NATURAL HYDROCHEMICAL VARIATIONS AND ANTHROPOGENIC INFLUENCES ON SURFACE WATER AND GROUND WATER SYSTEMS IN THE SELECTED URBAN CENTERS IN THE UPPER AWASH BASIN

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ABSTRACT

The study areas are found in the upper Awash River basin situated in the central part of the country. The study areas (Debre Zeite, Mojo and Nazret) are the selected urban centres from the upper Awash River basin. The town of Debre Zeite is located at $8^0$45'N latitude and $38^0$58'E longitude; Mojo is located at $8^0$36'N latitude and $39^0$05'E longitude and Nazret is located at latitude $8^0$32'Nand $39^0$16'E longitude.

Collection of water samples from surface (streams/ rivers, Lakes, and rainwater) and groundwater (boreholes, spring) was done in two field work periods in the year 2003/4.

The physical parameters such as appearance, turbidity, colour and odour of the ground water are in good condition. But, surface waters are contaminated.

The pH values of both groundwater and surface water in the areas range from 6.6 to 9.21.

The conductivity and TDS values of all groundwaters in the study areas are lower than 1000mg/l. i.e., groundwater is classified as fresh water. But, the conductivity and TDS values of certain surface water bodies are greater than 1000mg/l. The high values were recorded in crater lakes from Debre Zeite area and the polluted Mojo River from Mojo area.

The ground and surface waters of the areas can be classified as dominantly as very hard water types.

From the available water chemical analysis results of Debre Zeite area crater lakes are all sodium –bicarbonate type water and artificial lakes, boreholes and hand dug wells show calcium-magnesium- bicarbonate type water.

On the basis of these major chemical constituents, it can be indicated that the chemical composition of the waters are continuously enriched by calcium and magnesium cations

and bicarbonate anion due to the effect of the interaction between waters and the geological formations through which they reside and move.

The waters from Mojo area show both calcium and sodium- bicarbonate type water. However, sodium- bicarbonate type water is the dominant water type in the area.

The chemical analysis results of water from Nazret area also show the dominant waters are sodium- bicarbonate type water.

The major ions constituent the waters from Mojo and Nazret areas are characterized by higher content of sodium and bicarbonate.

The chemical and bacteriological analyses of surface and ground water samples confirmed the occurrences of pollutants, which are organic and inorganic nutrients and micro-organisms in their origin. This is mainly attributed to the improper waste disposal from industrial and municipal sources.

The major sources of water pollutant in the area include liquid and solid wastes generated from industries, municipal and agricultural activities.

The extent of pollution is not uniform through out the areas. It varies from highly polluted or affected to slightly affected areas. Highly affected areas are Mojo river at the vicinity of the town due to direct discharge of both industrial and municipal wastes, central part of Nazret town due to municipal wastes, Awash river down the stream and Shimbira Meda seasonal stream due to agricultural wastes.

The protective measures to be taken in order to protect surface and ground water are not to dump industrial and municipal wastes on surface water bodies prior to the necessary treatment.

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CHAPTER ONE: INTRODUCTION

1.1 Background (Upper Awash Basin)

The Upper Awash basin extends from its source at Ginchi up to Metehera. The upper Awash basin comprises an area of 10,400 km^2, which is about 14% of the total basin of the area (Adane Bekele, 1999). It is bounded by the Blue Nile basin in the north and west, by the Omo basin in the Southwest, by the rift valley lakes basin in the south and by the middle Awash basin in the east.

The upper Awash basin is situated in the central part of the country where the capital city, Addis Ababa, was founded. Today the basin encompasses the most densely populated and most industrialized regions of the country. Important commercial towns, including Nazret, Debre Zeite, and Mojo are found with in this basin. The socio-economic developments are growing faster and wider in the Upper Awash basin than anywhere else in Ethiopia.

The facts about the Upper Awash basin indicate that the exploration and utilisation of both surface and subsurface waters has always been a subject of prime importance. The demand of water in the Upper Awash basin will soon be much greater and urgent need than it has already been. This will be both in quantity and quality of water.

The demand will rise for all water uses such as for domestic uses, irrigation development, sanitation and industrial development. Ground water and surface waters are the major sources of water, which contribute a lot to satisfy water demand.

The demand of fresh water resources is increasing along with increasing of population and advancement of technology. This matter requires urgent attention since fresh water is scarce and needs detailed scientific research in all regions of the world in order to protect the water resource from pollution and for wise utilisation.

Human intervention to natural system has a significant effect on the quality of natural water. Human activities like discharge of untreated toxic chemical and industrial waste in to the stream (river), over pumping of aquifers and contamination of water bodies with substance that promote algae growth are some of the prevailing causes of water quality degradation.

The rapid increase of all kinds of anthropogenic activities in the last few decades has affected the terrestrial and aquatic ecosystems, and the atmosphere on a global scale. As a result, complex interrelation ships between socio-economic factors and natural hydrological and ecological conditions have been identified. The following three major urban centres are studied.

1.1.1. Debre Zeite

Debre Zeite is about 47km South of Addis Ababa on the way to Nazret. The town is located at 8045'N Latitude and $38^{0}58'$E Longitude.

The elevation of the area is ranging from 1860m to 1940m above sea level.

Debre Zeite is one of the most impressive areas geologically. This area is known for its prominent volcanic activities as it is found in the rift valley. Intense volcanism and active tectonic processes characterise it. There are also different lakes in Debre Zeite area.

Volcanic rocks of trachyte, rhyolities and basaltic origin form the relief of the area. The surfacial deposits are alluvial and lacustrine deposits.

The present water supply of the town is from a well field with six wells located at Shimbira Meda well field equipped with electric submersible pumps. The water from the wells is collected in the 1,000 cubic meter reservoirs.

Shimbra Meda valley is located about 9km to the northeast of the town centre. In this well field the wells are positioned about 800m apart from each other (Debre Zeite town water supply service).

The existing experience has shown that some of the boreholes, which are source of water supply to the town, are vulnerable to different types of pollutants.

1.1.2. Mojo

Mojo is located to the south east of Addis Ababa on the main asphalt road on the way to Nazret. It is about 73km by road from Addis.

The area to be studied is bounded with in 8°34"6"N to $8^0$36"8 N latitude and $39^0$06"E to $39^0$08"E longitude. The town is found on the floor of the rift valley. The elevation ranges from 1780m to 1781m a.s.l.

The main source of water supply for the town is solely groundwater through boreholes. Boreholes well field is located to the southwest of the town at about 2 km. There are a number of factories (textile, tannery and others) in and at the vicinity of the town, which appears to cause contamination of the water supply of the town.

1.1.3. Nazret

Nazret town is located at about 100 km southeast of Addis Ababa. The town is found in the Great Rift Valley of Africa in flat lowland between two mountain ridges. The average elevation in the town is about 1620m above sea level. Its location is at the crossing of roads leading to eastern and south eastern parts of the country and the existence of the railway station enhanced its growth as a major town.

The area studied is bounded with in $8^0 31'4''$ N latitude and $39^0 15'$ to $39^0 18'$ E longitude. Nazret and the surrounding low lands are predominately covered with lacustrine and alluvial deposits. Along the river cuts and high lands outcrops of volcanic rocks are observed.

The history of Nazret as an urban centre began with the emergence of the Addis --Djibouti railway that passes through the town.

The water supplies of the town are from groundwater (boreholes) and surface water (Awash River). The current predominant water supply of the town is from Awash River. The Awash River down stream of Koka dam is used as a raw water source for the town. Most water samples taken from the Awash River at different spots of the area show that the concentration of fluoride, total dissolved solids and iron concentrations are high.

