in SNNPR. The northern end of the study area is about 260 km from Addis Ababa which stretches N to S from the regional capital Awassa to Gedeb (Gedeo zone) on the road to Moyale. Geographically the area is approximately bonded between 37^0 54' N to 39^0 8'm N latitude and 5^0 52' E to 7^0 13' E longitude. Physiographically it lies with in the Ethiopia Main Rift at the western edge of the rift valley lakes basin. It is bounded by Oromia region in the North, East, West, South and North Omo in the west.

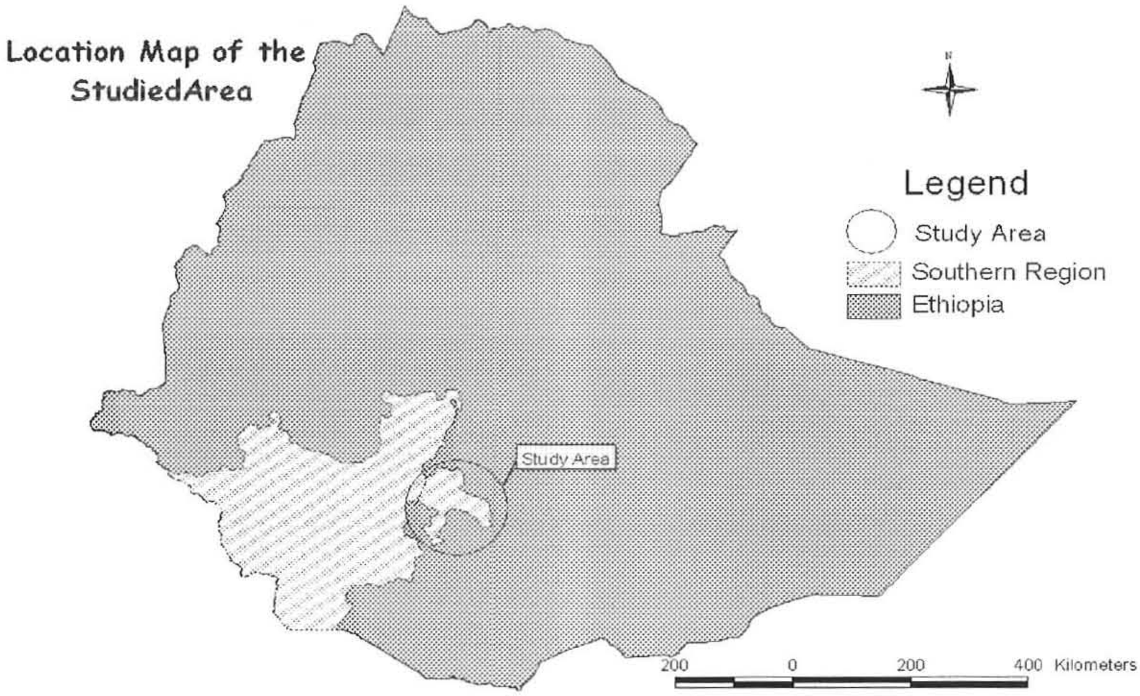

Fig.2.1 Location map of the study area.

Generally, the area is an accessible area with moderate number of roads. Two types of road exist; asphalted or gravel roads, which are all weather, and others are motorable tracks that may only be used during fair weather. Hence large part of the study area except ridges and gorges is accessible by a field vehicle.

2.2 Socio-economic condition

Agriculture is the major dominant economic activity of the study area. From the agricultural crops coffee being the major product. Agriculture encompasses growing of plants and raring animals. However due to cultural and environmental factors farmers in the zone mainly depends on production of enset and coffee for consumption as well as for commercial purposes. Traditional farming is mainly practiced in the area. According to their production and suitability, Hagereselam, Awassa, Arbegona, Aroresa and Bule woredas are termed as food growing areas while Aletawondo, Dale, Dara, Shebedino,Bensa, Wonago, Ylcheffee and Kochre woredas are coffee growing. The crops produced in the zone are annual and (perennials) such as Teff, Barely, Enset, bean, coffee and these are some of the crops grown in the area. Moreover the crops such as vegetables and fruits are also grown widely. Even though there is insignificant activity in the production of food crops, animal raring is important which is adopted side by side with crop production. Livestock production in the region is mainly attributed to the poor genetic, potential feed and health service. Livestock's are raised for various economic and social reasons. Livestock provide draught power, transport and food (milk, meat, eggs) and are a source of cash income for the farmhouse hold. Opposed to the huge number of livestock population the yield obtained is very low. Coffee is the most important cash crop grown in the area. For example if we take the case of Sidama zone about 75, 4287 hectares of land is covered with local and improved varieties of coffee trees. The average land covered by coffee for each farmer is estimated to 0.415 hectare. Coffee was delivered to central market by private farmers and co-operatives. The amount of washed coffee delivered to the central market in 2004 as estimated to 20,469 tones. There are a total of about 283 private and co-operative pulping industries and also 57 private and co-operative hulling industries in the region.

Small private farms are the major source of crop production. Most crops are produced in the Meher or major rainy season, while lesser portion of crop production is attributed to big or short rainy season. In the area individual farmers own agricultural land. Land holdings in most part of the area are small mainly due to high population density. Agricultural production is highly dependent on traditional farming practices. The uses of modern agricultural practices are at a relatively low level. Even if not satisfactory, social services such as schools, health centers, water supply: infrastructures such as roads, electric light, postal and telephone services, bank and insurance present at a relatively higher coverage in urban than in the rural villages and towns.

2.3 Demography

Understanding of the human population dynamics is extremely important when considering the impact of various human activities up on surface waters as well as the water supply aquifers.

The 1994 housing and population census showed that the studied has a total population of 2,428,771. Mean while the projected population of the study area in the year 2005 will be 3,566 478. The results of 1994 census showed that out of the total population in the region, 1,268,192 are male and 1,218 459 are female. The average population density of the region is 494 persons per sq. km. The study area is one of the most densely populated areas in the regions. Even in the area there is a great variation in population size from one Woreda to another Woreda. For example Aroresa Woreda, which is found in Sidama zone, is sparsely populated having 157 people settled in per km^2 where as in highly populated Woreda such as Wonago in Gedeo Zone 1014 people settled per square kilometer.

In the area the population is not evenly distributed in the all Woreda's. The peoples are highly distributed in areas where there is fertile land, available water and pastures. In some cases mostly in Sidama zone population distribution is sparse due to different reasons such as the tropical disease like in malaria. However, the people of the whole study area widely distributed in 13 Woreda's. One of the most populated areas is Wonago in Gedeo zone and Awassa Zuria in Sidama zone. Awassa Zuria, Dalle, Aletawondo, Wonago, Kochore and Yirgacheffee woreda population accounts for 52.07% of the total population of the study area. In these areas there is much shortage of farming and pastureland due to high population density. In most rural areas of Sidama and Gedeo zones family planning is not accustomed. In this case the number of population shows increasing alarmingly so that much work is expected from the health service sector in this issue. The zonal governments took measurements in order to alleviate or minimize the cultivation land problem by the settlement program. Many farmers in the study area settled in the fertile lands of southwest Ethiopia by the action of the above settlement program. This action may help or solve the problem to some extent but what is expected for long life? Table in annex 4 shows number of rural & urban population by sex & Woredas

The 6 coffee producing woredas namely Aletawondo, Dale and Shebedino in Sidama zone, as well as Wonago, Yrgacheffe and Kochore are suffering from high population explosion.

Coming to population composition of the study area, age structure of a place can be a factor and indicator of socio-economic condition of a place. The age composition of the area shows the feature of most developing countries. That means higher concentration of young and dependent age group while there number starts to decrease towards the working age because of high mortality rate. In the area young age group (1-4) contain 41%, working age group (15-64) containing 57% and the remaining 2% is old age groups. From the above figure one can easily understands that 43% of the young and old age population is dependent on the 57% of the working age population. When we come to sex composition 51% is male while the remaining 49% is female. The following figure (Fig.2.2.) shows population growth vs. year.

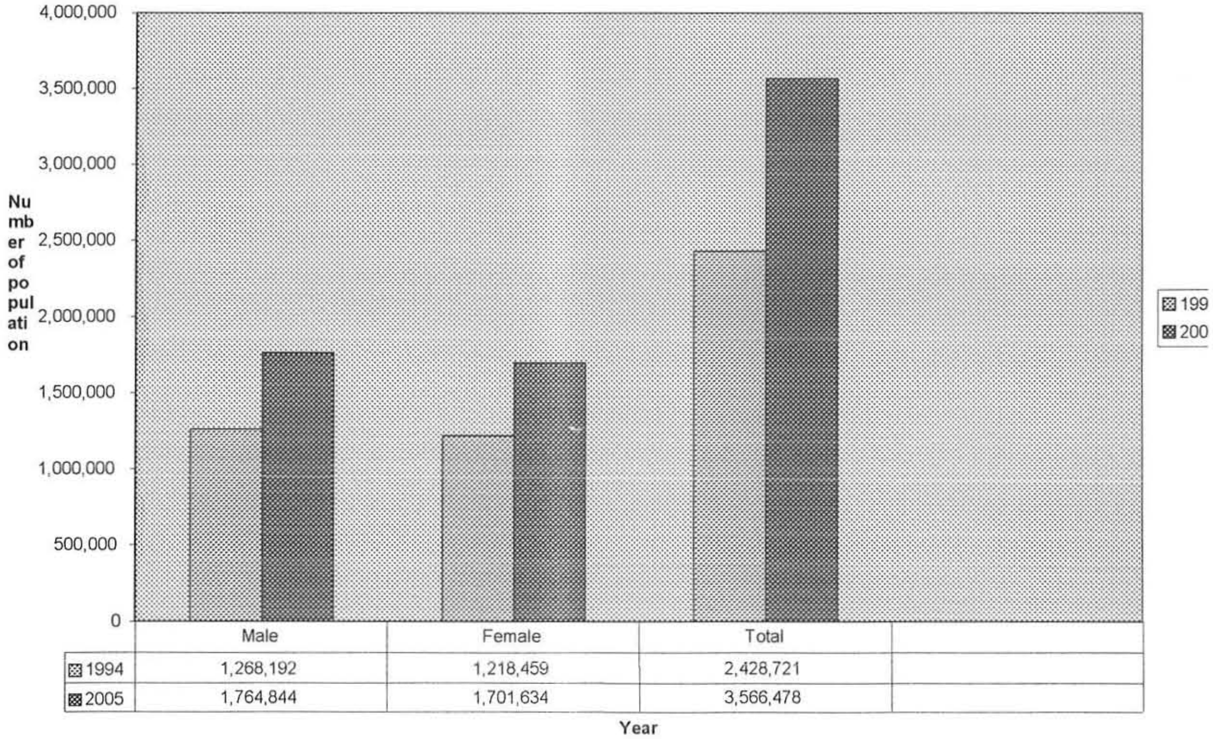

Fig 2.2. Increase in the number of population vs. year

2.4 Landcover

The area investigated is an agricultural area where different crops are cultivated in the raining season. Irrigation is not a common practice. For example the total area of Sidama zone, which has somewhat similar Agro-ecological social and economic trend as Gedeo zone, is estimated to be 720,000 hectares.

Out of this 353,629 ha is for crop production, 134,863 ha is grazing land, 47,703 ha is forest areas, 95649 cultivable, 58793 uncultivable and 31,163 ha covered by others. About 75428 ha of land are covered with local and improved variety of coffee trees.

CHAPTER III

CLIMATE, RELIEF AND SURFACE WATER HYDROLOGY

3.1 Reliefs and Climate

The study area has different land form characteristics varied from high mountains up to lowlands like different parts of the country. In Sidama the altitude varies from the highest peak of Geramba mountain 3300 m.a.s.l up to lowlands 1190m around Bilate River. Most part of Sidama area has relatively lower altitude ranging from 1501-2000 m a.s.l containing 46.34%. While the highland contains only lower proportionality 0.6% ranging forms 3001-3300 m a.s.l. From the above proportion one can clearly understand the Sidama has relatively moderate altitude. The remaining 20.57% and 20.43% is covered with altitude ranging from 2001-2500 and 2500-3000 m.a.s.l. respectively.

In Gedeo, which is located on the escarpment, has a wide variation of altitude. The elevation varies from 2993m in Benti gore ridge to 1400m around Sala River. The altitude of the escarpments is lower towards the west & NW, but higher towards the East and northeast.

The relief feature of any region can affect its physical, social and economical characteristics. It is common that topography and climate condition of any place is highly related. From this most of the Sidam's climatic condition can be described as "Kola" or worm temperature zone containing 46.34% of the zone followed by" Woinadega "and "Dega" climatic condition contains 20.45% and 20.50% respectively. While "Bereha" and "Worich" climatic conditions contain the remaining minute proportion.

While in Gedeo climatic condition of most part of the area (67%) can be described as Woinadega followed by Dega and Kola climate condition, which contains 30 and 3% respectively.

Table 3.1: Relief features of the zone

Altitude (ma.s.l)	Area ($Km^{2)}$
1501-2000	3336-669
101-1500	890-648
2001-2500	1470-734
2501-3000	1461-231
3000-3500	40-536

Table 3.2: Agro ecological zone

Agro-ecological zone	Area ($km^{2)}$
Wet (moist dega) 1499.0749	
Wet (moist weina dega)	3868.319
Dry weina dega	946.082
Dry Kola	647.361
Wet moist Berha	238.298

3.2 Temperature

Under Normal Conditions, air temperature decrease with increasing altitude at a mean rate of 0.7^0c for every 100m (Fetcher, 1981). This works also in Ethiopia where temperature decreases with increasing elevations. Generally the temperature of a place depends up on some or all of the following factors such as latitude, altitude, ocean currents, and distance from the sea, Winds, cloud cover, length of day and amount of dust particles and other impurities in the air. In the study areas, seasonal variations in temperature are controlled by prevailing winds over the region and pressure developments and migration of the inter tropical convergence zone (ITCZ) due to the movement of the sun north and south of the equator. Atlantic and Indian oceans have direct influence on the climatic (mainly temperature) conditions of the area. The monthly mean maximum and minimum temperature recorded of different observations such as Yirgalem, Awassa, Hagreselam, Dilla and Yirgacheffe for the years between 1994-2003, can be used to calculate monthly and annual average temperature.The computed average maximum and minimum is presented in annex 5.

It was shown in (Annex 5) that the highest mean monthly maximum temperatures at Awassa occur in the month of February ($30.7^{0\ c}$) and the lowest in the months of Dec ($10.1^0{}_C$). While the mean monthly minimum temperature ranges from the lowest in the month of July (14.6^{0}c).

In Yirgalem the highest mean monthly maximum temperatures occurs in the month of Feb. (29.5^{0}c) and the lowest is in the month of Jan (10.65^{0}c). While the mean monthly minimum temperatures ranges from the lowest in the month of Jan (10.65^{0}c) to the highest in the month of Aug. 12.4^{0}C

In Hagereselam the highest mean month maximum temperature occurs in the month of Feb. (21.7^{0}c) and the lowest in the month of Jan. (7.7^{0}c). While the mean monthly minimum temperature ranges from the lowest in the month of Jan. (7.7^{0}c) to the highest in the month of April. (9.3^{0}c).

In Dilla the highest mean monthly maximum temperature occurs in the month of February. (30.5^{0}c) and the lowest is in the month of Dec. (10.3^{0}c). While the mean monthly minimum temperature ranges from the lowest in the month of Dec. (10.3^{0}c) to the highest in the month of June (15.4^{0}c).

In Yirgacheffe the highest mean monthly maximum temperature occurs in the month of Feb (28.3^{0}c) and the lowest is in the month of Dec. (7^{0}c). While the mean monthly minimum temperature Ranges from the lowest in the month of Dec. (7^{0}c) to the highest in the month of July (11.8^{0}c).

Generally mean annual temperature ranges from 8.3^0 c at Hagereselam to 27.6^0 at Dilla.

Table3.3: - Annual average to hottest month & coldest month of the towns

Station	**Altitude**	**Annual Average Temperature**	**Hottest month**	**coldest month**
Awassa	1700	20.1	February	December
Yirgalem	1750	19.0	"	January
Hagereselam	2300	13.45	"	"
Dilla	1560	19.7	"	December
Yirgacheffe	1750	17.7	"	December

3.3 Precipitation

The variation in the seasonal distribution of rainfall in Ethiopia can be attributed with reference to the position of the inter tropical convergence zone (ITCZ), the relationship between upper and lower air circulation, the effect of topography, the role of local convection currents and the amount of rainfall. Regarding the type of precipitation in Ethiopia, Hadwen (1975) stated that there are very few areas in the country where snow is an important type of precipitation but hailstorms are quite common in the rainy season especially in areas above 2,000m.a.s.l. From all forms of precipitation rain is the most common form of precipitation in the study areas. Precipitation in each area is recorded by rainguage. In the study areas rainfall records are available from currently operating rainguage stations, (data source is from national meteorological service agency) located at Awassa, Leku, Yirgalem, Hagereselam, Aletawondo, Kebado, Dilla, Yirgacheffee, Chelelektu and Bule at an elevation of 1700, 1850, 1750, 2300, 1900, 1800, 1560, 1750, 1680, and 2200 with Rainfall records from 1994-2002, 2001-2003, 1966-2003, 1994-2003, 1965-2003, 1994-2003, 1966-2001, 1966-2003 and 1985-2003 respectively.

In this paper, monthly total rainfall records of 8 stations for the year specified above is used to analyze monthly mean rainfall, annual mean rainfall and rainfall coefficient (Table 3.4). As indicated in Annex 6 and figure3.1.the precipitation occurs throughout the years and shows variation in amount from season to season.