1.2. Populations

According to the 1994 population and housing census result, the total urban population residing in Nazret town was 139052, in Bushoftu (Debre Zeite) 100,175 and Mojo 26,471. According to this statistics Nazret (Adama) has the largest urban population. The population size of the three towns and some other towns in the area are shown below.

Table 1.1. Population size of main towns in the study areas.

	Population		
Town	Male total	Female total	Grand total
Bushoftu (Debre Zeite)	47,198	52,977	100,175
Dukam	2,654	3,626	6,280
Mojo	12,415	14,056	26,471
Koka	2,804	2,852	5656
Adama (Nazret)	66,467	72,585	139,052
Awash Melkasa	1,006	1,421	2,427
Wonji Gefersa	6,615	7,093	13,708

Source: Regional State of Oromia Statistical Abstract; 1994.

1.3. Physiography and Drainage

The studied areas (Debre Zeite, Mojo and Nazret) are bounded by the plateaux to the east and west.

The average altitude of the plateaux, on both sides of the rift, is about 2500m a.s.l, while the floor of the rift valley gently decreases from the west to east to an altitude of 1350m a.s.l. to the east of Nazret town.

The main rivers are Awash, Dukem, Wedecha and Mojo. They run from north to south. The other rivers are all the tributaries of Awash River. The location map of the study area is depicted on Figure 1.

1.4 Previous Works

Numerous reports both published or unpublished on the geology, hydrogeology, and climate on the study area (upper Awash River basin) are available (particularly on the Awash basin as a whole).

The most relevant works for this study include:

-Geology and development of the Nazret area Northern Ethiopian Rift by Kazmin and Seifemichael (1978).

-The work of Kazmin and Seifemicael Berhe in the Ethiopian rift valley and on the geology of the Nazret area (1979).

-Hydrogeology of the Nazret Area NC 37-15 by Getahun Kebede, (1987).

-The master plan of the development of the surface water resource in the Awash River basin final report (volume 4, 5, 9 and 10 by, HALCROW, 1988/89).

-The hydrogeology of Debre Zeite area by Tamiru Alemayehu (1992).

-Hydrogeology of Nazret area by Woldu Ameneshoa (1994).

-Five towns water supply and sanitation study, phase 1-report volumes 1, 2, & 3. By DEVECON Engineers and Architects.

-The origin of high bicarbonate and fluoride concentrations in waters of the Main Ethiopian Rift Valley, East African Rift system by Berhanu Gizaw.

-Hydrogeology and Hydrochemistry of Bushoftu crater Lakes (Hydrological, hydrochemical and oxygen isotope modelling) by Seifu Kebede (1999).

- Surface water and ground water pollution problem in the upper Awash basin by Adane Bekele (1999).

1.5 Objectives

The areas under consideration are among the fast growing towns in the country and located in the upper basin of Awash river and its tributaries. Awash drains the central industrialized part of Ethiopia known to face the problem of water quality degradation.

Mojo River, one of the major tributaries of the Awash River is flowing through the Mojo town. It is especially facing water quality problems from the effluents in different factories in the town. If the present process of waste disposal is allowed to continue, surface and groundwater pollution will be further intensified with the increasing industrialization and urbanization processes of the areas as a whole. Hence, protection of the water resources from pollution should be taken up as an urgent priority that needs prompt action.

Thus, the general objective of this research is to study the groundwater and surface water chemistry and pollution of the areas and to identify the possible sources of pollution, type and extent of pollutants of the water resources of the areas and based on the findings of the research to indicate the possible measures to be applied to prevent or reduce pollution of surface and groundwater.

More specifically the objective of this research includes.

- To identify the major sources of pollutants affecting the quality of ground water and surface water in the study areas,
- To identify the major human activities that causes the pollution of water.
- To identify the extent of pollution of both ground and surface water resources,
- To identify the possible measures to be taken to prevent or reduce pollution of the water resources.
- To study the surface water and the ground water quality for various uses.
- To suggest possible future sustainable utilization of the surface water and ground water resources.

1.6. Methodology and materials used

For successful completion of this research work the following methods and materials have been employed.

1. Field equipments during the fieldwork:-

. GPS 310 model; global positioning system (GPS) was used to get the location (longitude/latitude) and elevation of the sampling point and as well the location and elevation of some of previously collected data.

. pH meter, calibrated with standard solution (pH 4.01+0.1 and pH 10.01+0.1 at 25 degree centigrade) was used to measure the pH, Eh and temperature of the samples.

A kit to measure total dissolved solids (TDS), electrical conductivity (EC), salinity and temperature of the water samples in-situ.

2. Topographic maps at the scale of 1:50,000 were used. They were also used to classify drainage pattern and morphology of the regions

3. Hydro meteorological data; hydro meteorological data were collected from the National Meteorological service Agency. The data include; rainfall and temperature for Debre Zeite Air force, Mojo and Nazret stations.

4. Water quality analyses: Physical and chemical tests have been carried out in the field and in the laboratory. In the fieldwork, physical parameters such as pH, Eh, salinity, TDS, temperature and EC were measured in situ. The laboratory work was done in Oromia Water Resource Bureau, central laboratory for the samples physical, chemical and bacteriological analyses. During the analyses, using, spectrophotometric, and atomic absorption and gravimetry method for the series analysis determined physical properties of water samples, major cations and anions, some heavy metals, some trace elements. Some biological analysis; E.coli and total coliform were also analyzed.

5. Pollution point sources; A series of information were gathered about the distribution and type of industries. The conditions of sewage systems and means of waste disposal from different sources in Debre Zeite, Mojo and Nazret were investigated in order to know the influence of those on the quality of water in the areas (surface and ground water)

6. Data processing; Data processing was done using the following application softwares; AquaChem, EXEL, MapInfo and Arcview.

MapInfo and Arcview were also used to prepare different maps.