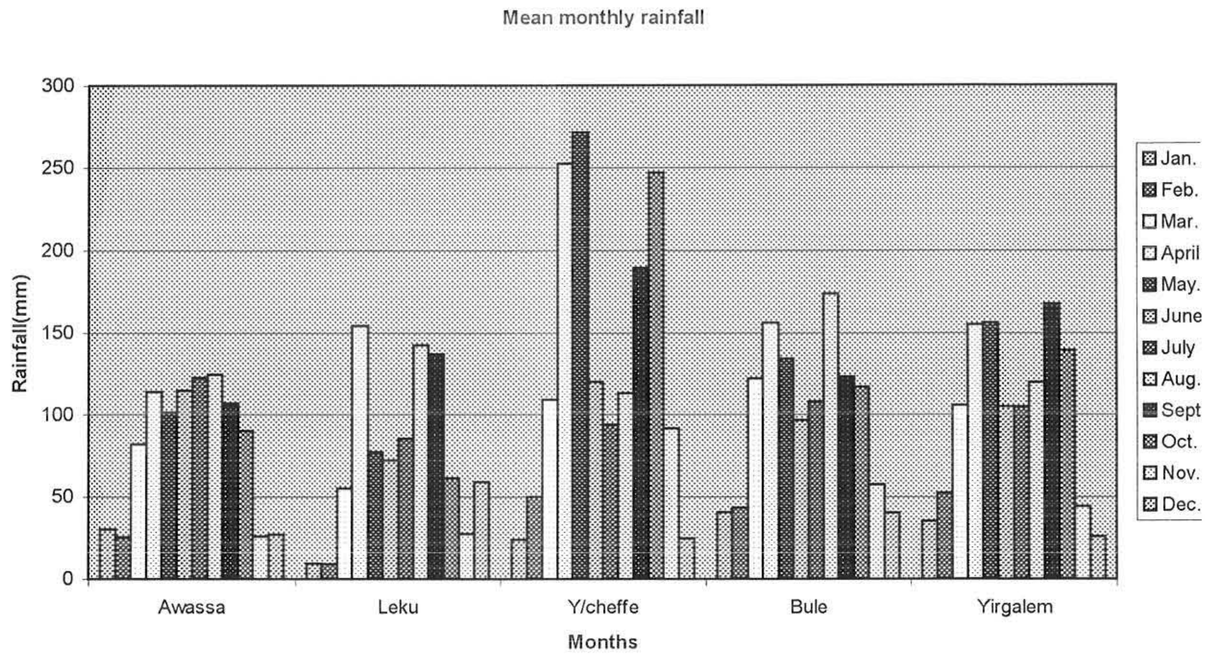

Fig 3.1 Mean monthly rainfall for selected station.

The monthly mean records of rainfall shows that the mean annual rainfall at Awassa (an elevation of 1700m), Yirgalem (at an elevation of 1750 ma.s.l), Leku (at an elevation of 1850 ma.s .l), Hagereselam (at an elevation of 2300 ma.s.l), Aletawondo (at elevation of 1900),kebado (at an elevation of 1800 ma.s.l), Dilla (at an elevation of 1560 ma.s.l), Yirgacheffee (at an elevation of 1680 ma.s.l) and Bule at an elevation of 2200 are 965.4, 1211.3, 890.1, 1300.2, 1519, 1465, 1311, 1588.3, and 1212.9mm respectively. The following map describes the generalized mean annual rainfall of the study area and from this we can see that the part of the study area that is shaded with yellow colour (Yirgacheffe Woreda) has a higher mean annual rainfall than the other.

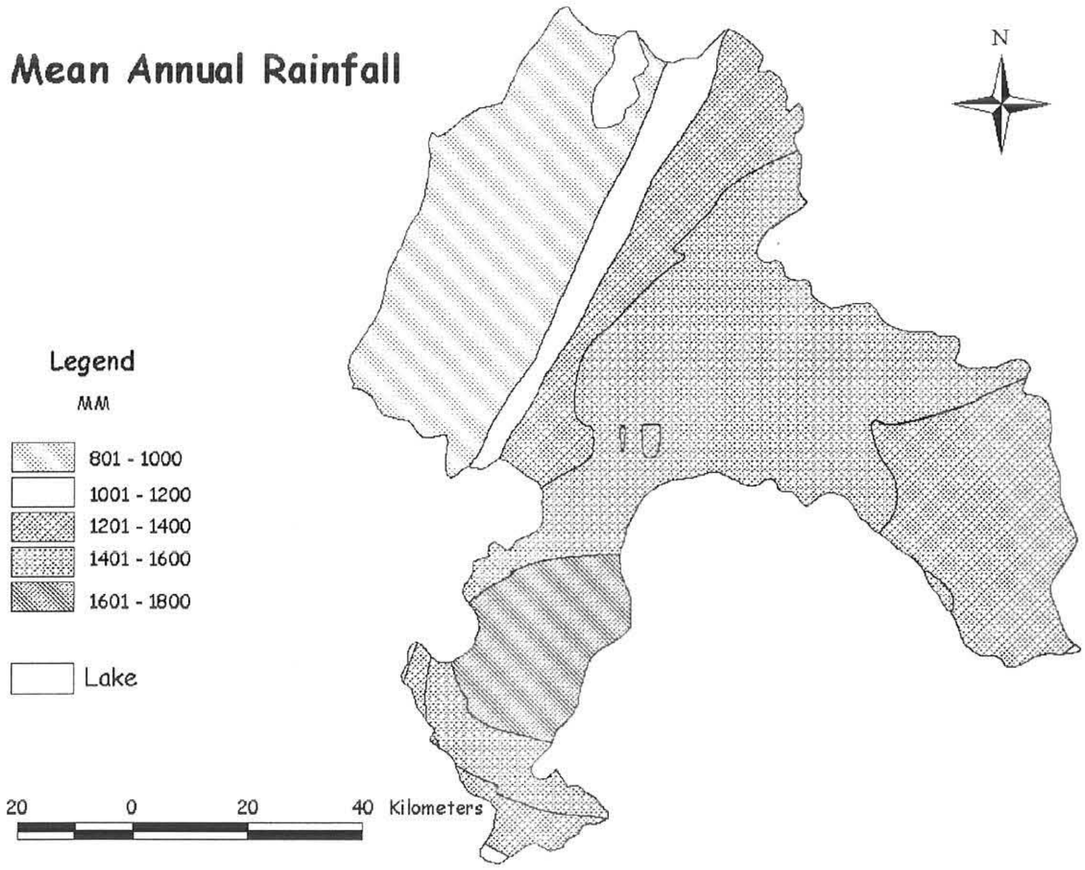

Fig3.2.Mean annual rainfall of the study area

Mean monthly Rainfall for some station is presented in figure3.3. Moreover in all stations the heaviest amount of rainfall occur in the months of April, may, June, July, August, Sept, October, with the highest RF in the month of April and May. Lowest rainfall was recorded in the month of January and February. The highest rainfall recorded is 271.3 at Yirgacheffe and minimum is 9.3^{0}c at Leku, hence this shows a negative correlation between elevation and precipitation for the stations in the study areas for the specified period of time.

The above data also reveals that in the study area more than 60% of the total amount of RF occurs in the months of April, May, June, September and October.

To distinguish between "rainy" months and "dry months", it is necessary to calculate the RF coefficient (RC) of each months in all stations which is given by

RC= P (m)

1/12P (Yr)

Where P (m) = mean monthly precipitation.

P (yr) = mean annual precipitation.

A month is distinguished as rainy when the corresponding monthly rainfall coefficient reaches 0.6; where as dry month has less than 0.6 rainfall coefficients. Danieal (1977) classified rainy months of Ethiopia in to small rains (0.6 to 0.9) and big rains (1.0 ad over). The big rain months are further classified into three groups as:

$1 \leq RC \leq 2$ – big rainy months with moderate concentrations

$2 \leq RC \leq 3$ – big rainy months with high concentration

$RC \geq 3$ – big rainy months with very high concentration

Table 3.4 Rainfall coefficients

Station	Jan	Feb	Mar	April	May	Jun	July	Aug	Seb.	Oct.	Nov.	Dec
Awassa	0.37	0.31	1.02	1.42	1.26	1.43	1.52	1.54	1.33	1.12	0.32	0.33
Leku	0.13	0.12	0.74	2.08	1.04	0.97	1.15	1.92	1.85	8.83	0.37	0.8
Yirgalem	0.35	0.52	1.05	1.53	1.55	1.04	1.04	1.2	1.66	1.38	0.44	0.25
Hagereselam	0.49	0.58	0.7	1.45	1.47	1.1	1.09	1.63	1.26	1.38	0.54	0.26
Aletawondo	0.27	0.44	0.84	1.72	1.85	1.12	1.11	1.11	1.52	1.33	0.142	0.24
Kebado	0.27	0.29	0.98	1.87	1.86	1.17	0.8	1.00	1.36	1.43	0.5	0.43
Dilla	0.27	0.46	0.96	1.85	1.89	0.99	0.92	0.87	1.54	1.38	0.6	0.24
Yirgacheffe	0.18	0.38	0.83	1.91	2.05	0.9	0.72	0.86	1.43	1.87	0.69	0.18
CheleleKtu	0.19	0.42	1.08	2.08	1.85	1.15	0.49	0.58	1.13	1.93	0.82	0.28
Bule	0.4	0.43	1.21	1.55	1.33	0.96	1.07	1.72	1.22	1.16	1.56	0.39

From the analysis of seasonal variability of rainfall in each of the stations, it can be observed that the rainfall have a bi-modal pattern in all station having the first peak from march to may and the second in September and October (figure3.1)

As it is shown above, the rainy months in the area range from the month of March to October and 4 dry months from November to February. The small rains occur in December & March in Leku station, March in Hagereselem and Aletawondo, July in Kebado, August in Dilla, March, July, August & November in Yirgacheffe, November in Chelelektu; the big rain is from April to October in all stations with high concentration in April and may in Yirgacheffee and Chelelektu stations.

The mean yearly rainfall depth of the study area is 1293.8mm for the specified year. The calculated mean monthly rainfall depth of the area for the same year is presented in the following table.

Table 3.5: mean monthly rainfall depth for the studied area.

Months	Jan.	Feb.	Mar.	Apr.	May.	Jun	July.	Aug.	Sep.	Oct.	Nov	Dec.	Annual mean
RF (mm)	31.3	42.8	99.5	185.4	176	114.2	102.4	126.8	150.6	150	568	342	1293.8

3.4 Drainage and River Basins

There are a number of different scale perennial and intermittent streams and gullies, which usually originate from the sides of the sloppy scarps and ridge flow in to Lake Abaya via major rivers such as Gidabo, Gelana and Bilate River. Some of the intermittent and perennial streams such as the eastern part of the studied area Hulla, Arbegona, Bensa and Boricha, Logita, Bonora, Getancho, Adilo, Asaro and Gambello are the tributaries of Genale river which drains in to Genalledawa basin the three main perennial rivers which flow in to the lake Abaya are Gidabo, Gelana and Bilate river which join the lake at east, south east and north direction respectively. The region can be divided in to two major drainage basins namely the rift valley lakes basins which is the largest basins in the studied covering approximately 80% of the studied area, and the other Genale dawa basins that rises from the eastern highlands of sidama zone (Hulla and Arbegona). Again the rift valley Lakes basin can be divided into four sub basins called Bilate, Gidabo Gelana and Awassa basins.

Gidabo River

The Gidabo River rises in the highland area of the wondo escarpment. It is joined by numerous large tributaries draining extensive catchments with in the eastern highlands and the Yirgalem dissected plain make in et al (1975). The main Gidabo rivers extreme catchments boundary extends in between 6^0 57 20" & 6^0 57 3" N and joins the Abaya Lake as an Eastern tributary at 6^0 33'N & $38^0$2.5 'E.The total drainage area of Gidabo is 3446.62 km^2.

The annual flow of Gadabo at Aposto reaches a mean value of 7.5 m^3/s and the other two tributaries Kola and Bedessa are having 2.74$m^{3/s}$ and 2.03m^3/s respectively.

Gelana River

The Gelana River starts from Yirgacheffee and flows southwards and passes Chelelektu and enters narrow gorges. The total catchments area of this river is 3463.2km^2 . This river is also one of the rivers that contribute significant quantities of flow to Abaya Lake.

Bilate River

The Bilate River which contributes significant quantity of flow to the Lake Abaya enters to the lake at its northern tip. The total drainage area of this river is 5,756.9-km2 .Bilate is considered as one of the most important rivers because of its suitability mainly for irrigation development activities and its current level of use. Currently the river is utilized for activities of Abaya state farms prison farms and chicho state farm.

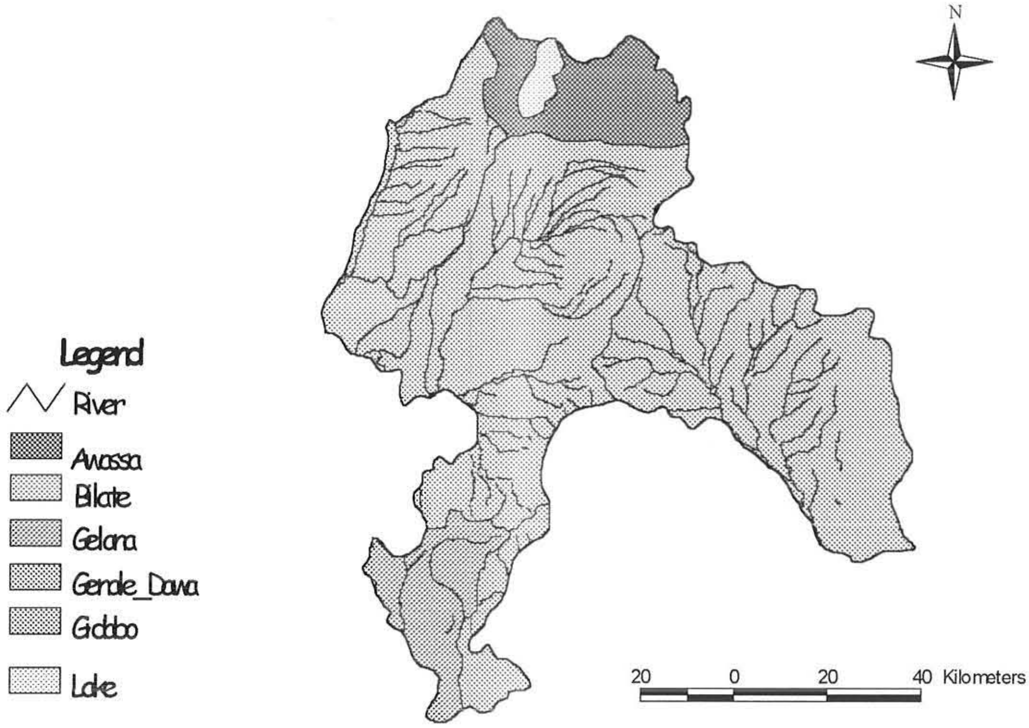

Fig 3.3.Basins and sub basins in the study area

CHAPTER IV

RESULT AND DISCUSSION ON WATER QUALITY /POLLUTION PARAMETERS

4.1. General

In view of the complexity of factors determining water quality and the large choice of variables used to describe the statistics of water bodies in quantitative terms, it is difficult to provide simple definition of water quality. Furthermore, our understanding of water quality has evolved over the past century with the expansion of water use requirements and the ability to measure and interpret water characteristics. To the purpose of this paper the following definitions have been accepted (Deborah Chapman, 1996)

Quality of the aquatic environment:

1 Set of concentrations, speciation, and physical partitions of inorganic or organic substances.
2 Composition and state of aquatic biota in the water body.
3 Description of temporal and spatial variations due to factors internal and external to the water body.

Pollution of the aquatic environment:

Introduction by man, directly or indirectly, of substances which result in such deleterious effects as:

1 Harm to living resources
2 Hazards to human health
3 Hindrances to aquatic activities including fishing.
4 Impairments of water quality with respect to its use in agricultural, industrial and economic activities, and
5 Reduction of amenities.

Each water use including abstraction of water and discharge of wastes, leads to specific, and generally rather predictable, impacts on the quality of the aquatic environment. In addition to these intentional water uses, there are several human activities, which have indirect and undesirable, if not devastating effects on the aquatic environment. Examples are uncontrolled land use for organization or deforestation, accidental (or unauthorized) release of chemical substances, discharges of untreated wastes or leaching of noxious liquids from solid wastes deposits. Similarly, the uncontrolled and excessive use of fertilizer and pesticides has long term effects on ground and surface water resources.

4.1.1 Surface water pollution:

Every human's activities affecting watershed components can have a strong impact on the surface water pollution.

One-way people influence surface water composition is by adding potential pollution sources to the watershed. There are many different materials that may pollute surface water and groundwater. The identification of pollutants is limited to the results of chemical of organic, inorganic and bacterial analysis of water samples.

As for groundwater, surface water pollution can derive from point sources and distributed non-point sources. Run off over watershed or punctual discharges of industrial and urban wastewater determine an immediate and direct contact between pollutants and superficial water bodies, which consequently attain high concentrations of most all type of pollutants. In the case of groundwater only some contaminant (the more soluble ones) are of serious concern as soil and rock layers above aquifer act as an active filter for most of the compounds dissolved or suspended in the leach ate.

Therefore while for groundwater the pollution problem, even if of great hazard is limited to dissolved mineral (such as nitric and chloride) to the most soluble heavy metals and to some organic compound (such as pesticides) there are no limits to the type and to the concentration of substance which can enter surface waters.

The major sources of pollution to fresh water originate from discharge of domestic wastewaters, industrial wastes, agricultural activities such as animal husbandry and use of chemicals (Rao, 1996, Manahan, 1991).

Domestic wastes are those wastes generated from commercial establishments and residential activities. They are the primary source of organic waste released in to fresh water (Tesfaye, 1988 referred in Deshu Mamo, 2004). Pollution of rivers and lakes with organic matter results in extensive fish kill and destruction of other organisms due to an increase in organic load and the concomitant depletion of dissolved oxygen in water. When fish or other organisms are not immediately killed they accumulate pollutants like toxic heavy metals, which are eventually transferred to man via the food chain (Ogabanna et al., 2002)

The pollutant components of industrial wastewaters are of great diversity in composition depending on production process, raw materials used in the process, technology and of the industry treatment levels before discharge (Ayres, 1966).

The potential high-risk pollutants are toxic heavy metals such as Cd, Pb, Zn, Cr, etc. (Dawodu, 1986; Rhem et al, 1999). Heavy metals generated from industry may cause different environmental risks through damaging aquatic life, plants, animals and humans.

Similarly inorganic nutrient like nitrate and phosphate have negative impact on human and aquatic eco-system. High concentration of nitrate in drinking water has the potential health risk that causes a disease known as methaemoglobinema in infants and pregnant women. High nitrate containing water creates conditions that prevent the baby blood syndrome" that occasionally causes fatal effects.

The characteristics of industrial wastewaters can differ considerably both with in and among industries. The impact of industrial discharge depends not only on their collective characteristics such as biochemical oxygen demand and the amount of suspended solids but also on their content of specific inorganic and organic substances.

4.1.2. Groundwater pollution

Entry of pollutants in to shallow aquifers occurs by percolation from ground surface. through wells, from surface waters and by saline water intrusion. The extent of pollution in groundwater from a point source decreases as pollutants move away from the source until a harmless or vary low concentration level is reached. Because each constituent of a pollution source may have a different attenuation rate, the distance to which pollutants travel will vary with each quality component.

The sources and causes of groundwater pollution are closely associated with human use of water. Most pollution originates from the disposal of wastewater following the use of water for any of wide variety purposes. Thus a large number of sources and causes can modify groundwater quality, ranging from septic tanks to agricultural activities (Todd, 1980).

Municipal, agricultural and industrial wastes entering an aquifer are major sources of organic and inorganic pollution. Large-scale organic pollution of groundwater is infrequent, however, since significant quantities of organic wastes usually can't be easily underground. The problem is quite different with inorganic solutions, since these move easily through the soil and once introduced are removed only with great difficulty. In addition the effects of such pollution may continue for indefinite periods since natural dilution is low and artificial flushing or treatment is generally impractical or too expensive.

The data collected and analyzed from groundwater in this work are very limited to characterize groundwater pollutant well. In spite of its limitation to characterize the specific pollution parameter in relation to the Coffee processing plants previous chemical analysis results have been used. As we discussed earlier, entry of pollutants in to shallow aquifers occurs by percolation from ground surface, through wells and from surface waters and the extent of pollution in groundwater from a point source decreases as pollutant moves away from the source. In the case of the study area during field investigation only three water samples were taken from underground source (spring and boreholes) and analyzed for their physical and chemical characteristics. The organic pollutants are analyzed only in samples collected from actual field observation where as other chemical parameters such as major and minor ions were analyzed in water samples collected from other sources of previous study.

4.2. Result

Regarding physical parameters for water samples collected during coffee harvesting period the highest value of pH was 4.85 units upstream of Dilla treatment plant at Dara river where as the lowest value was 3.77 from wastewater lagoon. Where as water samples collected during the other seasons from wastewater lagoon as well as immediate downstream of the lagoon to observe the effect of seepage was 6.6 and 4.4 units respectively.

pH value taken from other previous sources and collected during the period in which there was no coffee processing activities shows that the value ranges between 6.6 and 8.39 in wells and between 6.97 and 8.12 in rivers.

The highest temperature value recorded in the analysis was 25.6^{0}c in water sample collected from traditional lagoon and the lowest temperature value recorded in the sample analyses was 12^{0}c.

The WHO 1971 International standard for substances and characteristics affecting the susceptibility of water for domestic use shows that the highest desirable level is 5 formazin turbidity units and the maximum permissible level is 25 formazin turbidity units.

Coming to the measured value of the turbidity of the water samples collected from the study area out of 19 samples the highest value was recorded at S_{16}. It was also observed physically that the surface water was covered with coffee pulp especially near and below the coffee processing plants.

The maximum COD and BOD values were recorded in Melkadimtu River downstream of Alem Asefa coffee processing plants having values of 24600 and 10604 mg/l respectively. Where as the lowest concentrations were recorded in Bentinenka River upstream of Membea coffee processing plants having recorded values of 25 and 14 mg/l respectively.

The highest BOD and COD concentration in water samples collected from borehole was 12 and 21mg/l respectively where as the lowest was 1.6 and 4mg/l.

The maximum DO concentration in river water was 16.3mg/l at Bentinenka River around Dilla and 17.6mg/l at Chichu borehole and the lowest (0.77mg/l) was recorded in Melkadimtu river down stream of Alem Asefa coffee processing plants in yirgacheffe woreda.

The highest concentration of NH_3 –N in the river water samples was 74mg/l in Melkadimtu River and 0.5mg/l in chichu borehole, where as the lowest was 2.2mg/l in Kola River near motto kebele and 0.3mg/l in protected spring.

The highest NO_3- concentration in the river water sample was 13.64 mg/l in Gidabo River at gauging station and 16.28mg/l in Dilla college borehole where as the lowest was 7.04 mg/l in Kola River at gauging station and nil in boreholes at Donbosco selesian fathers Dilla town

The highest NO_2 – concentration was 60mg/l in Melkadimtu River where as the lowest was nil in Chichu and Dara river in which their water samples were taken during March 1999 when there was no coffee processing activities.

The chemical analysis results of major ions in the water bodies show a considerable variation. . In general the dominant cation in the samples is Sodium (Na) and the anion bicarbonate (HCo_3), thus Na-HCo3 type of water is the dominant type of water in the rivers. The following table shows the concentrations of major cations and anions in the river.

Table 4.1 Major cations and anions in the river.

	Major ions (mg/l)						
	Na	K	Ca	Mg	HCO_3	SO_4	Cl
Minimum	0.04	1.5	4	2.43	7.33	nil	2.5
Maximum	17.86	5.08	20.8	7.29	85.4	4	25

Table 4.2.Major Cations and anions in groundwater

Amount	Major ions (mg/l)						
	Na	K	Ca	Mg	HCO_3	SO_4	Cl
Minimum	12.45	3.13	11.2	2.3	4088	Nil	1.2
Maximum	304.3	11	44	19.2	732	95	2.0

As compared to the other water bodies the river water is less enriched with major cations and anions.

The highest TDS and EC value was 280mg/l and 560 µs/cm respectively in river water sample taken from Dara River upstream of Dereje coffee processing industries. The lowest value was 30mg/l and 60.6 us/cm in Dara River down stream of Dereje coffee processing plants.

A total 34 samples collected during coffee processing time and a total of 14 river water samples collected during summer season when there was no any coffee processing activities.

Out of these, 9 water sample analyses were taken from previous works in the study area especially from Msc. thesis of Kedir Yassin.

The highest NH_3 concentration (0.378mg/l) was recorded in Chichu Gabriel borehole where as the lowest was nil in both Dilla college and Donbosco salesian fathers around Dilla town.

The highest NO3-N (11.2 mg/l) was recorded in sample taken from wastewater lagoon where as the lowest (nil) concentration was recorded at downstream of Fitche coffee processing plant in Kola River at Aleta wondo woreda. Unfortunately the NO_3-N analysis was done only for 7 samples and the above Comparison was done based on this fact.

The highest concentration (60mg/l) of nitrite (No_3-) was recorded in Melkadintu River downstream of Alem Asefa coffee processing plants where as the lowest concentrations was recorded in river water.

The maximum ammonium ion NH_4^+ concentrations (95mg/l) was measured in melkadimitu and the lowest concentration was 0.4 mg/l recorded at water sample taken from well developed spring. Here the lowest concentration which is almost equivalent to the former was recorded at water samples taken from boreholes in different localities.

The highest ammonia (NH3) concentrations (90mg/l) was recorded also in the above river and the lowest concentration were recorded at water sample collected from well developed spring. Water samples taken from deep wells at different localities have almost similar concentrations as the above value.

The highest acidity value (as Ca co_3) recorded was 120mg/l at Gelana river where as the lowest was 35 mg/l upstream of Dilla treatment plant in Dara river. Total alkalinity as $Caco_3$ was not recorded at any of the water samples collected in the study area.

The highest total hardness as $Caco_3$ (108mg/l) was recorded at water sample collected from wastewater storage lagoon where as the lowest value was almost similar in the remaining sampling station between 82 and 86 mg/l.

When we see other chemical parameters such as TDS and conductivity, the highest values of TDS was 1162 mg/l in water samples collected from wastewater lagoon during coffee processing period and 645 mg/l in other seasons. Where as the lowest concentrations was 82 mg/l during coffee processing season and 12mg/l during the other season.

The highest Electrical conductivity (EC) value recorded for water samples collected during coffee processing period were 2230ms/cm where as 1287 for the other season from wastewater lagoon. The lowest EC value recorded for the 1st season was 176 mg/l where as 55.4mg/l in Dara River for water sample collected during September where there was no coffee processing activity was taken place.

Out of five samples that were analyzed the highest concentration of phosphate recorded in the period where coffee harvesting and processing activity taken place was 4.4 mg/l where as the lowest concentration was nil in the other four sample

The highest chlorine concentration (37·5mg/l) was recorded at where as the lowest was recorded at S_{24} upstream of Dilla treatment plant. No Chromium (Cr) and hydrogen sulphide (H_2S) were recorded in any of the analyzed samples.

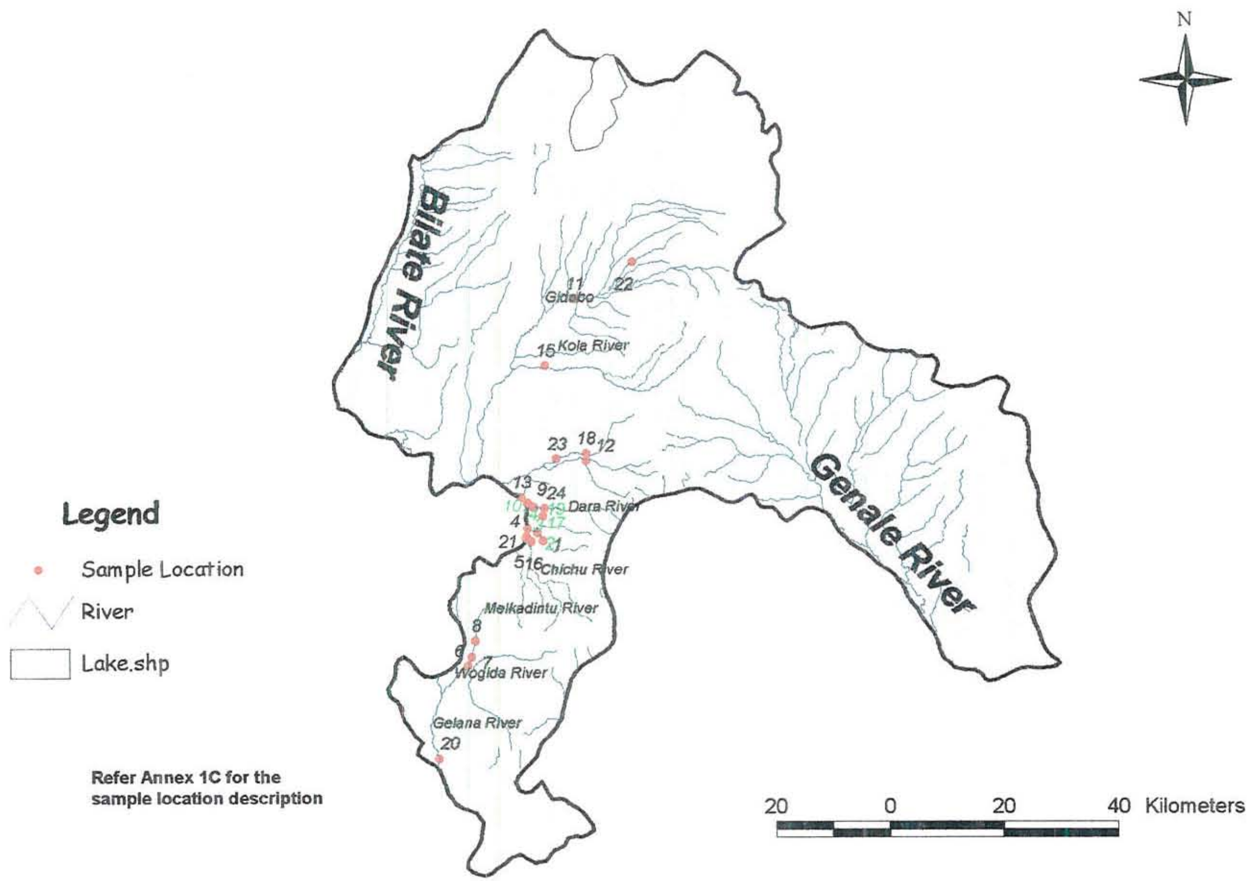

Figure 4.1 location of sampling

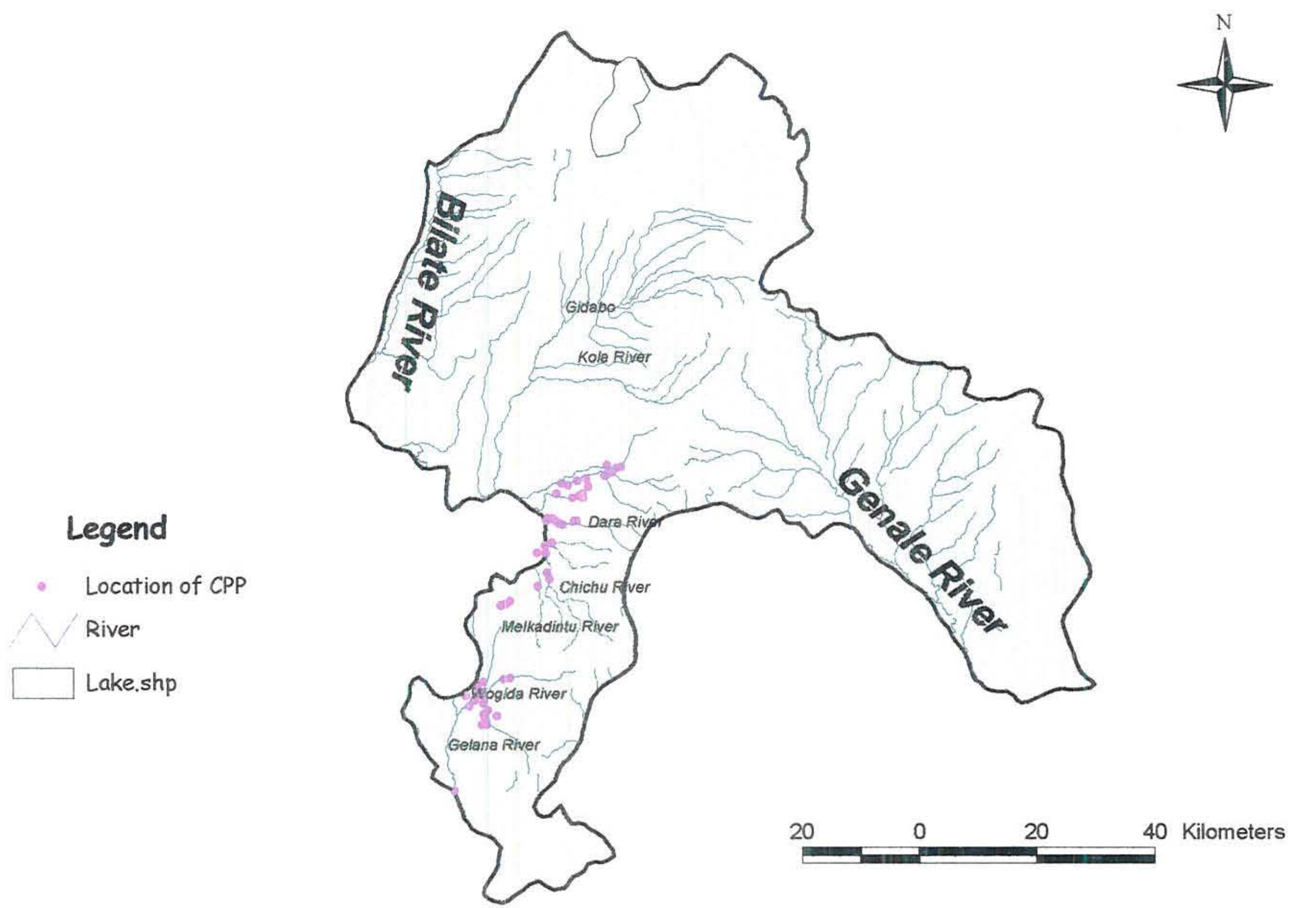

Figure 4.2 a map showing location of some coffee processing plants

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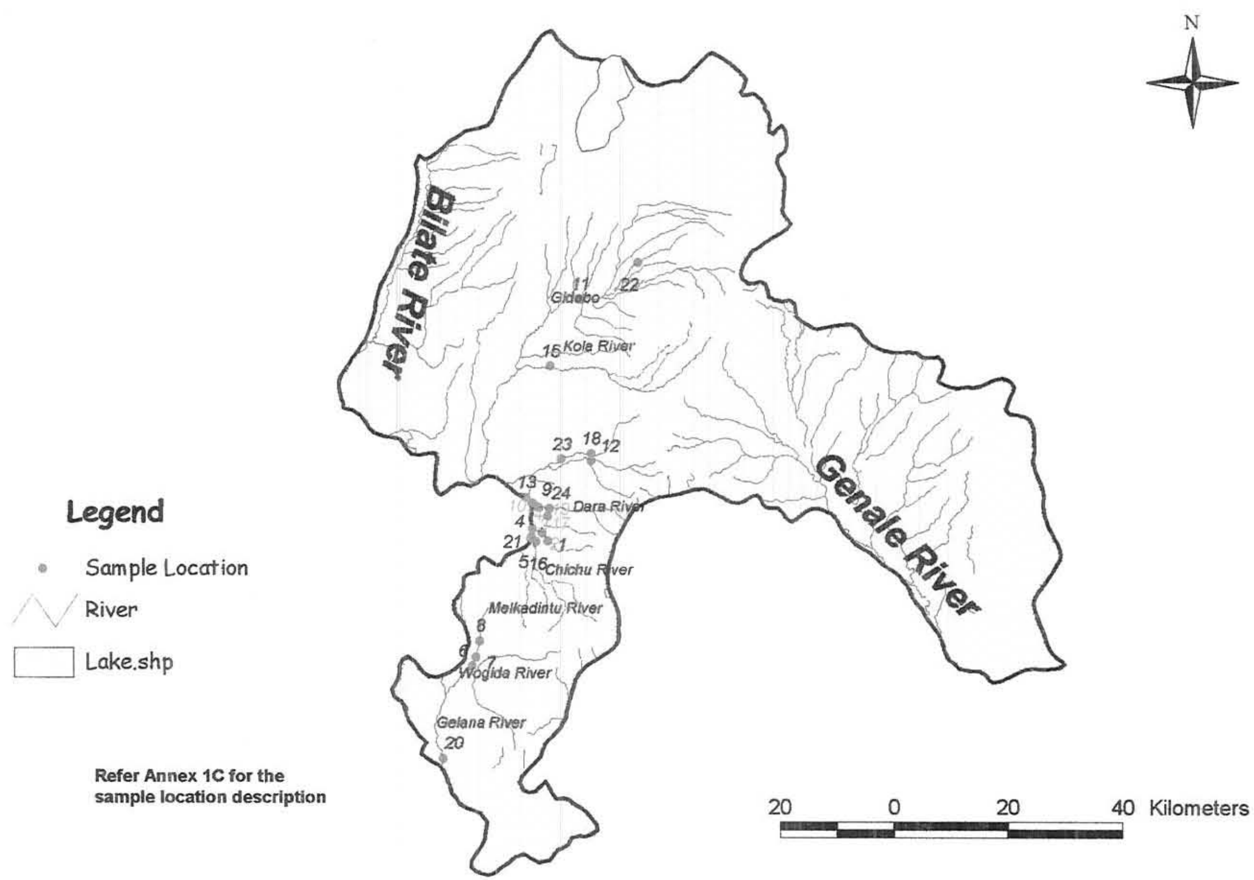