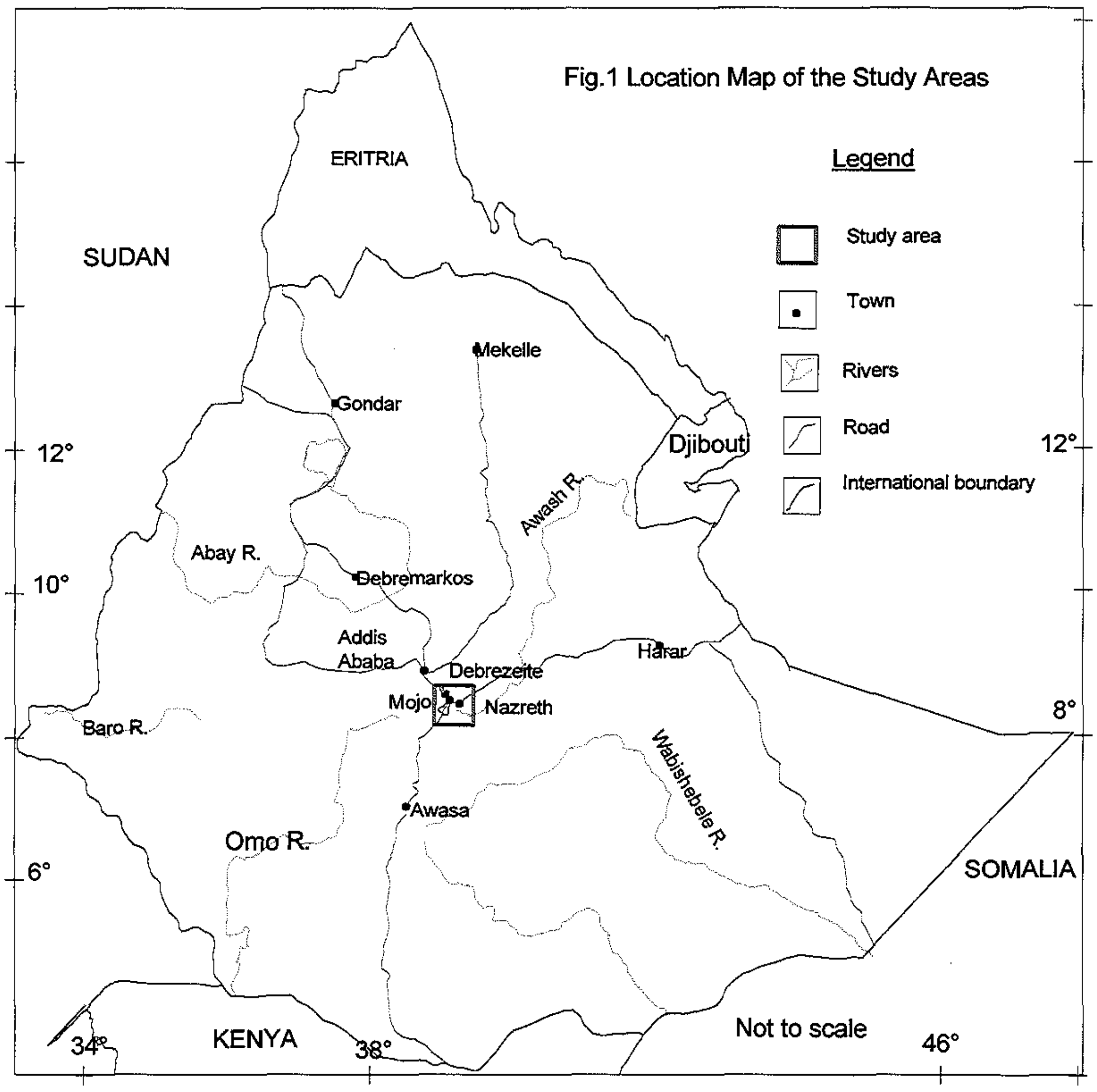


Fig.1 Location Map of the Study Areas
Legend
Study area
Town
Rivers
Road
International boundary
ERITRIA
SUDAN
Mekelle
Gondar
Djibouti
12°
12°
Awash R.
Abay R.
10°
Debremarkos
Addis
Ababa
Harar
Debrezeite
Mojo
Nazreth
8°
Baro R.
Wabishebele R.
Awasa
Omo R.
6°
SOMALIA
KENYA
34°
38°
Not to scale
46°

CHAPTER TWO: GEOLOGY

2.1 General

In Ethiopia, the rift system runs in a north- northeast direction and extends in to the red sea-Afar to Gulf of Aden system. It is possible to divide it in to the south western rift zone, the main Ethiopian rift zone (MER) and the Afar (Alula Damte, 1990).

The southwestern rift zone is a broad structurally disturbed area containing for rift valleys, which are the northwesterly trending Kibish rift, the north south striking Omo, Usno and Chew Bahir (Stephanie) rifts. The main Ethiopian rift (MER) represents a structural depression with an average width of 80km. It starts in the north from an arbitrary Yerer-gugu cross-rift lineament and extends in the south where it bifurcate in to Ganjuli and Galana graben (Alula Damte, 1990)

The MER subdivided Ethiopia in to a northwestern Ethiopia plateau and southeastern Somalian plateau. These plateaus are composed of extremely folded and foliated basement of Precambrian age overlain by sub-horizontal Mesozoic transgressive and regressive sedimentary strata separated by a marked Paleozoic unconformity, and covered by Tertiary volcanics.

The successive periods of volcanic activity, according to Di Paola (1972), in Alula Damte (1990) the MER include fissure eruptions with emplacement of explosive, dominantly ignimbritic products followed by volcano tectonic collapses. The youngest volcanic cycle include the building up of basaltic fissure eruptions and edification of the recent mostly pantelleritic centers with associated "sub- historical" basaltic fissure eruptions.

The present surface rock distribution, the land configuration and other natural phenomena in the study areas are all the results of the past geologic history and tectonic movements in the upper mantle-lithospheric portion of the Afro-Arabian land mass.

The existing relief features, rock distributions and other natural phenomena in the area, similar to other parts of the country, are the results of the past geologic history, tectonics, denudation and peneplation in the upper mantle- lithosphere portion of the horn of Africa.

2.2. Regional Geology

The Ethiopian rift system, which is part of the East African rift system, may be sub-divided into three main sectors. These are; the southwestern Rift zone, the main Ethiopian rift, and Afar.

A persistent belt of intense, fresh marks the floor of the MER, faulting which has been termed the Wonji Fault belt (WFB) (Mohr, 1960). The WFB extends from south of Lake Chamo in southern Ethiopia to the lake Abhe area in central Afar.

Two main tectonic events have been recognized concerning the tectonic evolution of the Ethiopian Rift system. The first event, which started since Eocene (Mohr, 1967) in Alula Damte, 1990, involved the uplift of the Ethiopian swell. Large scale faulting later took place across the swell to form the Afar and the Ethiopian Rift and this represents the second major tectonic event. The initiation of the Ethiopian Rift and the Afar can be traced to 14 my ago (Kazmin and Seifemichael, 1978).

Meyer et al. (1975) in Alula Damte, 1990, distinguished two main volcanic units in the northern part of the rift system. The first of these units is identified as "Nazret series", later replaced by group by Kazmin and Seifemichael (1978), with an age range of 5-2 my. According to Kazmin and Seifemichael (1978), this series includes a thick succession of ignimbrites, unweldded tuffs, ash flows, rhyolites and trachyte flows. They form the large part of the rift floor and also outcrop in the rift escarpments and on the adjacent plateau margins. In Nazret area according to Meyer et al. (1975), rhyolites and ignimbrites represent this series. Eruptions of these units are considered to be mainly through fissures and vents, but local centers also occur (Alula, 1990).

The second volcanic unit of Meyer et al (1975), is the young "Wonji series", group by Kazmin and Seifemichael, (1978), which built up mainly from extensive basaltic flows, later replaced series. Ignimbrites, rhyolite and trachyte flows and pumice deposits are also found in this series. This volcanism is spatially restricted to the axial extension zone of the rift system, which is the WFB. The volcanic products of these series are observed to be associated to NNE-SSE running faults or are erupted from fissures and vents in this direction (Alula, 1990). The Wonji volcanism spanned from Pleistocene up to Recent, according to several authors. In the Nazret area this series is mainly represented by basaltic and rhyolitic lava flows.

The Nazret and Wonji volcanic units are separated by a major episode of rift faulting. This faulting phase came into activity 1.6-1.8 my ago (Kazmin and Seifemichael, 1978, Mohr 1986).

2.3. Regional Stratigraphy (Main Ethiopian Rift and Adjacent Plateau)

The stratigraphic sequence of the various volcanic products in the northern part of the MER and adjacent plateaus, which have been emplaced since Eocene to recent has been reconstructed by Di Paola.1972, as depicted in the following table.

Unit (Stratigraphy)	Age
Alluvial and lacustrine sediments	Recent to Pleistocene
Recent alkaline and peralkaline rhyolitic pumice, ashes and obsidian lava flows.	Holocene
Alkali trachytic lava flows and domes.	Recent to Pliocene
Recent basaltic lava flows and spatters cones.	Recent to Pleistocene
Basaltic hyaloclastites.	Recent to Pleistocene
Old alkaline and per alkaline rhyolitic lava flows and domes, associated with pumice and ashes.	Early Pleistocene to late Pliocene.
Alkaline and per alkaline ignimbrite associated to pumice, ashes and lahars (mud flows).	Pliocene
Tertiary basalts and ignimbrites of the plateau Trap series.	Pliocene to early Eocene.