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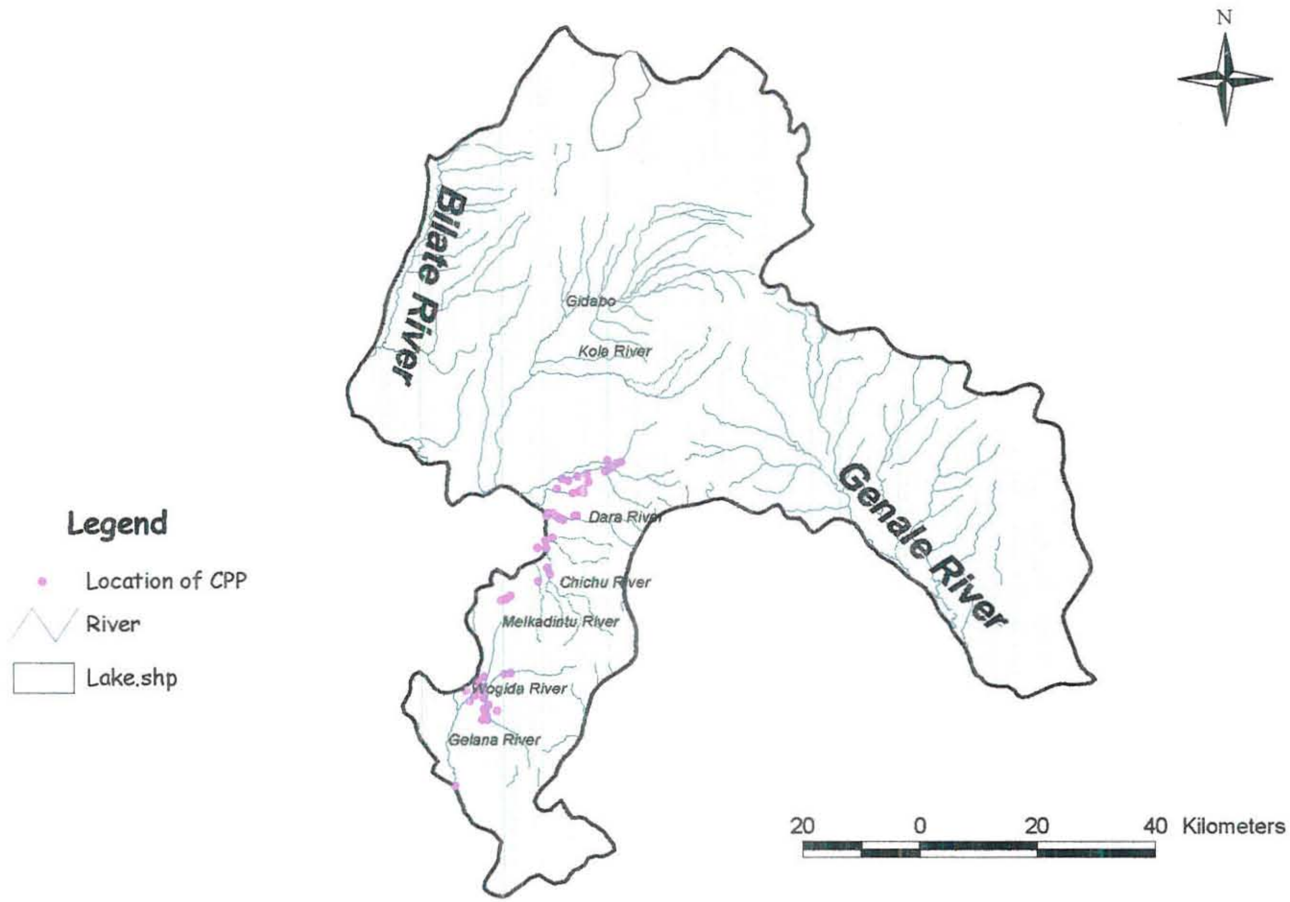

Figure 4.2 a map showing location of some coffee processing plants

4.3.Discussion

4.3.1 physical parameter

pH

The pH values of the river as well as the wastewater lagoon were found with in the range of 3.77 and 6.6. Acidic pH values recorded at water samples collected during coffee harvesting period from wastewater lagoon. A little higher pH value than the former but with in the acidic range was recorded in water samples collected during the same period of time as the former but from rivers which could be suspected victims of the wastewater discharges from the industries.

The PH is an important variable in water quality assessment as it influences many biological and chemical processes with in water body and all processes associated with water supply and treatment. When measuring the effects of an effluent discharge it can be used to help determine the extent of the effluent plume in the water body. The natural acid base balance of a water body can be affected by industrial effluents and atmospheric deposition of acid forming substances. Changes in pH can indicate the presence of certain effluents. For surface waters, pH value typically range between 4 and 11, but for most fresh water pH ranges between 6 and 8.

Industrial activities generally cause acidification rater than alkalization of rivers. One of the cases of acidification is a low ph point source effluent from industries as in the case of the study area. A change in pH from that normally encountered in unimpacted streams may have source effects up on the biota. The extent of acidification or alkalization is important in determining the severity of the effects. Extremes of the pH value and rapid change in pH values are detrimental to most aquatic organisms. Common aquatic plant and animal populations flourish within a fairly narrow range of PH values although most will tolerate, at least for a while, variations between 6&9. Direct effects of PH changes consist of alterations in the ionic & osmotic balance of individual organisms.

Gradual reductions in pH may result a change in community structure, with acid tolerant organisms replacing less tolerant organisms. Streams with acidic pH values have different periphery for communities of microfilaria & fauna and a lower over all production compared with less acidic streams (Deborah chapman, 1996).

Generally the measured value of the pH of water bodies (rivers and streams) in the study area is below the standard & the guide live values (WHO, 1984; MOWR, 2002; (PA, 2003) for drinking water quality that ranges from 6-9)

So the rivers that are used by most of the rural community in the study area as source of drinking water are not suitable or unfit for such purposes.

Turbidity

Turbidity gives a rough indication of the quantity of undissolved matter in water and easily measured hence it is an important initial taste. Now days the preferred unit of turbidity is the formazin turbidity unit, which is produced by a specific concentration of formazin. (Open university, 1975). Turbidity is an expression of the optical properties that causes light to be scattered and absorbed rather than transmitted in straight lines through a water sampleThe scattering of light is caused by suspended matter such as clay, silt and finely divided organic material, while the absorption of light is caused by inorganic matter, plankton and other microscopic organisms and soluble coloured organic compounds, such as fulvic, humic and farnic acids.

The actual concentrations of suspended, settleable and dissolved substances also give quantitative indication of the water's impurities although they do not define the nature of the impurities.

Natural variation in rivers often results in changes in the TSS, the extent of which is governed by the hydrology and geomorphology of a particular region. In general all rivers become highly turbid and laden with suspended solids during the rainy season. The major part of suspended material found in most natural waters is made up of soil particles derived from land surfaces.

The WHO 1971 International standard for substances and characteristics affecting the susceptibility of water for domestic use shows that the highest desirable level is 5 formazin turbidity units and the maximum permissible level is 25 formazin turbidity units.

Coming to the measured value of the turbidity of the water samples collected from the study area out of 19 samples the highest value was recorded at S_{16}. It was also observed physically that the surface water was covered with coffee pulp especially near and below the coffee processing plants.

Temperature

Water bodies undergo temperature variations along with normal climatic fluctuations. These variations occur seasonally and, in some water bodies, over periods of 24 hours. The temperature of surface waters is influenced by latitude, altitude, season, time of day, air circulation cloud cover and the flow and depth of the water body.

Surface waters are usually with in temperature range 0^0 c to 30^0c, although 'hot springs may reach 40^0c or more. These temperatures fluctuate seasonally with minima occurring during winter or wet periods, and maxi main the summer or dry seasons, particularly in shallow waters. As temperature has an influence on so many other aquatic variables and processes, it is important always to include it in a sampling regime and to take and record at the time of collecting water samples.

The measured temperature value of the study area was on average between 12 and 25^Oc that was with in the EPA standards (2003) for effluent discharges to inland water, which is 40^0c, so that all the recorded values were found to meet the WHO (1984) guide lines values (12-25^0c).

Biochemical and Chemical Oxygen Demand (BOD and COD)

Biochemical Oxygen Demand that was measured and analyzed on water sample collected from the study area at different site to evaluate its aerial distribution along a watercourse. Even if it is essential and a must to evaluate the temporal variation to know the background value in the BOD amount, due to the shortage of finance it was not possible to take samples during seasons where there weren't coffee processing activities. Before discussing the results of the BOD measurement of different water samples taken from different areas, let us see a few things about BOD.

When organic matter is discharged in to a watercourse it serves as a food for the bacteria present there. These will sooner or later commence the breakdown of this matter to less complex organic substances and ultimately to single compounds such as carbon dioxide and water. If previously unpolluted, the receiving water will be saturated with dissolved oxygen (DO), or nearly so, and the bacteria present in the water will be aerobic types. Thus the bacteria breakdown of the organic matter added would be an aerobic process- the bacteria will multiply degrading the waste and utilizing the DO as they do so. If the quantity of waste present is sufficiently large the rate of bacteria uptake of oxygen will outstrip that at which the DO is replenished from the atmosphere and from the photosynthesis, and ultimately the receiving water will become anaerobic.

Bacterial degradation of the waste will continue but now the product will be offensive in nature.

The Biochemical Oxygen demand (BOD) is an approximate measure of the amount of biochemical degradable organic matter present in a water sample. It is defined by the amount of oxygen required for the aerobic microorganisms present in the sample to oxidize the organic matter to a stable inorganic form (Deborah Chapman, 1996).

According to the book of Open University press BOD is a measure of the polluting capacity of an effluent due to the dissolved oxygen taken up by microorganisms in decomposing the organic matter it contains. It is the weight of the oxygen in milligrams, consumed by a liter of a sample when it is stored in dark for 5 days at 20^0C. So an effluent with a high BOD has the potential for greatly decreasing the level of dissolved oxygen in a stream.

Organic compounds that are used as nutrients and therefore decomposed by microorganisms are known as biodegradable compounds. Bacteria are responsible for most of the decomposition.

BOD is a measure of the "strength" of a water or wastewater: the grater the concentration of ammonia-nitrogen or degradable organic carbon, the higher the BOD. Note that chemical strength is expressed here in terms of its impact on the environment.

Domestic and industrial wastes often contain high levels of BOD, which if discharged untreated, would seriously deplete oxygen reserves and reduce the diversity of aquatic life.

Sources of BOD:

The simple carbohydrates produced through photosynthesis are used by plants and animals to synthesize more complex carbon-based chemicals such as sugars and fats. These compounds are utilized by organisms as an energy source, exerting a carbonaceous oxygen demand.

Even unpolluted natural waters contains some BOD, associated with the carbonaceous and nitrogenous organic matter derived from the watershed and from the water themselves (e.g. decaying algae and macrophytes, leaf litter, fecal matter from aquatic organisms). Dissolved oxygen levels in surface waters (excluding those with excessive algae photosynthesis and attendant O_2 productions) are often below the saturation level due to this "natural" BOD. Domestic wastewater and many industrial waters are highly enriched in organic matter compared with natural waters.

When we come to the measured value of the BOD of water samples from rivers, springs, boreholes, and traditional wastewater lagoons higher values were recorded in water samples collected from wastewater lagoon and down stream of coffee processing plants. The highest value is 10604mg/l in wastewater lagoon from Taddesse Berisso coffee processing plants (wonago-woreda). Lowest values were recorded in protected springs & water points where their source of water is borehole, the lowest being 1.6mg/l in water point at chichu kebele (around Dilla town).

The EPA (2003) industrial effluent standards for BOD 1580 mg\l, however the measured value of this parameter for effluents in the study area is much higher so that it can easily pollute when dumped directly to water courses. Minimum limit of pollution or recommended limits for raw water to be used, after treatment, as drinking water (world health organization, 1963)

The increase in BOD either in the wastewater or in the water course polluted by such wastes is explained by the simple carbohydrates produced through photosynthesis are used by plants and animals to synthesize more complex carbon based chemicals such as sugars and fats. These compounds are utilized by organisms as an energy source, exerting a carbonaceous oxygen demand. In addition plants utilize ammonia to produce proteins. Proteins are ultimately broken down to peptides and then monoacids. Conversion of the amino group to ammonia completes the degradation process. The ammonia is then available to exert a Nitrogenous Oxygen Demand when utilized by microorganisms. As discussed in chapter eight the composition of coffee is N, P K, Ca and Mg.

Another major pollutant which grouped under oxygen demanding wastes or sometimes referred as chemical indicators of pollution together with BOD, total nitrogen, NH_3 and Greases is the chemical oxygen demand (COD).

The chemical oxygen demand is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate. The COD is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the effluents from sewage and industrial plants. The test for COD is non-specific, in that it doesn't identify the ox disable material or differentiate between the organic & inorganic material present. Similarly it doesn't indicate the total organic carbon present since some organic compounds are not oxidized by the dichromate method where as some inorganic compounds are oxidized. Nevertheless, COD is a useful, rapidly measured, variable for many industrial wastes and has been in use for several decades.

The concentrations of COD observed in surface waters range from 20 mg/l O_2 or less in unpolluted waters to greater than 200 mg/l O_2 waters receiving effluents. Industrial wastewater may have COD values ranging from 100 mg/l O_2 to 60,000 mg/l O_2. The standard method for measurement of COD is oxidation of sample with potassium dichromate in a sulphuric acid solution followed by a titration. Saying this much about COD, let us see the case in the study area.

As we have seen from the results in the measured values of COD (annex 3), except in the case of water samples collected from water point, Spring and borehole having values of 4,20 and 21 mg/l respectively and in three water samples from rivers, all other water samples have value of COD on average between 600-1000 mg/l the highest value being 24600 mg/l in wastewater lagoon from Tadesse Beriso coffee processing plant. In rivers the highest value is750 mg/l down stream of Alem Asefa coffee processing industries in Melkadimtu River

(Yirgacheffe woreda). This increase in the amounts of COD and other parameters in this river are may be due to the inefficiency of the traditional wastewater lagoon so that the owner discharged almost all of their waste directly to the specified river.

The lowest COD value in water points, boreholes and protected spring is explained by the fact that these areas (points) are less chance of interaction with the polluted surface water irrespective of their distance from the source.

EPA industrial effluent standards for COD is 250mg/l and recommended limits for raw waters to be used, as drinking water after treatment should be $10g/m^3$ (Open university press, 1975). From the result of the analysis and the above standard for drinking water and effluents the river in which most of the rural population used for drinking purposes is unfit for drinking and also unsuitable for aquatic organisms that largely dependent on the amount of oxygen for their survival and reproduction.

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The maximum average values of COD (24600 mg/l) and BOD (10604 mg/l) were recorded at a point where coffee processing effluents discharge in to the traditional wastewater lagoon where as the lowest values of COD (4mg/l) and BOD (1mg/l) were recorded in water sample taken from borehole in Chichu kebele around Dilla town. Fig 6.2 shows concentration of BOD (in mg/l) concentrations in wastewater lagoon, rivers and wells.

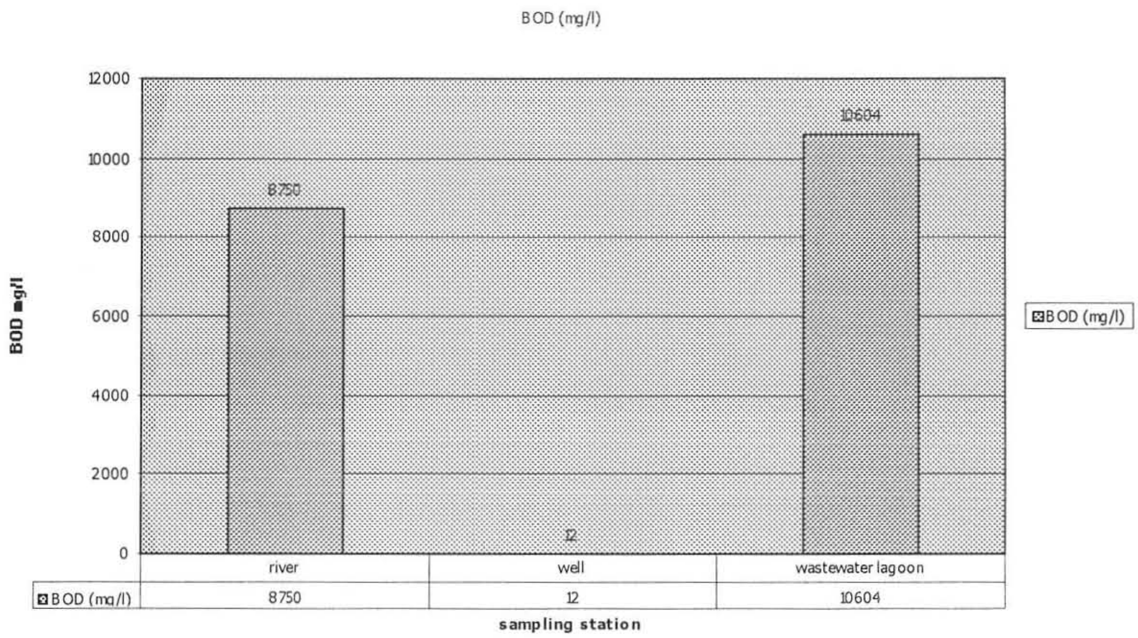

Fig 4.3. Concentration of BOD of different water sample

Dissolved oxygen (DO)

Oxygen is essential to all forms of aquatic life, including those organisms responsible for the self-purification processes in natural waters. In fresh waters dissolved oxygen (DO) at sea level ranges from 15mg/l at 0^0c to 8 mg/l at 25^0c (CKVARSHNEV, 1983).

Organic waste constitutes the major stream pollution problem. Biological decomposition of organic matter in a stream depletes the dissolved oxygen content of the water. Organic matter exhausts the oxygen resources of rivers, and creates unpleasant test, odors, and general septic conditions (Leonand, 1963). As we have seen from the recorded value of DO of water samples collected from different water bodies such as surface waters as rivers and streams, wastewater from lagoon and from groundwater especially in spring and boreholes in the study area, the DO value is higher in unpolluted water body where as lower value of DO was recorded in water samples collected from protected spring and water point that have less chance of interaction with the polluted surface waters.

Waste discharges high in organic matter and nutrients can lead to deceases in DO concentrations as a result of the increased microbial activities (respiration) occurring during the degradation of organic matter

Determinations of DO concentrations is a fundamental part of a water quality assessment since oxygen is involved in or influences nearly all chemical and biological processes with in water bodies. Concentrations below 5 mg/l may lead to the death of most fish. Measurement of DO can be used to indicate the degree of pollution by organic matter, the destruction of organic substances and the level of self purification of the water. Its determination is also used in the measurement of biochemical oxygen demand.

Dissolved oxygen is of much more limited use as an indication of pollution in groundwater, and is not useful for evaluating the use of groundwater for normal purposes. Water that enters groundwater systems as recharge can be expected to contain oxygen at concentrations similar to those of surface water in contact the atmosphere. Organic matter or oxidizable minerals present in some aquifers rapidly deplete the dissolved oxygen. Therefore in aquifers where organic materials are less plentiful, groundwater containing measurable concentrations of DO (2-5 mg/l) can be found (Deborah Chapman, 1996).

Effects:

Aerobic organisms are dependent for respiration on the presence of DO in water. Juveniles of many aquatic organisms are more sensitive to physiological stresses arising from oxygen depletion, and in particular to secondary effects such as increased vulnerability to predation and disease (EPA, 2003).

The presence of high organic matter in wastewater has negative impact on aquatic life. High BOD levels leads to higher consumption of DO by anaerobic bacteria that robbing other aquatic organism the oxygen they need to live. Depletion of DO can cause major shifts in the kinds of aquatic organism found in water bodies. Species that can not tolerate low levels of DO like may fly, stone fly, beetles larvae will be replaced by few kind of pollution tolerant organisms such as warms and fly larvae (Mifchell & Stapp, 1994; Tesfaye 1988).

The water consisting of high DO is usually considered to be healthy and stable ecosystem capable of supporting many different kinds of organisms. However, a fall in DO level is one of the indicators that organic matter pollutes a water body. Stream and river with low DO will have limited natural purification capacity for wastes discharged in to them where as the presence of oxygen in water is a positive sign (Tesfaye, 1988; Mifchell & Stapp, 1994)

The maximum concentration (17.6mg/l) of DO was measured at a site where the water sample was taken from Borehole near Chichu kebele around Dilla town and the lowest concentration was (.012mg/l) in wastewater.

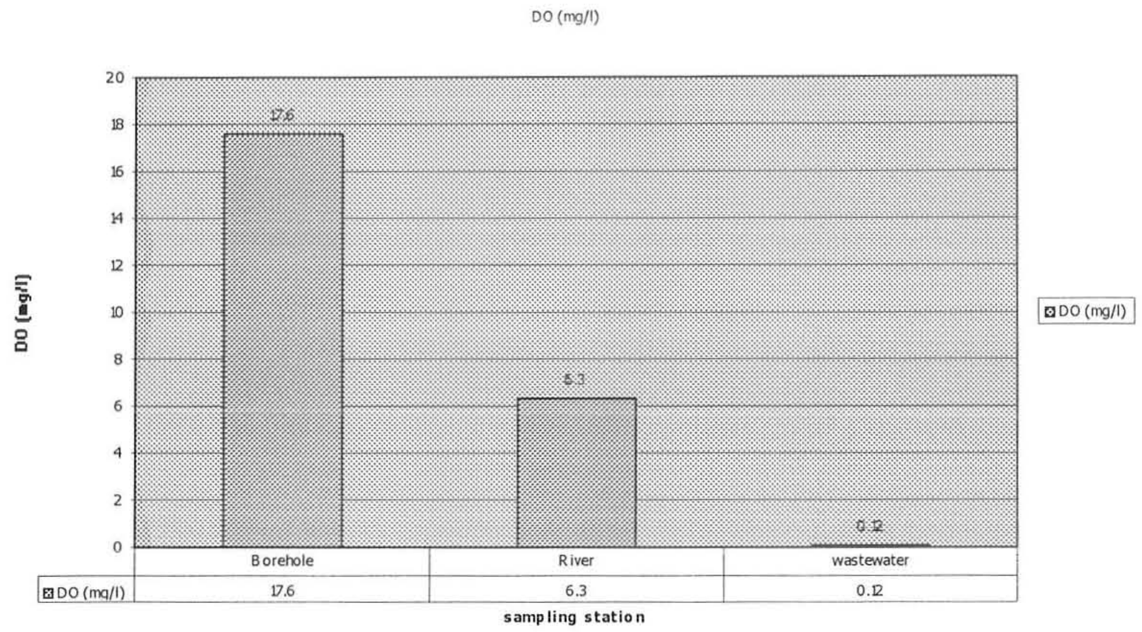

Fig 4.4. DO concentration at different water bodies.

Nitrogen compounds:

Nitrogen is essential for living organisms as an important constituent of proteins, including genetic material. Plants and microorganisms convert inorganic nitrogen to organic forms. In the environment, inorganic nitrogen occurs in a range of oxidation states as nitrate (NO_3-) and nitrite (NO_2-), the ammonium ion (NH_4+) and molecular nitrogen (N_2). It undergoes biological and non-biological transformations in the environment as part of the nitrogen cycle.

Ammonia:

Ammonia occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of the nitrogen gas in water by microorganisms and form gaseous oxygen with the atmosphere.it is also discharged into water bodies by some industrial process (e.g. ammonia based pulp and paper production) and also as a component of municipal or community waste At certain pH levels,high concentration of ammonia(NH_3) are toxic to aquatic life and,therefore,detrimentsal to the ecological balance of water bodies.

Ammonia may be present in the free, unionized form (NH_3) or in the ionized form as the ammonium ion (NH_4+). Both are reduced forms of inorganic nitrogen derived mostly from aerobic and an aerobic decomposition of organic material. They exist either as loons, or can be adsorbed on to suspended organic & inorganic material.

In aqueous solutions, unionized ammonia exists in equilibrium with the ammonium ion. Total ammonia is the sum of these two forms. Ammonia also forms complex with several metal ions and may be adsorbed in to colloidal particles, suspended sediments and bed sediments. it also may exchanged between sediments and the overlying water.

The toxicity of ammonia is directly related to the concentration of the unionized form (NH_3), the ammonium ion (NH_4+) having little or no toxicity to aquatic biota. The ammonium ion does, however, contribute to eutrophication. Modifying factors may after the acute toxicity by altering the concentration of Un-ionized ammonia in the water though charge in the ammonia. Ammonia ion equilibrium, or may increase the toxicity of the un-ionized ammonia to organisms.

Unpolluted waters contain small amounts of ammonia and ammonia compounds, usually <0.1mg/l as nitrogen. Total ammonia concentrations measured in surface waters are typically less than 0.2mg/l but may reach 2.3mg/l N. Higher concentrations could be an indication of organic pollutant such as from domestic sewage, industrial waste and fertilizer run-off. Ammonia is there fore, a useful indicator of organic pollution.

The highest ammonia concentration was 90 mg/l in Melkadimtu River, which is far higher than the recommended limits where as the lowest was 0.4 mg/l in protected spring.

Nitrate and Nitrite:

Determination of nitrate plus nitrite in surface water gives a general indication of the nutrient status and level of organic pollution. Consequently, these species are included in most basic water quality surveys and multipurpose or background monitoring programs, and are specifically included in programs monitoring the impact of organic or relevant industrial inputs. As a result of the potential health risk of high levels of nitrate it is also measured in drinking water sources.

The most common contaminant identified in groundwater is dissolved nitrogen in the form of nitrate (No_3). This contaminant is becoming increasingly widespread because of agricultural activities and disposal of swage on or beneath the land surface. Its presence in undesirable concentrations is threatening large aquifer systems in many parts of the world. Although No_3- is the main form in which nitrogen occurs in groundwater dissolved nitrogen occurs in the form of NH_4^+, No_2-, N2 , N_2O and organic nitrogen (Freeze and cherry, 1979)

Nitrate in groundwater generally originates from nitrate sources on the land surface, in the soil zone or in shallow sub soil zones where nitrogen rich wastes are buried. In some situations No_3- that enters the groundwater system originates as No_{3-} in wastes or fertilizers applied to the land surface. In other cases, No3- originates by conversion of organic nitrogen or NH_4+, which occurs naturally or is introduced to the soil zone by mans activities.

Concentrations of No_3- in the range commonly reported for groundwater are not limited by solubility constraints. Because of this and its ionic form No_3- is very mobile in groundwater. In groundwater that is strongly oxidizing, No_3- is the stable form of dissolved nitrogen. It moves with the groundwater with no transformation and little or no retardation. Very shallow groundwater is highly permeable sediment or fractured rock commonly containing considerable dissolved O_2. It is in these hydrogeologic environments where No_3- is commonly migrates large distance from input areas.

Nitrate naturally occurs in groundwater with concentrations below 10mg/l. However due to activities related to anthropogenic sources such as intensive farming practices and domestic waste disposal sites, nitrates level in some groundwaters may be very high. High nitrate values in groundwaters are considered as indicators of water pollution. Excessive nitrate in drinking water is a public health concern; it contributes to illness known as methamoglobinemia that is commonly referred to as blue baby syndrome. For comparison of the concentration of N- compounds, 16 water samples chemical analysis result from previous study were also compared with the others.

The Nitrate ion (NO_3^-) is the common form of combined Nitrogen found in natural waters. It may be biochemically reduce to Nitrite (NO_2-) by dentrification processes, usually under an aerobic conditions. The nitrite ion is rapidly oxidized to nitrate. Natural source of Nitrate to surface waters includes igneous rocks, land drainage and plant and animal debris. Nitrate is an essential nutrient for aquatic plants and seasonal fluctuations can be caused by plant growth and decay. Natural concentrations, which is seldom exceed 0.1 mg/l NO_3-N, may be enhanced by municipal and industrial wastewaters, including leachates from waste disposal sites and sanitary land fills. In rural and suburban areas, the use of inorganic nitrate fertilizers can be a significant source.

When influenced by human activities, surface waters can have nitrate concentrations up to 5 mg/l NO_3-N, but often less than 1 mg/l NO_3-N. Concentrations in excess of 5mg/l NO_3-N usually indicate pollution by human or animal waste, or fertilizer run off. In cases of extreme pollution, concentrations may reach 200 mg/l NO_3-N. The world health organization (WHO) recommended maximum limit for NO_3^- in drinking water is 50 mg/l (or 11.3 mg/l as NO_3-N), and waters with higher concentrations can represent a significant health risk for infants (Deborah Chapman, 1996).

Coming to the results of the measured value of NO_3-N & NO_3- of the water samples collected in the study area, due to some problems out of the total samples only seven representative samples were taken during field investgation, analyzed and the result shows that 2 of the samples have NO_3-N & NO^-_3 value below the range of the instrument that can possibly dictate. The first sample (having measured value indicating under-range) taken from borehole near Donbosco in Dilla town. This value is actually expected from such samples that were collected from a great depth since pollutant transport is mainly affected by depth of water table.

Unfortunately the measured value of these parameters in the other water sample that was taken from down stream of Alem Asefa coffee processing plant is similar to the above, but this is may be due to the fact that the Nitrate would be converted in to nitrite (?).

In the remaining 5 samples, samples taken from Tedese Beriso coffee processing plants have a bit higher value of NO_3-N (11.2 mg/l) than the others which were taken from down stream of Wondu Alemayehu coffee processing plants (Kochore woreda), down stream of fiche coffee processing industries, Tulula river and in Darra river upstream of Dilla treatment plant and have values of 2.5 mg/l, 0.4 mg/l, Nil and 1.1mg/l respectively.

Generally the value of NO_3-N & NO_3- concentrations in the representative water samples from rivers, which serve us, a source of the drinking is much below WHO standards for drinking water maximum permissible concentrations and therefore not a threat for population that uses this river water for different uses.

Nitrite

Because Nitrite is an intermediate in the oxidization of ammonia to nitrate, because such oxidation can proceed in soil, and because sewage is a rich source of ammonia nitrogen, waters which shows any appreciable amounts of nitrite are regarded as being of highly questionable quality.

Nitrite concentrations in fresh waters are usually very low, 0.001 mg/l NO_2-N, and rarely higher than 1mg/l NO_2-N. High Nitrite concentrations are generally indicative of industrial effluents and are often associated with unsatisfactory microbiological quality of water. The low concentration of Nitrite in different water bodies is because the nitrogen will tend to exist in the more reduced (ammonia, NH_3) or more oxidized (Nitrate NO_3) forms. Levels in unpolluted waters are normally low, below 0.03 mg/l NO_2. Values greater than this may indicate sewage pollution.

The significance of nitrite (at the low levels often found in surface waters) is mainly as an indicator of possible sewage pollution rather than as a hazard itself although; it is nitrite rather than nitrate, which is the direct toxicant. There is accordingly, a strict limit for nitrite in drinking waters. In additions, nitrites can give rise to the presence of nitosamines by reaction with organic compounds and there may be carcinogenic effects (EPA, 2003).

Looking to the results of nitrite (NO_2) from the analysis of water samples that were collected from different locations in the study area, the recorded value was 60 mg/l of NO_2 downstream of Alem Asefa coffee processing plant (Yirgacheffe Woreda) in Melkadimtu River, The lowest value being nil. About 50% of the representative samples analyzed were their values of NO_2 could be >1mg/l that indicate the potential of being polluted. From the measured results we can easily seen that the concentration of the nitrite is not uniform or not follow the same trend. Sometimes water samples that must have a relatively high amount of nitrite could have nil amounts and in other times water samples that were expected to have lower or sometimes not to contain any significant amount were recorded containing a significant amount.

In other instance, the highest concentration of NH_3-N (74 mg/l) was measured at river water downstream of coffee processing plants and the lowest concentration was measured (0.3mg/l) in protected or developed spring near Abinet coffee processing plants at Gola kebele in Wonago woreda.

Regarding physical parameters for water samples collected during coffee harvesting period the highest value of PH was 4.85 units upstream of Dilla treatment plant at Dara river where as the lowest value was 3.77 from wastewater lagoon.