Table 2.1 Summary of stratigraphy and age of volcanic products out cropping in the northern part of the main Ethiopian Rift, Di Paola (1972). For their spatial distribution and identification refer to Fig. 2.1 and 2.2 (other source).

2.4. Stratigraphy of the study areas

2.4.1. Debre Zeite

In defining the stratigraphic sequences of Debre Zeite, there are three complexes, ten volcanic and two sedimentary units were distinguished Abebe et al, 1999. The names of the complexes have been attributed mainly on the basis of the morphostructural features in relation with the main Ethiopian rift; the units are depicted on Fig 2.1. They are going to be described as follows;

1/ Western Rift Margin Complexes:

This complex exhibits ages ranging from 7.5 to 2 my. It is constituted by four volcanic units dominated in the lower part by basaltic lava flows (Addis Ababa basalts unit), followed by a pyroclastic sequence, mainly formed by ignimbrites (Addis Ababa ignimbrite unit) and finally , by central composite volcanoes (central volcanoes unit) and small spatter cones and lava flows (Akaki unit).

2/ Intra Rift Complexes

In this complex we include upper Miocene- Quaternary products, which constitute the floor of the main rift and its successive filling. The basal unit forming the floor of the rift named Nazret unit (NZ). We consider NZ as a part of the widespread volcanic sequence, known as "Nazret Group", which comprises different formations with ages ranging from about 7my up to 3my (Mohr, 1971; Zanettin & Justin-Visentin, 1974; Meyer et al., 1975 Kazmin & Behre, 1978 and F.Innocenti et al., 1999).

3/ Rift Axis Complex

It is made up by a quaternary-Holocene sequence consisting of young central volcanoes, lacustrine deposits and basaltic cinder and spatter cones. This sequence presents the same volcanic and structural features recognized in the younger sequence of the adjacent MER (Kazmin and Behre, 1978). This zone is interpreted as formed along a rift axis, as previously suggested by Di Paola (1972) and Wolde (1996).

Zikwala volcano unit (zv), Zikwala is an isolated, well preserved composite cone standing 1300m above its regional base, located in the southern part of the studied area, fig.2.1. Lavas are the dominant products, with pyroclastics mainly occurring at the southeastern foot of the volcano. It is slightly elongated along the NE-SW direction and has a summit caldera. Lavas are dominated by peralkaline trachytes.

Bede Gebabe Volcano unit (BGV); Bede Gebabe, located in the central part of the studied area, is a volcanic complex with a quasi-circular shape; slightly NNE elongated and with a maximum relief of 400m above the surrounding topography. Its morphology is dominated by the occurrence of several coalescent calderic structures. Lacustrine deposits rest above BGV all over its marginal portion. Further more, spatter cones and basaltic lava flows belonging to the younger Bushoftu Volcanics are present in the central part of the volcanic complex. Rhyolitic obsidians represent the most recent products.

Pumices and lavas show a composition ranging from rhyolites to minor trachytes.

Bushoftu volcanic unit (BV); this unit forms a NNE trending belt outcropping mainly in the central flat area of Debre Zeite. It was previous called Bushoftu basalts to call collectively the volcanics erupted along the axis of MER, also known as Wonji and Wolenchiti basalts by some authors.

In BV we distinguished two groups represented by spatter and cinder cones with associated tabular lavas and phreatomagmatic deposits.

Lacustrine deposits (LD); they represent the exposed rocks and developed on a relative NE elongated depression in the central sector of the area (Fig 2.1). They are upper Pleistocene-Holocene in age.

4. Alluvial Cover, the alluvial cover mainly out corps above the products of the western rift margin complex and consists of regolith, red soils, and talus and alluvium deposits.

2.4.2. Mojo

The lithologic units in and surrounding Mojo area are dominantly volcanics and sediments Fig.2.2. Exposures or outcrops of these Tertiary- Quaternary volcanics and sedimentary rocks are found in quarries, along road cuts especially the road to Nazareth, along streams and gullies and on scraps.

The Quaternary volcanic rocks comprise of tuff, pumice, ignimbrite, pyroclastic flows and different volcanic fragments, scoria and basaltic flows. Scoria cone and basalt flows, which exposed in the northern and southern section of the town, are probably related to the Bushoftu volcanic activity.

Basically two types of ignimbrite have been identified. There is the slightly welded ignimbrite (top) and intermediately welded ignimbrite (bottom) both separated by paleosoil and lacustrine deposits.

The top ignimbrite flow has darker grey-to-grey color and relatively compacted and jointed. Vesicular basalt (probably related to Bofa basalt) is found associated with and or sandwich between pyroclastic and lacustrine deposit and covering the volcanic tuff in some parts of the area.

The Quaternary sediments composed of fluvo-lacustrine deposits of alluvium, colluvium, elluvium, coarse sand, silty sand, siltstone and shallow marine deposition of limestone and diatomite. Mojo and its surrounding areas are supposed to have been covered by the ancestral lake during the pluvial period of the Quaternary. The lacustrine sedimentations are the result of deposition in this large ancestral lake (Mohr, 1966 and Abebe, et al., 1999). These sedimentary Late Quaternary rocks were deposited alternating with the volcanic tuff and pumice. The volcanic and associated sedimentary rocks are fine grained or cemented with fine-grained materials.

Contact between volcanic rocks, Lake Sediments and alluvium deposits are irregular and complicated, partially due to erosional contacts and partially due to tectonic faulting.

2.4.3. Nazret

It has been tried to reconstruct the composite Stratigraphy of the area based mainly on lithologic correlation aided by available absolute age determination data and previous works (Fig 2.2).

Tertiary volcanic (N1a)

The Mesozoic sediments are overlain by the tertiary volcanics consisting of basalts and silisics of Miocene to Pliocene age. According to V. Kazmin and Seife Michael Berhe (1978) the ages of these volcanics vary from 28 million years for Alaji basalts to 9.5- 3.5 million years for the Nazret group of ignimbrites.

Pleistocene (quaternary) volcanics (Qwb1)

They include all rift volcanics, which are known as the Wonji group. They are formed after the last faulting, which occurred 1.6 to 1.8 million years. They are controlled by tectonic features of the Wonji fault belt and are restricted to the rift floor.

The wonji group volcanics consist of ignimbrites, patelleritic volcanic centres, and sub – recent and recent fissure basalts with some minor units such as hyaloclasties, explosion centres and rhyolite domes.

Holocene volcanics Qw, Qwo)

It consists of recent aphyric basalts, recent pantelleritic and commenditic obsidian flows and domes

Lacustrine sediments (Qt)

In the low plains of Nazret and in the immediate vicinity, lacustrine deposits of clays, silts, tuffs, and diatomite with intercalation of pumice are predominant.

Within the rift proper, the lacustrine sediments are consisting of clay, silt, tuffs, and travertine.

2.5. Geology of the Study Areas

The major geological/tectonic events in the study areas are associated with the formation of Main Ethiopian Rift (MER) system and out pouring of enormous amount of lava and deposition of sediments.

The Tertiary volcanic rocks (comprising of Trap Volcanics and Nazret Series) are covering the most parts of the areas. Nazret Group rocks (constituting welded ignimbrite, pumice, ash and rhyolite flow and dome with rare intercalation of basaltic flows) are occurs in MER and rift margin especially north and east of Mojo town. Bushoftu Formation includes basalts and trachyte, which are characteristically alkaline and represent Pleio-Pleistocene commonly, marginal basalt volcanism controlled by transversal structures in the MER Fig 2.1 and 2.2.