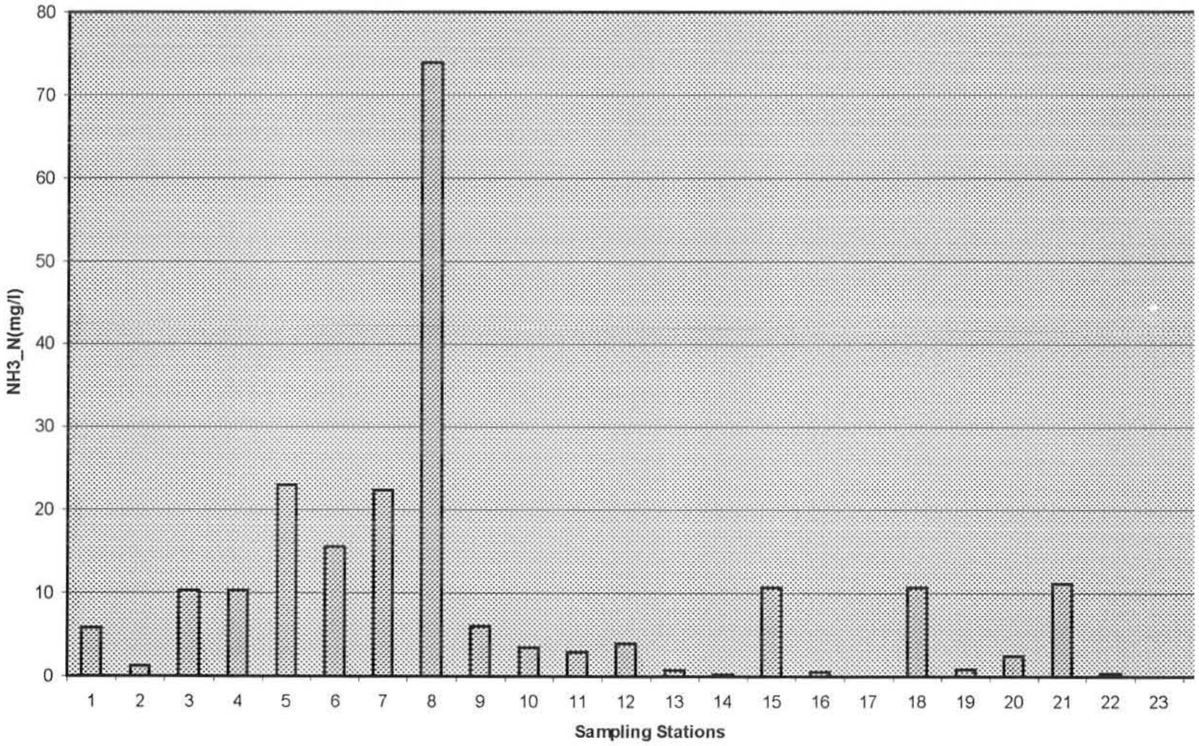

Fig 4.5 Concentration of NH_3-N in d/t water samples at different sampling stations

For water samples collected during September 1997 where there was no any coffee processing or harvesting activities was not taken place, the highest value of pH recorded was 6.6 where as the lowest pH value was 4.4. Even if the samples were collected during the above seasons the analyzed samples were taken from wastewater lagoon and it's immediate downstream.

The highest temperature value recorded in the analysis was 25.6^{0}c in water sample collected from traditional wastewater lagoon and the lowest temperature value was 12^{0}c.

Regarding the temperature 10 water samples collected from wastewater lagoon and the immediate down stream and upstream of the traditional wastewater lagoon shows that the tem aperture is in average between 12 and 25.6^{0}c.

The highest TDS value in the same sample cited above was 1162 mg/l and the lowest value was 27.8 mg/l in Dara River upstream of Dilla treatment plant around Dilla Town.

The highest conductivity value in the same water samples mentioned above was 2230ms/cm in wastewater and the lowest being 55.4 in Dara River upstream of Dilla treatment plant. The highest TDS value recorded in water samples collected by other persons from previous source was 707mg/l from borehole at Debub University where as the lowest was 38.2 mg/l in Darra river

Conductivity or specific conductance is a measure of the ability of water to conduct an electric current. It is sensitive to variations in dissolved solids, mostly mineral salts. For a given water body conductivity related to the concentration of total dissolved solids and major ions.

The conductivity of most fresh waters ranges from 10 to 1000µs/cm but may exceed 1000µs/cm, especially in polluted waters, or those receiving large quantities of land runoff. In addition to being a rough indicator of mineral content when other methods can't easily be used, conductivity can be measured to establish a pollution zone, example around an effluent discharge or the extent of influence of runoff waters.

The results of the measured value of conductivity in the study area indicates that higher value was recorded in water samples collected from wastewater lagoon than those from rivers that are at the immediate upstream and downstream of coffee processing plants. The highest recorded value was 2230µs/cm and the lowest being 55.4.The highest value in the wastewater may be explained in terms of the different chemical constituents (minerals) that make up green coffee.

Since total dissolved solids (TDS) may be obtained by multiplying the EC by a factor, which is commonly between 0.55 and 0.75,the same analogy for EC can be applied to TDS.

Acidity and alkalinity are the base and acid neutralizing capacities of water. When the water has no buffering capacity they are inter related with pH. However, as most natural waters contain weak acids and bases acidity and alkalinity are usually determined as well as pH.

The alkalinity of water is mostly taken as an indication of the concentration of carbonate, bicarbonate and hydroxide, but may include contributions from borate, phosphates, silicates and other basic compounds. Waters of low alkalinity (24 mg/l as $Caco_3$) have a low buffering capacity and can, therefore, be susceptible to alterations in pH, for example from atmospheric, acidic deposition. The amount of strong acid needed to lower the pH gives the total alkalinity (CK VARSHNEY, 1983)

Coming to the results of the analysis of the water sample for alkalinity as Caco3 all the water samples had recorded total alkalinity value of Nil or zero showing that the water is highly susceptible to alterations in pH from different source. Regarding the acidity the average recorded value was 76 mg/l, the highest being 120mg/l.

Another important and more widely known characteristics of natural fresh water is hardness, due to the presence of dissolved solids. Hard water is mainly due to the presence of ions of the metals calcium (Ca^{2+}), magnesium (Mg^{2+}) and iron (Fe^{2+}). Rivers fed by water that has run from limestone's ($Ca\ co_3$) contains an abundance of calcium. The total content of dissolved Mg and Ca salts is known as general hardness, which can be further divided in to carbonate hardness and non carbonate hardness (determined by Ca and Mg salts of strong acids).

Seasonal variations of river water hardness often occur, reaching the highest values during low flow conditions and the lowest values during floods. Where there are specific requirement for water hardness in relation to water use it is usually with respect to the properties of the cat ions forming the hardness.

Regarding the recorded value of hardness in the study area shows that all the values were grouped under soft or moderately hard so that it will not be a threat for domestic use since hardness in water used for ordinary domestic purposes doesn't become particularly objectionable until it reaches a level of 100mg/l or 50 (Tenalem & Tamiru, 2001)

Plate 1- Wastewater lagoon in Dara woreda

Plate 2 -Wastewater lagoons in Wonago Woreda

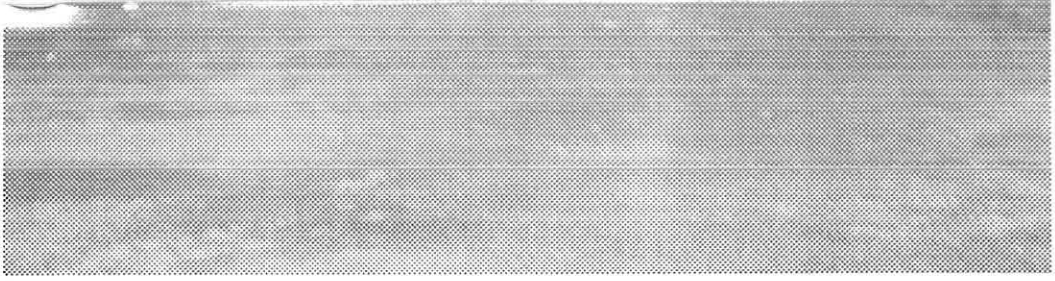

Plate 3 -Wastewater lagoons in kochore woreda

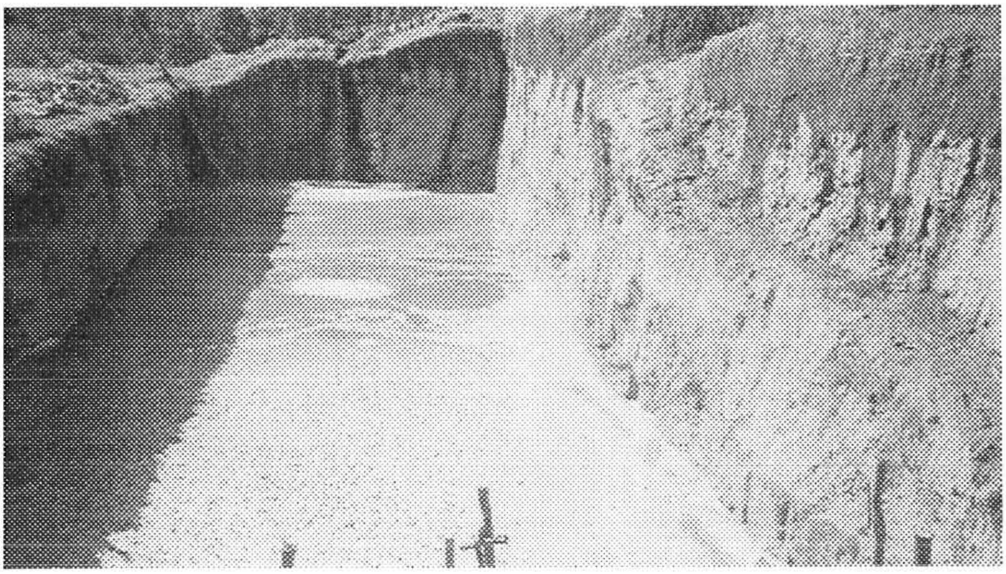

Plate 4 -Wastewater lagoon in Yirgacheffe Woreda

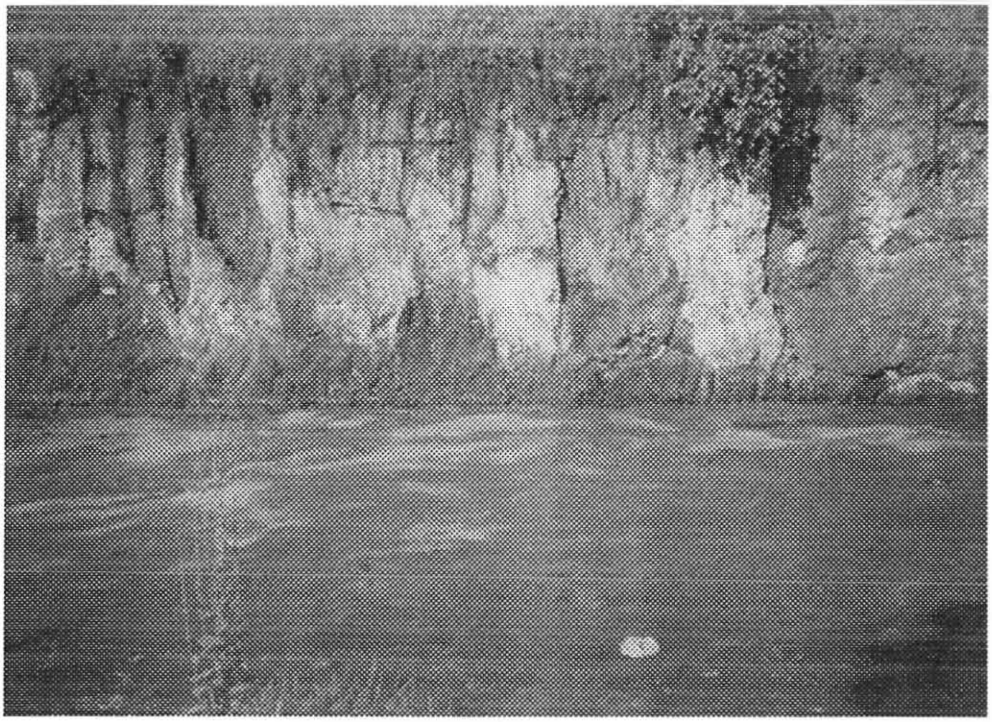

Plate 5-wastewater lagoon in Aletawondo Woreda

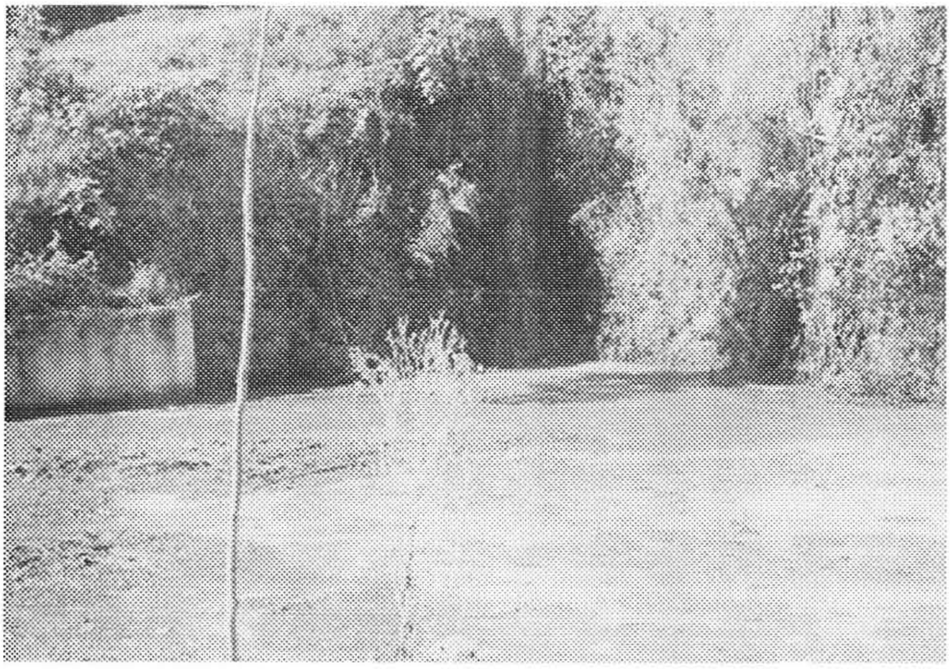

Plate 6-wastewater lagoon in Yirgacheffe Woreda

Plate 7- Wastewater lagoon in wonago Woreda

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

Due to direct discharges of coffee byproducts to water courses the recorded turbidity value was higher than the recommended limit and this leads to the reduction to light penetration that also leads to a decrease in photosynthesis this may then leads to changes in the structure of the biotic community by decline of organisms. Water with high turbidity value that is turbid water may adversely affect the use of water for various purposes. Turbid water may aesthetically unsatisfactory for bathing. Generally turbidity values of groundwater (spring and borehole) are very low.

The measured value of pH in surface waters and wastewater during coffee processing period (Nov-Jun) indicated that the value was between 3.77 and 4.85units. Water analysis data collected from previous source indicates that water samples that were taken from spring, borehole and river during the period in which there were no coffee processing activities taken place and that represent the background value had pH value in between 6.6 and 8.3 which is in the range of the WHO drinking water quality guideline value. Low pH or acidic pH in river water affect aquatic life and impair recreational use of water.

The measured and recorded value of TDS in rivers in field observation as well as from other collected previous sources whether surface or groundwaters indicated that the water is fresh. Based on the measured value of total hardness in river, spring and borehole waters show that the area can be classified as moderately hard water types.

The limited number of chemical analysis of water samples from the study area and collected from previous sources indicated that the dominant cation being Na and the dominant anion was H co_3 So that the water is dominantly Na H CO_3 type of water.

Rivers that are highly victims of coffee byproducts have a higher value of BOD and COD value. The maximum BOD and COD value in the river was 8750 and 3120mg/l respectively at Melkadimtu River down stream of Alem Asefa coffee processing plants. Comparing to EPA (2003) standards for effluent discharge to inland water, the maximum value obtained form these rivers were 35 and 39 times higher than acceptable limit. The maximum effluent (wastewater) value of COD was 24,600mg/l that was 98 times higher than the recommended limit. This high concentration of BOD in the above river and effluents was may be due to the higher organic matter content of nature of the raw material and the absence of partial or full treatment facility. This high value will have the potential for greatly decreasing the level of dissolved oxygen in the rivers, and then reduce the diversity of aquatic life.

Boreholes and springs in the study area have a lower BOD and COD value, which was below the WHO guideline values and standards. This is due to the low content of oxygen demanding wastes.

The highest value of DO was shown in boreholes and springs where as the lowest values was recorded in wastewater or effluents and rivers that receive higher amount of oxygen demanding waste from coffee processing plants located exactly at the upstream position.

The concentration of ammonia (NH_3) measured in the river water ranges from 0 (nil) to 90mg/l. The highest was recorded at Melkadimtu River and is higher than to MOWR guidelines for drinking water as well as EPA (2003) standards for the emission limit. The effect is manifested by the bad odor or evil smelling that can be sensed from up to many kilometer radius the river courses during coffee processing periods.

Higher concentration of ammonia increase in toxicity to aquatic organisms and affects the respiratory systems of many animals, either by inhibiting cellular metabolism or by decreasing oxygen permeability of cell membranes.

The highest Nitrite (No_2-) concentration was 60mg/l. From the total analyzed samples about 50% of the river water had nitrite values of greater than 1mg/l, which are far higher than recommended levels in unpolluted waters (<0.03mg/l). Rural communities that use river water as their source of water supply may expose to carcinogenic effects due to this level of nitrite.

Generally the value of NO_3-N and NO_3- concentration in the representative water samples from rivers, which can possibly serve as a source of drinking, is much below the WHO standards for drinking water and therefore, not threat for population that uses this water.

Higher water usage (160 cubic meters for processing 2.8 tons of parchment coffee) to achieve top quality coffee standards causes for most of the wet coffee processing plants not to incorporate re-circulation system in their operation to decrease the amount of wastewater that can be discharged directly or indirectly to water courses.

Biodegradable pulp and the effluent that are originated from mucilage removal are causing marked impact in the amenity values of the water courses so that they have characteristically turned in to an evil smelling and black in colors.

The efficiency and effectiveness of the re-circulation systems of those, which are operational, are very low almost less than 10%.

Unless the large quantities of the processing by products produced will not managed properly it would represent a major source of environmental pollutions.

Generally if the growth of wet processed coffee is allowed with out a sustainable and environmentally sound strategy, the adverse environmental impact will be more serious.