2.5.1. Bushoftu (Debre Zeite)

The Bushoftu region is situated on the ill-defined Western margin of the main Ethiopian rift. It represents a transition zone between the Ethiopian plateau and the main Ethiopian Rift (MER).

In this area the following lithologic units have been mainly identified (Fig 2.1):

Trachytic domes, rhyolitic flows, rhyolitic ignimbrites, olivine basaltic flows, basaltic cinder cones, surge deposits, ash flows and alluvial sediments. While the mafic volcanic rocks are mainly dominated by basaltic cinder cones and olivine basaltic lava flows the acidic ones are dominated by rhyolitic flows and surge deposits with only small outcrops of Trachytic domes. In this area, fractures and faults are mostly aligned in NE direction.

Descriptions of the various lithological units are given below:

Trachytic Domes

From stratigraphic point of view, it is the oldest rock outcropping in the area and probably overlies the deepest trap basalt. The olivine rich basalt has a porphyritic texture with phenocrysts of plagioclase and olivine in a glassy ground mass.

The rock is deeply fractured, weathered and partially filled up by secondary calcite within the fissured plagioclase phenocrysts.

Rhyolitic Flows

The rhyolite outcrops in the most elevated parts of the area. Top and the southern flank of the Mt. Yerer and the southern most ridge of the Mt. Sokoru.

The rhyolite of Mt. Yerer and Mt. Sokoru seems to have different eruption centres. In particular, the eruption of the second one is supposed to have prompted a caldera collapse. Inside and outside the related depression various post caldera spatter cones have been successively accumulated (Tamiru Alemayehu, 1992).

Rhyolitic ignimbrite

The ignimbrite covers small part of the Debre Zeite area. The unit is highly welded and shows vertical columnar jointing structures.

Olivine basaltic lava flows

The porphyritic basalt outcrops in different places: near Bushoftu lake, south west of the Godino village and in the valley of the Wodecha river, where it shows clear vesicular structures and underlies a thick yellow surge deposit.

Lower Surge Deposits and Alluvial

After the extrusion of Yerer rhyolitic dome, a prolonged explosive phase occurred in the area, which has given rise to several pyroclastic deposits of many types emitted from vents along the steep flanks of the mountain.

Surge Deposits Associated with Explosion Craters (surge 2):

Important surge deposits outcrop mainly around the explosion crater lakes (surge 2).

Basaltic cinder cones

The unit is exposed in the form of cinder cones, which are variously distributed in the area. Some of them are exposed within the collapse caldera. The scoriaceous basalts are constituted by vesicular ejecta thrown out by lava with high gas content during volcanic eruption.

Alluvial Sediments

The alluvial sediments are mainly exposed along the gullies of the intermittent streams occurring in the flat central part of the area above Debre Zeite and in the lower course of the Wodecha River. The unit is covered by black clay horizon. Despite the great lateral variability, the unit shows a regular vertical sequence from coarse sand near the bottom to the clay at the top. Generally these sediments are very loose so that they can be easily eroded away.

2. 5. 2 Mojo

Mojo, like the other rift valley areas was subjected to tectonic activities and intense volcanism. But, what in reality seen around Mojo is a vast plain area covered by thick black clayey soil and different detritus and fragments (Fig 2.2). The main lithology found here are tuffs, pumice, siltstones, limestone (travertine), ignimbrites, pyroclastic flows and different volcanic fragments.

The outcrops of these rocks are mainly seen along the slopes, gullies and deep cutting rivers like Mojo River. The presence of sedimentary rocks at this locality is related to the lake cover of the area during the pluvial times. The area is covered by thick black to ashy colour soil derived from weathered acidic rocks. Different detritus and pumice are also seen; obsidians are abundant through out the area. This generally indicates that the area is struck by different volcanic episodes.

Sand and gravel were deposited along the river (Mojo), which can be easy for surface water infiltration.

Alluvium and flood plain deposits (Cl)

These soils are mostly found along the rivers and dry streams banks and channels. It is covered the southern, northern and the very eastern part of the town.

These materials are loose, sandy-silt to sandy-clay in composition and accompanied with flood plain and transported overburden.

2.5.3. Nazret

The rocks observed in the area, Nazret group includes ash flow tuffs, pantelleritic ignimbrites and unwelded tuffs.

These rocks were observed covering the area in west, NW and SW of Nazret. In the area between Nazret and Lake Koka as well as around Lake Koka, the ash, tuff and pumice flows are thick and alternate in sequence. Thick welded and unwelded tuffs are also prominent in the area. The welded tuffs (ignimbrites) are highly fractured and jointed.

Nazret and the surrounding lowlands are predominantly covered with lacustrine and alluvial deposits of Pleistocene to Holocene time.

In the low plains of Nazret and in the immediate vicinity, lacustrine deposits of clays, silts, tuffs, and diatomite with intercalation of pumice are predominant. It is assumed that they had been deposited in Pleistocene pluvial when vast areas of the rift valley around lake regions were covered with extensive lakes.

In Nazret area, reasonably good outcrops are found along ridges and escarpments (in many cases bound by faults), across road cuts, river cuts and in quarries. The rocks exposed in the area consist of various volcanic and younger sediments. The volcanic vary from basalt to rhyolite in lithology and include basaltic flows, basaltic cinder and spatter products (forming cones), acidic lava flows and ignimbrite as well as pyroclastic flows and falls (mainly pumice and ash deposits). These rocks are products of rift volcanism that spanned from Pliocene to recent (Mohor, 1978 and others in Woldu Ameneshoa, 1994). While the sediments (which are lacustrine and fluvial are of quaternary age (Kazmin 1978 and Di paola, 1972). The fluvial sediments are being present-day deposits.

Since Nazret is situated within the central part of the main Ethiopian Rift valley, the geology of the area reflects the rift formation and the subsequent structural deformation and depositional process that took place within it.

The geology of the area is composed of the so-called Nazret and Wonji groups associated with alluvium and lacustrine deposits, which have volcanic and sedimentary origins.

The rocks outcropping in the study area have been put into six units mainly based on lithologic variations, though in some cases (pyroclastic deposits) relative age relation was also considered. These lithologic units are:

A/ older pyroclastic deposits: which include poorly to intensely welded ignimbrites, ash flows and pumice fall deposits;

B/ basic lava flows (basalts): consisting of an older aphanitic basalt flow and younger porphyritic vesicular basalts;

C/ acidic lava flows: consisting of older acidic lava flows which form the Boku ridge (south of Nazret) and other younger acidic products which mainly form elongated domes northeast and southeast of Nazret;

D/ younger pyroclastic deposits: which include ash flows and falls, pumice falls, ignimbrites and surge deposits which are products of the Gedemesa central volcano together with much younger Unwelded tuff which usually occurs in many topographically low lying places;

E/ basaltic cinder and spatter products which form volcanic cones and associated basaltic lava flows; and finally

F/ reworked volcanics, lacustrine sediments, and colluvium and alluvium sediments.

Older intensely welded ignimbrite (Nn)

This unit represents the lowest and probably the oldest exposed lithology in the study area. It is mainly exposed along north-northeast oriented major normal faults forming steep scarps west of Nazret. Other outcrops are found north-northeast (Mermersa) and southwest Melka Hida) of the town again along similarly oriented normal faults.

The ignimbrite is generally characterized by light green color, dense welding, and contain abundant flame.

Aphanitic basalt

These flows have been observed within and overlying the welded ignimbrite unit and are characterized by aphanitic fabric with scarce vesicles and carrying few phenocrysts. They are mainly exposed on the top of the Kechema Ridge (also named as Adam horst), bounded by NNE-SSW trending normal faults, west of Nazret. Other outcrops have been observed at the floor of Kimbibit River and along a scarp just west of the town.

Older pumice and ash deposits (Nn)

This unit, which is believed to have about similar age as the above two units, is constituted by pumice falls and ash flows, which are often, associated with paleosoil horizons. Main outcrops are found west and southwest of Nazret. They are generally best exposed in quarries and at the base of fault scarps.

The pumice fall deposits are characterized by coarse-grained irregular shaped pumice clasts, which are dominantly of lapilli size.

Older acidic lava flows (N2r)

Older acidic volcanics, which occur as lava, flows form the Boku Ridge (south of Nazret) in the study area. The flows mainly constitute white rhyolitic unit, which is often associated with obsidian layers, occasional layers of pumice and ash have also been observed. The thickness of the flows in this area is estimated to be more than 100 m.

Lithic rich ignimbrite (Nn)

This is a poorly- welded, light yellow, coarse pumiceous ignimbrite characterized by abundant lithic fragments, which are randomly distributed throughout the rock mass. It is mainly exposed in the area about 4 km west of Nazret and usually occupies relatively lower topographic levels, other patchy outcrops are found to the northwest and southeast of the town. The lithics are mainly basaltic (sometimes scoriaceous) and silicic.

Porphyritic basalt (QWb2)

This unit generally consists of crossly porphyritic vesicular basaltic flows mainly exposed along north-northeast south-southwest oriented normal faults forming small ridges.

These porphyritic vesicular basalts are fractured and weathered at places.

Most of these flows are believed to be fissure eruptions, although, probable point source (central vents) could be inferred to some outcrops.

Younger acidic flows (domes) (N2C)

Younger acidic volcanic in the area occur as typical dome-forming flows and lava outpourings. The domes appear to be slightly elongated along north-northeast direction. Rocks generally consist of white crystalline rhyolities, which are often associated with dark colored obsidian interlayering. Localities where main outcrops are found include; northeast (Dibibissa Dome), east (Migira Dome) and southeast (Wogillo) of Nazret. The rhyolitic rocks in these localities are fresh and slightly affected by significant faulting, contrary to the older acidic flows at Boku, which are intensely dissected by major normal faults.

Younger pyroclastic deposits (QWPU)

This unit consists of ignimbrites, ash flows and falls, surge, and pumice fall deposit, all belonging to the products of the volcanism associated with Gedemsa center. The much younger unwelded tuffs are also included here. From their occurrence within the floor of the caldera, these pumice fall and surge deposits are considered to be post caldera products of Gedemsa volcanism (Alula,, 1990).

The pumice fall deposit, which in the area is associated with pyroclastic surges, is characterized by angular pumice clasts that rarely exceed lapilli size. The tuff usually form different layers separated by paleosoils, colluvium or alluvium as can be clearly observed in many sections along stream cuts.

Basaltic pyroclastics and lava flows (cinder and spatter products forming cones with associated basaltic lava flows) (QWb1)

Cinder and spatter products of basaltic composition (scoria and scoriaceous basalts) are abundantly distributed in the form of cones in the study area. These cones mainly occur southeast and southwest (around Wonji) of Nazret town.

At places, these cones are associated with basaltic lava flows. The flows mainly represent very dark vesicular poorly porphyritic basalt.

Recent Lacustrine, Alluvial and Colluvial Sediments (Q1)

This group includes recent lacustrine, alluvial and Colluvial sediments which represent the only non-volcanic deposits in the study area.

Lacustrine sediments in the area cover almost the entire low-lying flat land. The sediments are poorly consolidated and are moderately grained deposits of manly silt and sand. Alluvial deposits in the Awash river are mainly formed in the river channel and the associated flood plain. The flood plain in this area is mainly swampy particularly in the part, which lies down stream of the Wonji Bridge (south of Boku ridge). Sediments outcropping in the flood plain are mainly fine-grained (clays and silts) which represent levee and flood basin deposits.

Other alluvial deposits in Nazret area occur along the course of Mermersa stream and in the channels of other small ephemeral streams.

2.6. Structures and Volcano tectonic History

Tectonics refers to movements that result in the deformation of the earth's crust over geologic time. It is such crystal movements in the past geologic history that accounts for the ever-altering distribution of land and sea, mountains and lowlands. Though continental plat forms and ocean basins have persisted for over hundred million years, they are subjected to changes through crustal tectonics over time.

The main geological structures that have been observed in the study areas include; - faults, joints, and fractures (and other Mesostructures like flow layering and folding associated with silicic lavas).

The areas are intensively dissected by a number of minor and major normal faults running almost parallel to each other in a NNE-SSW direction and are usually arranged in "en echelon" fashion. These faults belong to the Wonji Fault Belt. They form steps and local graben-horst structures.

The faults dissect almost all units outcropping in the area and recent volcanism has been observed to be associated with these faults.

Joints are abundant in the intensely welded ignimbrite unit (mainly in its middle portion) in the study area. Joints and fractures (mainly conchoidal) have also been observed in the other flows.

Flow layering and folding have mainly been observed in the basaltic and acidic lava flow units.

Since the three towns are located at the floor of the great east African rift valley of the late tertiary, it is still an active tectonic zone. The towns are in the Wonji fault belt, which is the latest major fault. The Wonji fault belt is responsible for all the rift volcanics of the Pleistocene to Holocene time. The Wonji group of the Pleistocene volcanics consists of ignimbrites, patellerites, and sub- recent and recent fissural basalts.

Most parts of the course of the drainage systems in the areas are controlled by these geological structures.