It is therefore necessary to develop and plan technically appropriate, economically viable and socially appreciated technologies for environmentally sound management of coffee processing byproducts. But developing an effective coffee effluent pollution protection program requires increasing public awareness, which is important to build consistent and pragmatic site-specific pollution management activities. This would include integrated approach to identify clean technology and approaches to reducing the amount of waste generated, as well as to disposing them in a manner consistent with the assimilative capacity of the environment. The integrated planning approach and other recomendations are suggested as follows.

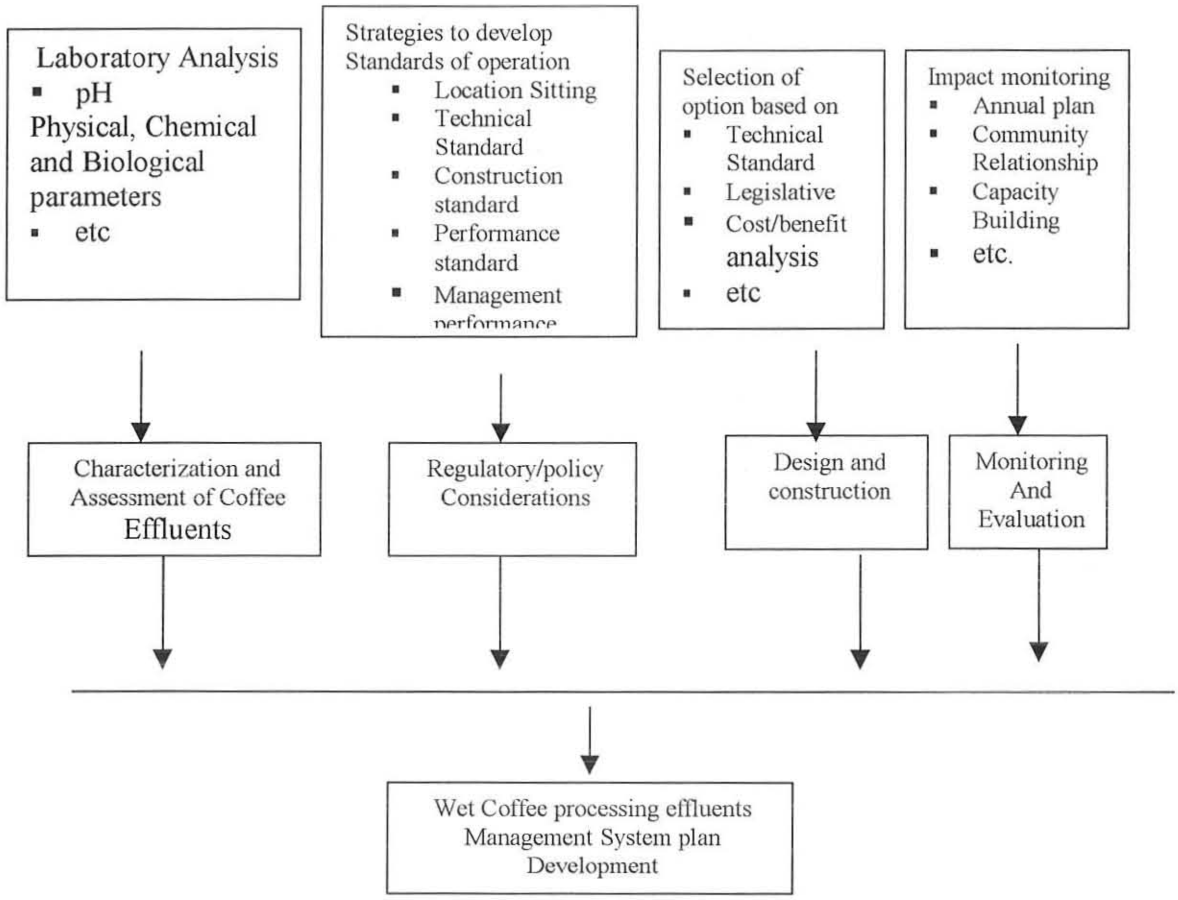

Fig 5.1. An Integrated Approach to Wet Coffee Processing Effluents Management

Residual Water (Wasterwater) Management

The major contributors of wastewater are the pulping, hulling, pre-grading and fermentation processes of the system. Pollution arises when the waster waters from these systems are disposed directly to watercourses. Since the Biological Oxygen Demand (B.O.D) measures the weight of pollution, as a standard a river of 10mg per letter B.O.D. would normally be classified as grossly polluted. As discussed in the preceding sections, pollution arises when raw water used in coffee processing operations is discharged to watercourses. Similar effects have been also observed from drainage and seepage of row effluent from waste disposal pits. As observed, pits alone would not be adequate because of the high water usage; they will be filled with in few days and the over flow would drain to watercourses. Conversely since the pectin part of the mucilage is lighter than water by adhesive forces it will form a film type structure, which covers the water body. Since O_2 has relatively low solubility in water and microbial activity may rapidly deplete dissolved O_2 anaerobic fermentation would be encouraged. The wastewaters will have evil smell and the color changes into black. Both the overflow and the seepage from the disposal pits would pollute the watercourse more severely than directly discharging the effluents to watercourses. Therefore collection of wastewater in pits or pond requires precautions and closer attentions. As land is a limiting factor in wet processing plants, waste treatment pits have to occupy the minimum space possible and should employ uncomplicated and inexpensive treatment processes. The practical method may incorporate two consecutive tanks. The effluent flow enters the primary tank which serves as sedimentation tank the suspended pectin's which comprise over 50% of the effluent solids and originated from the important mucilage removal stage of the process can be precipitated out of suspension in waste by simple treatments of using flocculants such as cement, lime, Aluminum sulphate, etc. the discharged to watercourses. The periphery between the pits and the river could be also covered by toxic tolerance and deep rooted plants, which could filter the seepages, sugarcane (Shenkora), Vetiver grass, Reed grass (Shenbeko), Napir Grass can be used for such purposes. During prolonged flooding (rainy Seasons), the residual effluents in the primary and secondary tanks should be cleaned and may have to be discharged directly into watercourses. This procedure is not hazardous, as it seems the watercourse will generally be in spate at the time. The system effectiveness however should be justified by regular operation of determination of BOD and pH values of the treated water at the watercourses inlets. However, the system should be evaluated and monitored on pilot plants.

An attempt is also made to find and recommend methods for improving environmental control of the wet processing plants and rational utilization of coffee processing by products. In particularly coffee pulp have some economical implications that may become evident as their use is increased. In this regard, perhaps the availability of coffee pulp in larger quantity may warrant efforts to develop profitable uses. The proceeding sections discuss some of the suggested measures.

Compost and fertilization

The traditional way to increase organic matter in cropland is to add undecompensed raw materials in the form of animal manure and household wastes. In the coffee extension service well-decomposed coffee pulp has been recommended as a suitable fertilization especially during coffee establishment. From the mineral composition of the pulp it is evident that composed pulp would yield suitable organic fertilizer

Table 5. 1 the mineral composition of coffee pulp

N	1.74%
P	0.10%
K	5.26%
Ca	0.48%
Mg	0.11%

Source Kenya coffee, 1996 cited in Gordon Wrigley,1988,

In general terms coffee pulp could be composed either by anaerobic or aerobic conditions. The anaerobic composting involves preparation of a rectangular pits and filling the pit with pulp and covering by plant and soil materials where the pulp would decay by anaerobic microorganism's activities. In the case of aerobic, the pulp is piled above ground into long trapezium or pyramid shape heaps. For ease of management the base could vary from 1.5 meter by 1.5 meter to 2 meters by 2 meter and atop width would vary from 1 meter by 1 meter to 1.5 by 1.5 meter and a height of 1 to 1.5 meter. In the Aerobic composting, the pulp should be turned at least once in a day for few days since the high moisture content may not lead to compaction and the development of anaerobic conditions. After few weeks the decomposed pulp could be spread in farmlands. However research has to be carried out in identifying appropriate tools that make pilling and turning the hips easier and identification of microbial activators that could speed up composting with encouraging result. The only back draws of converting the pulps to compose fertilizes are the operation is tiresome and bulky. Since farmers do not have access to tractors or pickups the industry has to load the compost on pickups and the car has to travel along the accessible areas to disperse the compost nearer to farmlands. This would incur additional transportation costs to the industries, since the farmlands are scattered. The extension agents have also to organize their contact farmers to a routine work of returning the composted pulp to the farmlands. Conversely, in this country where rapid depletion of soil productivity is resulting in marked effects to unfertilized crops and where commercial fertilizers are not effectively and economically used, composed pulp fertilizer is essentially needed to reduce the decline in soil productivity, in addition to its indirect benefits of minimizing the impacts of river water pollution from wet processing plants. In spite of all these valid reasons, the cost of composting and transportation to scattered farmlands would be minor concern in coffee effluents management schemes.

Pulp Beverage

In some localities, especially, in pastoralist areas people use the dried coffee pulp for preparing a tea-like beverage. Besides its known effects of stimulating, people boil the pulp with milk in order to give special flavor for milk. This beverage is also considered as energy boosting drink, which gives strength after heavy works or travel tiresome. Provided that there is no risk of pesticide contaminations, and if the pulp is cleanly collected and dried it appears that the demand would be higher and since production and/or drying costs is negligible, it would be an additional merchandised commodity for the wet processing plants. This again would increase the income in addition to minimizing the pollution problems. Pulp beverage production would involve construction of pulp collection chamber, where the pulp will be collected through draining the residual water and the collection chamber could be constructed in a cheaper price either with concert and/ or with sheet metal, while the raised drying bed could be constructed from eucalyptus poles and mesh wires or local materials like bamboo and reeds.

Animal feed

According to informal information the use of coffee pulp as an animal feed ingredient is being investigated in the various universities of Ethiopia (Addis Ababa, Alemaya, Jimma, Awassa). However even if definite research justifications are not still forthcoming, it appears that from the unofficial information that cattle will accept coffee pulp in their feeds to a limited extent. This calls for an immediate collaboration between coffee stockholders, higher education institutes and research organizations in order to develop cattle feed from coffee pulp. Thus, immediate emphasis has to be given to research the values and limitations of pulp as animal feed and how profitable be incorporated in the concentrated mixture of animal feeds.

Matrix for Mushroom Cultivation

Crop production, as traditional source of protein in Ethiopia diet has not kept pace with population growth. Acute protein malnutrition is a glaring reality in Ethiopia and it is forcing to think about alternate source of protein. Production of protein rich nutritious food by unconventional method is therefore needed to supply the demand for protein by the growing population as well as to overcome malnutrition in rural Ethiopia. Mushrooms, one of the highest protein producers per unit area and in time from ago-wastes, fit in well in the scheme of the things to fight malnutrition. Due to ample availability, coffee pulp can be also a suitable matrix for mushrooms cultivation. Mushroom cultivation has various advantages as it converts complex organic compounds into nutritious food, aids recycling of pulps, contributes to pollution control, does not compete with croplands and provides avenues to self-employment. Hence there is urgent need to popularize the technology in the coffee zones.

Fuel Wood Substitutes (briquettes Production)

Biomass fuels will continue as the major source of energy for many years to come and will result in further deteriorating the natural resources basis of this country. There is already significant imbalance between wood consumption and establishment of new plantation, and sustainability and environmental impacts are serious issues for Ethiopia. Conversely due to the traditional practices of multistory coffee productions across the coffee zones, wood resource is not yet in scares. As learned from the other parts of the country as wood resource diminishes in the coffee zones rural households will definitely suffer very much, coffee production will decline, land degradation will be encouraged and the environmental degradation will be irreversible. This calls immediate interventions in the reduction of energy dependence on wood. Coffee residual briquettes could be alternate energy source in the coffee zones. There would be a definite advantage of converting coffee residuals to briquettes, because pollution would be controlled, it Provides rural employment in addition to supply fuel to small towns and settlements. Since the wet processing plants are powered by 10 to 20 HP diesel engines and the plants are not operational for 8months in a year, this would allow powering the briquette machine. Ex-Ministry of Coffee & Tea Development initiated briquette from coffee pulps, as a pilot project, in the 1980's but for unknown reasons it was seized and whether the result is documented or not remains vague. However there are different types of briquette making machines to suit specific needs, it is, therefore strongly suggested to reinitiate a pilot Briquette project across the coffee zones.

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Physico-Chemical analysis of samples collected during September 1997

Annex 1A

S. No	Sampling station	pH	Temperature (0c)	Conductivity (µs/cm)	Total dissolved solid (mg/l)	Remark
1	Dara river (down stream of Dereje site)	6.4	17.5	60.6	30	
2	Waste water (Alemekoncha village)	4.4	12	767	385	Sidama (from lagoon)
3	Waste water (Alemayehu yirdaw site)	4.6	25.6	208	105	Gedeo (from lagoon)
4	Waste water (Dereje Belete's plant)	4.8	23	1287	645	Gedeo (from lagoon)
5	Downstream of Dereje Belete's CPplant)	6.4	17.4	560	280	Dara river
6	Waste Water (membea's plant)	4.6	24	414	208	
7	Chichu river (downstream of member sites)	6.5	18.1	70	34.4	Gedeo (Wonago)
8	Dara river (upstream of Dilla treatement plant	6.6	16.1	55.4	27.8	
9	Waste water reservoir (lagoon)	6	22	1096	549	Sidama (worku site)
10	Chichu river (downstream of Mebea sites)	6.5	18.3	69.2	34.6	Gedeo

N.B Down stream implies the immediate down stream of the traditional wastewater lagoon

Physico Chemical analysis of water samples collected during coffee harvesting and processing periods (Nov/Dec- 2004)

Annex 1B

S. No	Sampling stations	Parameters											Remark
		P^H	TDS (Mg/L)	EC (Mg/L)	H_2S (Mg/L)	PO_4 (Mg/L)	SO_4 (Mg/L)	Cr (Mg/L)	Cl (Mg/L)	Acidity (ca Co (Mg/L)	Total Alkalinty as Ca Co_3	Total hardness Ca Co_3	
1	Down stream of wondu Alemeyehu CPP (Kochore-Kore Kebele)	4.26	221	467	0	3.98	Nil	Nil	8.5	120	Nil	82	
2	Waste water from lagoon	3.77	1162	2230	Nil	4.4	37.2	Nil	37.5	76	Nil	108	
3	Fitcne CPP (motto)	3.88	82	176	Nil	0.8	Nil	Nil	8.5	60	Nil	84	
4	Tulula river	4.51	124	259	Nil	2.33	Nil	Nil	5	88	Nil	86	
5	Upstream of Dilla teatment plant	4.85	114	242	Nil	2.46	Nil	Nil	4.5	35	Nil	82	

Location of Sampling Sites
Annex 1C

No.	Site of Sampling	Geographical Co-ordinate	NH_3	COD	BOD	NH3-N	NO_3 -N	NO_3^-	NO_2^-	NO_2^- - N	NH_4^+	$NaN0_2$
1	Down stream of memebe a CPI.	$06^0$23'00 N, 38018'45 E	7.1	710	240	5.9			UR	UR	7.6	UR
2	Upstream " " " " " " "	$06^0$22'50 N, 38019' E	1.48	25	14	1.22			29	9	1.57	44
3	Down stream of Shaffi site(Chichu) CPI	06^0 22' 56 N, 038^0 18' 24 E	12.6	798	290	10.4			6	2	13.4	9
4	" " " Tadese Berisso CPI	06^0 22' 31 N, 038^0 17' 46 E	12.6	756	249	10.4			5	1	1.34	7
5	" " " Redeat CPI	06^0 22' 07 N, 038^0 17' 52 E	27.9	774	516	23.0			UR	UR	29.6	UR
6	" " " Ferenju CPI	06^0 10' 46 N, 038^0 11' 52 E	19.0	861	279	15.6			UR	UR	20.1	UR
7	" " " Workicho CPI	06^0 11' 28 N, 038^0 12' 12 E	27.1	1614	538	22.3			UR	UR	28.7	UR
8	" " " Alem CPI	06^0 12' 08 N, 038^0 10' 30 E	90.0	8750	3120	74.0			6	2	95	9
9	" " " Dereje Desalegn	06^0 25' 35 N, 038^0 17' 49 E	7.3	875	290	6.0			UR	UR	7.8	UR
10	" " " Mengesha CPI	06^0 25' 11 N, 038^0 18' 48 E	4.3	589	200	3.5			3	1	4.5	4
11	" " " Gidabo river	06^0 45' 55 N, 038^0 20' 40 E	3.6	569	193	3.0			UR	UR	3.8	UR

	(Yirgalem)											
12	" " " Shilcho CPP	06^0 29' 46 N, 038^0 23' 28 E	4.9	145	41	4.0			15	5	5.2	22
13	Near Rift Valley Resort (Dara River)	$06^0$26'05 N, $038^0$17'22 E	1.0	25	16.6	0.8			10	3	1.0	16
14	Protected spring near Abinet CPP	$06^0$24'39 N, $038^0$19'43 E	0.4	20	8.2	0.3			3	1	0.4	5
15	" " " Dubale Asefa CPI	06^0 35' 48 N, 038^0 19' 00 E	13.0	862	294	10.7			0	0	13.8	0
16	Water point around Chichu	$06^0$22'00 N, $038^0$18' E	0.6	4	1.6	0.5			1	0	0.6	2
17	Borehole near Donbosco	$06^0$25'00 N, $038^0$18'24 E	UR	21	12	UR			2	1	UR	3
18	" " " Shilcho Co-operative CPI	06^0 29' 42 N, 038^0 23' 32 E	13	881	299	10.7			1	0	13.8	2
19	Downstream of Dereje CPP	$06^0$25'20 N, $038^0$18' E	1.1	35	10	0.9			1	0	1.2	2
20	Down Stream of Wondu Alenegeh (Kore)	06^0 01' 02 N, 038^0 09' 12 E	2.86	3280	1056	2.5				Nil		
21	Waste water lagoon	$06^0$22'29 N, $038^0$17'19 E	2.24	24600	10604	11.2				Nil		
22	Down Stream of Fitche CPI (motto)	06^0 47' 30 N, 038^0 27' 00 E	2.2	786	330	.4				Nil		
23	Tullula River (Sidama Zone)	$06^0$29'45 N, $038^0$20'00 E	33.12	1263	531	Nil				Nil		
24	Upstream of Dilla treatment	06^0 25' 10 N, 038^0 19' 10 E	5.385	965	298	1.1				Nil		