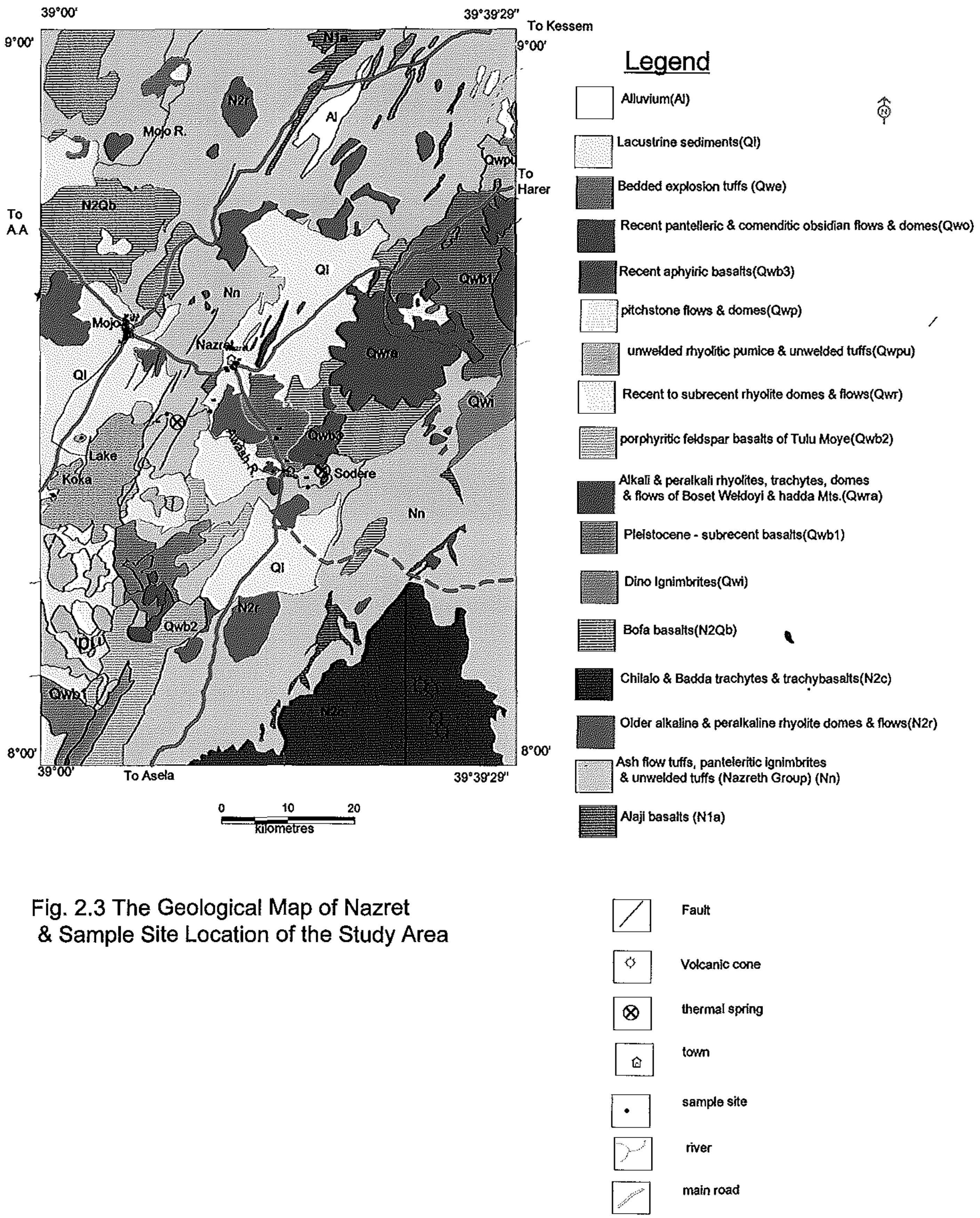


Fig. 2.3 The Geological Map of Nazret
& Sample Site Location of the Study Area

CHAPTER THREE: -CLIMATE AND SURFACE WATER HYDROLOGY

3.1 Climate

General

The climate of the upper Awash River basin comes under the influence of Inter Tropical Convergence zone (ITCZ), a zone of low pressure marking the convergence of the dry tropical easterlies and the most equatorial westerlies. The explanation of the seasonal rainfall distribution with in the region (basin) lies in the annual migration of the ITCZ across the basin. The ITCZ starts its advance across the basin from the south on March, bringing the small or spring rains. In June and July, the ITCZ reaches its most northerly location beyond the basin, which then experiences the heavy or summer rains through out. The ITCZ returns

Southwards during September and October, restoring a drier, easterlies air stream, which prevail until the ITCZ resumes its north word migration in March (Halcrow, 1988/1989).

3.1 Precipitation

Precipitation is moisture that falls from the atmosphere as rain, snow, sleet or hail. From all forms of precipitation rain is the most common form of precipitation in the study areas. Precipitation in each area is recorded by rain gauge. In the study areas rainfall records are available from three stations, (data source is from Ethiopian Meteorological Service) namely from Debre Zeite Air force, Mojo and Nazret stations. Debre Zeite Air force is located at an elevation of 1900m, above sea level longitude 38^0 57' and latitude $8^0$44' with rainfall records from 1980-2002, Mojo station is at an elevation of 1870m a.s.l. Longitude 39^0 07' and latitude $8^0$37' with rain fall records from 1983-2003, and Nazret station is at an elevation of 1622m a. s. l, longitude 39^0 17' and latitude $3^0$33' with rain fall records from 1983-2002.

As indicated in table 3.1 and figure 3.1 all parts of the study areas get their highest rainfall during June, July, August and September with the highest rainfall in the months of July and August. Lowest rainfall was recorded in the months of November and December. The highest rainfall recorded is 877 mm at Nazret and minimum is 832 mm at Debre Zeite Air force. Hence, this shows a negative correlation between elevation and precipitation for the three stations in the study areas for the specified period of time.

Comparison of the monthly rainfall at the three stations, which differ in the amount of rainfall they receive, can be done using the rainfall coefficient concept (table 2). Rainfall coefficient (crf) is given by the formula:

$$Crf = \frac{p(m)}{1/12\, p(yr)}$$

where P (m) = mean monthly precipitation.

P (yr.) = mean annual precipitation.

A rainy month is defined as one with a rainfall coefficient of 0.6 or exceeding 0.6 whereas a rainfall coefficient less than 0.6 define a dry month. Based on this, the rainy months in the area range from the month of March to September. All the three stations have higher coefficient in June, July, August and September, which indicate the highest rainfall of the areas. On the other hand October, November, December, January and February are the dry months of which November and December are the driest months.

Table 3.1:- mean monthly rainfall (mm) of the three towns (this work).

station	year of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Debre Zeite Air force	1980-2002	7.7	20.4	52.9	49.4	62	98.5	202.7	208.6	98.6	25.5	2.99	2.3
Mojo	1983-2003	10	22.7	62.9	45.3	51.5	86.8	236.5	226.7	99.1	27	6.41	1.5
Nazret	1983-2002	9.3	30.9	44.6	58.1	70	60.4	244.3	208.1	103	34.6	7.15	6.5

Fig 3.1 Mean Monthly RainFall (mm) of The Areas

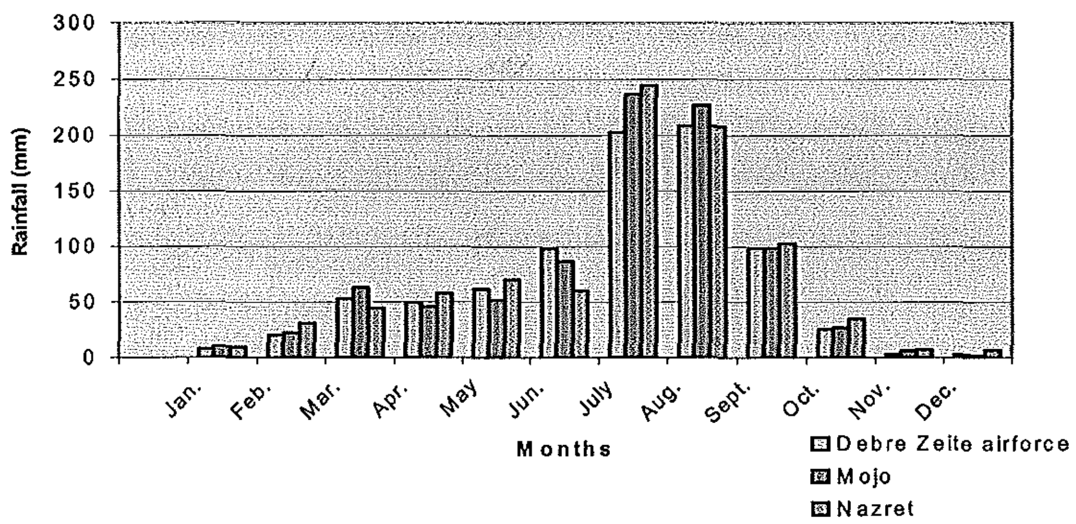


Table 3. 2: - Rain fall coefficient of Debre Zeite, Mojo and Nazret Stations (this work).

station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Debre Zeite	0.12	0.29	0.76	0.71	0.9	1.42	2.93	3.01	1.42	0.37	0.04	0.03
Mojo	0.14	0.31	0.86	0.62	0.71	1.19	3.25	3.1	1.36	0.37	0.09	0.02
Nazret	0.13	0.43	0.61	0.79	0.96	0.82	3.35	2.85	1.41	0.47	0.1	0.09

From these data therefore, generally, most parts of the study areas receive scant rainfall.

3.3. Temperature

The temperature of a place depends upon some or all of the following factors: latitude, altitude, ocean currents, distance from the sea, winds, aspect, cloud cover, length of day and amounts 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 areas. The areas are lying in the tropical zones,

Table 3.3 Annual average Temperature; hottest month and coldest month of the towns (this work).