Chemical analysis result of nitrogen compounds (from previous resources)

Annex 1D

No	Site	Date of sampling	No_3-	NH_3	NH_4+	No_2	NH_{3-N}	No_{3-N}
1	Aletawondo	Feb, 2002	4.3		-	0.02		
2	DTW_1 (close to chichu)	11199	6.6		-	0.03		
3	DTW_2 (close to chichu)	12199	3.52		0.01	0.006		
4	BH1 (kebele 05)	01195	4.4		0.01	0.02		
5	BH2(Dilla college)	29/01/98	16.28	Nil	Nil	0.003		
6	BH3 Donosco Silesian father	29/01/99	Nil	Nil	-	0.013		
7	BH4 Donbosco Silesian sisters	5/9/95	6.6	-	0.4	-		
8	BH5 Chichu Gabrieal	29/01/99	4.4	0.378	-	Nil		
9	Debub university (well #3)	17/01/2004	4.0	0.155	0.164	0.022		
10	Awassa Hospital(well#2)	10/11/2003	8.8	0.2562	0.27	0.0165		
11	Awassa main campus	16/11/2003	7.48	0.0366	0.0387	0.0132		

	(Well #1)							
12	BH5		Nil	0.6		Nil	0.5	nil
13	BH3		Nil	Nil		1	nil	
14	Witcho BH							
15	Soda sinita							
16	Germancho BH		Trace		Trace	Trace		

Location of some coffee processing plants
Annex 2A

.	Name of industries	Zone/Woreda/Kebele	Geographic Co-ordinate	Elevation (m)	Remark
1	Shilcho Co-operative (1)	Sidama/ Dara/ Shilcho	$06^0$29' 42 N, 038^0 23' 32 E	1700 m	
2	Ali Husen	" / " / Shilcho	$06^0$29' 46 N, 038^0 23' 38 E	1843 m	
3	Buna Buka Co-operative	" / " / Bunaxababa	$06^0$30' 31 N, 038^0 25' 16 E	1950 m	
4	Jigosa PLC.	" / " / "	$06^0$30' 01 N, 038^0 24' 53 E	1928 m	
5	Loya Andnet PLC.	" / " / Loya	$06^0$30' 13 N, 038^0 24' 09 E	1886 m	
6	Buna Buka Co-operative (2)	" / " / Bunaxababa	$06^0$29' 51 N, 038^0 23' 57 E	1871 m	
7	Shilcho Co-operative (2)	" / " / Shilcho	$06^0$29' 25 N, 038^0 23' 22 E	1849 m	
8	Setamo Co-operative	" / " / Setamo	$06^0$28' 56 N, 038^0 21' 20 E	1839 m	
9	Derancho PLC.	" / " / "	$06^0$28' 39 N, 038^0 20' 48 E	1827 m	
10	Sela PLC.	" / " / "	$06^0$28' 28 N, 038^0 21' 25 E	1842 m	
11	Bilal PLC.	" / " / Aleme Koriha	$06^0$27' 27 N, 038^0 21' 33 E	1890 m	
12	Dara Lalebo PLC.	" / " / "	$06^0$27' 58 N, 038^0 21' 24 E	1854 m	
13	Watadara Co-operative	" / " / Gelowacho	$06^0$27' 40 N, 038^0 20' 46 E	1849 m	
14	Guma PLC.	" / " / "	$06^0$27' 37 N, 038^0 20' 21 E	1840 m	
15	Almesho PLC.	" / " / Korati Kororesa	$06^0$25' 29 N, 038^0 20' 34 E	1800 m	
16	Kes Dangamo PLC.	" / " / "	$06^0$25' 35 N, 038^0 20' 53 E	1849 m	
17	Kasu Gidissa PLC.	" / " / Kumato	$06^0$28' 59 N, 038^0 19' 33 E	1645 m	
18	Fikre Belela PLC.	" / " / "	$06^0$28' 26 N, 038^0 19' 47 E	1745 m	
19	Setamo Co-operative	" / " / Shoinchcho	$06^0$30' 25 N, 038^0 23' 28E	1849 m	
20	Nore Korate	" / " / Odola	$06^0$25' 24 N, 038^0 19' 09 E	1602 m	

21	Tesfaye Getu	“ / “ / “	06^{0}25’ 43 N, 038^0 18’ 25 E	1598 m	
22	Kedir Bargichcao	“ / “ / Mesincho	06^{0}25’ 47 N, 038^0 17’ 41 E	1495 m	
23	Solomon Worku	“ / “ / “Kumato	06^{0}27’ 40 N, 038^0 19’ 13 E	1693 m	
24	Dereje Belete PLC.	Gedeo/ Wondo/ Dilla	06^{0}25’ 35 N, 038^0 17’ 49 E	1463 m	
25	Mengesha Dama PLC.	“ / “ / ”	06^{0}25’ 11 N, 038^0 18’48 E	1542 m	
26	Membea PLC.	“ / “ / Chichu	06^{0}23’ 05 N, 038^0 18’ 40 E	1538 m	
27	Tadese Beriso PLC.	“ / “ / “	06^{0}22’ 31 N, 038^0 17’ 46 E	1517m	
28	Abnet Desalegn PLC.	“ / “ / Gola	06^{0}24’ 39 N, 038^0 19’ 43 E	1674 m	
29	Jemal & his family PLC.	“ / “ / Chichu	06^{0}23’ 04 N, 038^0 18’ 04 E	1526 m	
30	Redieat PLC.	“ / “ / “	06^{0}22’ 07 N, 038^0 17’ 52 E	1535 m	
31	Sami PLC.	“ / “ / Tumata Chiracha	06^0 19’ 29 N, 038^0 17’ 01 E	1607 m	
32	Girma Lege PLC.	“ / “ / Chichu	06^{0}20’ 48 N, 038^0 18’ 17 E	1555 m	
33	Chichu Co-operative	“ / “ / “	06^{0}20’ 13 N, 038^0 18’ 16 E	1596 m	
34	Danchcho PLC.	“ / “ / Karasodit	06^0 18’ 35 N, 038^0 14’ 35 E	1832 m	
35	Kedir Ibrahim	“ / “ / “	06^0 18’ 18 N, 038^0 13’ 28 E	1856 m	
36	Andnet PLC.	“ / “ / “	06^0 18’ 38 N, 038^0 12’ 49 E	1885 m	
37	Haji Buser	Gedeo /Y-cheffe/ Dumerso	06^0 13’ 01’ N, 038^0 12’ 35 E	1843 m	
38	Sami	“ / ” / Konga	06^0 07’ 44 N, 038^0 12’ 06 E	1880 m	
39	Alemayehu Yirdaw PLC.	“ / ” / O3 kebele	06^{0}09’ 22 N, 038^0 11’ 49 E	1848 m	
40	Torencho PLC.	“ / ” / Konga	06^{0}07’ 14 N, 038^0 12’ 08 E	1913 m	
41	Hayat PLC.	“ / ” / “	06^{0}07’ 27 N, 038^0 12’ 11 E	1897 m	
42	Solomon Kemal PLC.	“ / ” / “	06^{0}08’ 06 N, 038^0 12’ 00 E	1870 m	
43	Danieal Fikadu PLC.	“ / ” / Y-cheffe (03)	06^{0}09’ 00 N, 038^0 12’ 17 E	1910 m	
44	Hafursa Co-operative	“ / ” / Hafursa	06^{0}09’ 28 N, 038^0 11’ 22 E	1846 m	

45	Kedir Haile PLC.	“ / ” / Adame	06^{0} 10’ 00 N, 038^{0} 12’ 18 E	1854 m	
46	Wondo Trade Company	“ / ” / “	06^{0} 09’ 57 N, 038^{0} 12’ 28 E	1845 m	
47	Amare Tesema PLC.	“ / ” / “	06^{0} 10’ 12 N, 038^{0} 12’ 49 E	1890 m	
48	Solomon Worku PLC.	“ / ” / Koke	06^{0}09’ 41 N, 038^{0} 12’ 44 E	1896 m	
49	Koke Co-operative	“ / ” / Orubetela	06^{0}09’ 29 N, 038^{0} 13’ 15 E	1920 m	
50	Edido Teramed PLC.	“ / ” / Edido	06^{0}10’ 48 N, 038^{0} 14’ 49 E	1935 m	
51	Ali	“ / ” / Aricha	06^{0}10’ 46 N, 038^{0} 13’ 56 E	1906 m	
52	Mohmmed Awolu PLC.	“ / ” / Suke	06^{0}10’ 45 N, 038^{0} 11’ 59 E	1853 m	
53	Haji Workicho PLC.	“ / ” / Adama	06^{0}11’ 28 N, 038^{0} 12’12 E	1797 m	
54	Ferenju Defar PLC.	“ / ” / H. Aranja	06^{0}10’ 46 N, 038^{0} 11’ 52 E	1836 m	
55	Alemayehu yirdaw PLC	Gedeo / Kochore / Kore	06^{0}01’ 02 N, 038^{0} 09’12 E	1722 m	
56	Haykel PLC.	“ / ” / “	06^{0} 00’ 34 N, 038^{0} 09’ 06 E	1692 m	
57	Dakdanaba PLC.	“ / ” / Chelelektu	06^{0}00’ 26 N, 038^{0} 09’ 23 E	1711 m	

Water Supply Coverage (2004) for the 10 Woreda's in Sidama zone.

Annex 3A

No	Woreda	199-- population			Population served			Water supply coverage%		
		Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
1	Shebedino	288486	9010	297497	128717	4093	128717	45	45	43
2	Boricha	245149	7658	252807	20748	-	20748	8	0	8
3	Awasa.zuria	355264	113070	468334	164892	94033	165636	46	83	35
4	Argegona	172218	4746	176964	88776	4061	88776	52	86	50
5	Dale	366951	37787	404738	144612	12644	144612	39	33	36
6	Aleta Wondo	332350	24852	357201	207911	4160	207911	63	17	58
7	Dara	130146	8016	138162	82620	2375	82620	63	30	60
8	Hagereselam	226248	7322	233570	167832	3756	167832	74	51	72
9	Bensa	234684	9214	243898	42120	7884	42120	18	86	17
10	Aroresa	121292	2597	123889	54432	3527	54432	45	136	44
Total		2472789	224272	2697061	1102660	136533	1103404	45	61	41

Water Supply Coverage Fore the Four Woredas of Gedeo Zone (2004)
Annex 3B

WOREDA	SORCE	GOV		NGO		RURAL		URBAN		TOTAL			POPULATION SERVED		
	TYPE	FN	NF	FN	NF	FN	NF	FN	NF	FN	NF	ALL	RURAL	URBAN	TOTAL
BULE	HDW	1			3	1	3			1	3	4	279		279
	MSW	10	7			10	7			10	7	17	3250		3250
	DBH	1						1		1		1		4762	4762
	PSS	2	5	2	2	4	7			4	7	11	1860		1860
	PMS														
	PLS														
		14	12	2	5	15	17	1	0	16	17	33	5389	4762	**10151**
															10413
KOCHORE	HDW														
	MSW	10		4		14				14		14	4550		4550
	DBH	2		1				3		3		3		11202	11202
	PSS	12		12		23		1		24		24	11160		11160
	PMS	1		1		2				2		2	9298		9298
	PLS														
		25	0	18	0	39	0	4	0	43		43	25008	11202	**36210**
															19.209
WONAGO	HDW														
	MSW	6	3	8	20	14	23			14	23	37	4550		4550
	DBH	2		2		2		2		3		3	7878	10622	18500
	PSS	14	6	26	12	40	18			40	18	58	18600		18600
	PMS	3	1	1		4	1			4	1	5	18596		18596
	PLS														
	RIT	1						1		1		1		20000	20000
		26	10	37	32	60	42	3	0	62	42	104	49624	30622	**80246**
															43.177
Y/CHEFFE	HDW														
	MSW	2	6	7	50	9	56			9	56	65	2925		2925

	DBH														
	PSS	6	10	22	13	28	23			28	23	51	13020		13020
	PMS			4		3		1		4		4	13947		
	PLS														
		8	16	33	63	40	79	1	0	41	79	120	29892	4649	**34541**
	21.701														
		TOTAL #OF POPULATION SERVED											109913	51235	**161148**

KEY

HDW=Hand Dud Well
MSW=Machine Drilled Shallow Well
PSS=Protected Small Spring
PMS=Protected Medium Spring
PLS=Protected Large Spring

Rural and urban population by sex and woreda

Annex 4

		Population 2005								
		Urban			Rural			Total		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
		178.166	167.535	354.227	1586678	1625573	212.251	1764.844	1801.634	3566478
1	Shebedino	5155	4849	8004	154644	149762	304406	159799	154611	314410
2	Boricha	4336	4121	8517	131413	127264	258678	135810	131386	267195
3	Awassa	62793	61592	124385	191760	183109	374870	254553	244701	499254
4	Arbegona	2531	2686	5217	91439	90283	181722	93970	92968	186938
5	Dale	20707	20828	41535	198461	188740	387201	219168	209568	428736
6	Alethawondo	13472	13845	27316	180171	170520	350691	193642	184365	378007
7	Dara	4380	4431	8811	67880	69447	137327	72260	73878	146138
8	Hagere selam	3959	4089	8049	119583	119150	238733	123542	123239	246781
9	Bensa	5033	5095	10128	126040	121595	247635	131072	126691	257763
10	Aroresa	1449	1406	2854	65647	62339	127986	67095	63745	130840
11	Wonago	32536	31202	63738	101015	101188	202203	133551	132390	265941
12	Yle coffee	9516	9509	19025	86661	86510	173171	96177	96019	192196
13	Bule	2997	3142	6139	53456	52603	106059	56413	55745	112198
14	Kochare	9242	9267	18509	18509	103062	121571	27751	112329	140080

Monthly average maximum, minimum & average temperature
Annex 5

Station	Element	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual averag
Awassa	A max.	28.9	30.7	29.8	28.4	27.2	25.5	24.3	24.7	25.6	26.9	28.1	28.3	27.38
	A min.	11.3	11.4	13.3	13.9	14.1	14.2	14.6	14.5	13.6	12.8	10.26	10.2	12.83
	Total average.	20.1	21.1	21.6	21.2	20.6	19.9	19.4	19.1	19.7	19.85	19.1	19.3	20.1
Yirgalem	,,	28.5	29.2	28.8	27.8	26	25.4	24	24.5	25	25.6	27.5	27.4	26.6
	,,	10.65	110.	11.2	11.4	11.6	11.5	12	12.4	11.2	12.4	11.2	10.68	11.3
	,,	19.6	19.6	20	19.6	18.8	18.45	18	18.45	18.6	18.8	19.35	38.1	19.0
Hageresela	,,	21.1	21.7	21.5	19.1	19.2	17.6	6.1	16.5	17	17.0	18.6	18.7	18.6
	,,	7.7	8.4	9.1	9.3	9.2	8.4	7.8	7.79	8	8.3	8.3	8.1	8.3
	,,	14.4	15.2	15.3	14.2	14.2	13	11.45	11.35	12.5	12.65	13.45	13.4	13.45
Dilla	,,	29.6	30.5	30.4	28.4	27.3	27.6	25.9	26.2	26.4	26.2	27.8	25.6	27.6
	,,	10.6	9.85	11.7	12.0	12.3	15.4	12.2	12.3	11.8	11.8	10.7	10.3	11.8
	,,	20.1	20.2	21.05	20.2	15.8	21.5	19.05	19.15	19.1	19	19.25	17.45	19.7
Y/cheffe	,,	27.5	28.3	27.2	25.5	24.1	24	23.2	23.8	24	24	25.4	26.4	25.2
	,,	7.5	8.4	10.4	11.4	11.6	11.5	11.8	11.7	11.4	11.15	9.2	7.01	10.25
	,,	17.5	18.3	18.8	18.45	17.35	17.75	17.5	17.75	17.7	17.6	17.3	16.7	17.725

Mean monthly rainfalls
Annex 6:

Station	Jan	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual mean
Awassa	30	25.3	82.1	114.6	101.7	114.8	122.4	124.5	107.2	90.4	25.8	26.6	965.4
Leku	9.7	9.3	55	154.2	77.4	72.2	85.4	142.2	137	61.3	27.4	59	890.1
Yirgale m	35.2	52.6	105.8	154.8	156.2	104.8	105	120.1	167.7	139.4	44	25.7	1211.3
Hageres elam	53.2	63.2	76.1	157	159.8	119.3	119.1	177.1	137	151	59	28.4	1300.2
Aletawo ndo	34.6	55.9	106.9	118.1	233.8	141.4	141	141	193	169.3	53.3	30.7	1519
Kebado	33.4	35.0	120.7	229.2	227.9	143.6	97.1	122.3	166.8	174.9	61.9	52.6	1465
Dilla	30	50.5	105.6	202.6	206.8	108.8	101.5	95.8	168.6	150.4	64.5	25.9	1311
Yirgach effe	24	50	109.2	252.5	271.3	120.4	94.4	113.4	189.3	247	91.8	24.5	1588.3
Chelele ktu	20.4	43	110.9	214.7	190.6	118.8	50.3	59.5	116.4	199	84	28.5	1236.1
Bule	40.6	43.3	122.2	156.2	134.3	96.7	108.2	173.9	123.2	117.0	57.1	40.2	1212.9

Declaration

This thesis is my original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged.

Dr. **Tamiru Alemayehu** (Advisor)

Signature____________________

Mesfin Gobena

Signature____________________

Date and place of submission, July 2005, Addis Ababa.