Towns	Altitude (M)	Annual average temp.(°C)	Hottest month	Coldest month
Debre Zeite	1900	19.35	May	December
Mojo	1870	20.04	May	December
Nazret	1622	21.24	May	November

The monthly mean maximum and minimum temperature records at Debre Zeite Air force for the years 1980 to 2002, at Mojo for the years 1983 to 2003 and at Nazret for the years 1980 to 2002 have been used to calculate monthly and annual average (annexes 2 and 3). The computed average maximum and minimum is presented in the following table.

Table 3.4 monthly average maximum, minimum and total average temperatures (°C) for the three towns (this work).

Area	Elements	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual average
Debre Zeite	Average Max.	26	27.8	28	28	29	27.5	27.5	24	24	26.1	26	25.9	26.66
"	average Min.	10	11.4	13.4	14	13.4	12.9	13.5	13.4	12.6	11	9.7	9	12.03
"	total average	18	20	21	21	21.1	20.2	20.5	18.7	18.3	18.6	18	17.6	19.35
Mojo	Average Max.	28	29.2	30	30	29	28.7	25.8	25	25	28	28	27.7	27.96
"	average Min.	9.8	11.5	14	14	13	13.8	14	14	12	11.2	9.72	9	12.11
"	total average	19	20.4	22	22	21	21.3	19.9	20	18	19.6	18.8	18.4	20.04
Nazret	Average Max.	27.5	29	30	30	31	30	26.5	26	27.3	28	27.4	27	28.21
"	average Min.	12.4	14	15	15	15.9	17	15.4	16	14.9	13	12	12	14.25
"	total average	19.9	22	23	22	23.4	24	20.9	21	21.1	20	19.5	19	21.24

As it was shown in the table 3.4 the highest mean monthly maximum temperature at Debre Zeite occurs in the month of May (29°C) and the lowest is in the months of August and September (24 °C). While the mean monthly minimum temperature ranges from the lowest in the month of December (9 °C) to the highest in the month of April (14 °C).

In Mojo, the highest mean monthly maximum temperature occurs in the month of March (30 °C) (Table 3.4). And the lowest is in the month of August and September (25 °C). While the mean monthly minimum temperature ranges from the lowest in the month of December (9 °C) to the highest in the month of July (14 °C).

In Nazret, the highest mean monthly maximum temperature occurs in the month of May (31 °C) and the lowest is in the month of August (26 °C). While the mean monthly minimum temperature ranges from the lowest in the month of November (12 °C) to the highest in the month of June (17 °C) table 3.4. In the three towns the diurnal temperature variation is largest during the dry seasons and it often exceeds 15 °C.

3.4. Streams and Rivers

The areas are drained by a number of different sized perennial and seasonal streams, which usually start from the sides of the sloppy scarps, ridges and domes. The main streams have relatively wide and deep v-shaped valleys. Watercourses initially begin as rills and gullies on the slopes and progressively join the main streams that have dissected the low lying flat land which ultimately feed Awash river. The perennial Rivers that fellow through out the year on the areas are Wedecha, Mojo and Awash Rivers. Wedecha and Mojo Rivers are the tributaries of Awash River. They drain large parts of the areas.

3.5. Lakes

There are natural (crater lakes) and artificial lakes found in the areas. The crater lakes of Hora, Babogaya, Bushoftu and Arenguade are closed with respect to surface water outflow (Seifu Kebede, 1999). They loss water basically via evaporation and minor ground water outflow. Abstraction of water for domestic, agricultural and industrial use from these Lakes is negligible.

Geology, climate, hydrology and geochemical reactions in the lakes therefore basically control the chemistry of the four crater lakes.

There are some artificial lakes in the study areas. Kuruftu Lake, a crater depression, which is later filled by diverting Wedecha river for irrigation and Koka lake for hydropower generation, are among artificial lakes in the area. These lakes gain a large part of their water from the rivers and small proportions come from precipitation on the lakes. Therefore, Groundwater plays a minimum role in the balance of these lakes as the static water in the areas is below the lakes levels.

CHAPTER 4: HYDROGEOLOGY

4.1 General

The nature and distribution of aquifers and aquitards in geologic systems is controlled by the lithology, stratigraphy and structure of the geologic deposits and formations, which in turn controls the ground water circulation, and the movement of pollutants.

The geology, including the mineral composition, grain size and grain packing of the rocks, is the main factor in the physical make up of the aquifer systems. The stratigraphy describes the geometrical and age relations between the various formations in the geologic systems, providing some framework for the staking of the various units and their hydrological properties. Structural features such as fractures, joints and faults are the geometric properties of the geologic systems produced by deformation or tectonism or crystallization (Freeze and Cherry, 1979) may provide secondary hydrogeological properties to the various rock bodies increased water transmissivity.

As the study areas are dominantly covered by volcanic rocks and alluvial materials, rocks which include materials having a wide range of hydrologic properties. A basic volcanic rock, like basalt are generally rich in cavities, (Debre Zeite area), due to rapid cooling and escape of gases, cooling joints and bubbles like pore space and are therefore highly permeable. On the other hand, acid igneous rocks (Nazret area) may or may not contain groundwater although they generally posses interstices. Pyroclastic rocks associated with lava flow are generally porous; however, their permeability varies depending on the degree of interconnection of pore spaces. Alluvial materials at Mojo and Nazret are also varying in their hydraulic properties.

4.2. Aquifer characteristics of the different rock units.

Heterogeneity among geological formation is the basis for having different water storing and water transmitting characteristic of different rocks. The genesis of rocks and different earth process that they pass through is responsible for the formation of openings and interconnections between them.

Groundwater moves into various soil and rock formations by processes of infiltration and percolation. Porosity and permeability of geological features are the decisive parameters between a formation, weather a rock is to be an aquifer or not.

4.2.1. Debre Zeite

The hydrogeological characteristics of the rocks out cropping in the area are discussed with particular reference to their infiltration capacity together with their availability to store or transfer ground water down wards. From hydrogeological point of view, the rocks exposed in the area can be divided in to two groups: volcanic rocks, which are relatively impervious and alluvial sediments, which are pervious (Tamiru Alemayehu, 1992).

Volcanic Rocks

The volcanic rock group includes materials having a wide range of hydrogeological properties such as trachytes, rhyolites, basalts, and scoria and pyroclastic rocks.

The surface water, which drains from the mountain and hilly sides, constituted by impervious units, feeds the aquifers occurring down streams; in fact no infiltration capacity of these rock bodies is expected. Porphyritic basalts which out crop in the upper part of the Wodecha river bed and near the Bushoftu crater lakes are characterized by a vesicular texture as a result it has a great porosity but a low permeability due to the fact that the vesicles are poorly interconnected (Tamiru Alemayehu, 1992).

Due to well-developed primary and secondary porosity, this complex unit is found to be the best and the most productive aquifer in the area (Tamiru Alemayehu, 1992).

Among the pyroclastic materials, surge deposits out cropping around Debre Zeite (Fig 2.1), covered by top layer of black soil, are characterized by high infiltration capacity and by moderate permeability due to their well-sorted granulometric condition.

Surge deposits alternate with old alluvial, ash bed and paleosols. Because of this peculiar stratigraphic sequence, the complete unit can be considered as multi layer aquifer system, where ash beds and paleosols may act as confining beds or aquitards. The unit is found to be affected by fractures and faults, which may act as easy ways for groundwater flow or storage.

Alluvial Sediments

These sediments are highly porous and permeable due to their loose nature, and moreover characterised by an extremely high infiltration capacity, which allows the river water and rainfall to seep directly in to them down to the bedrock at great depths. Their grain size constitution, which varies from coarse to silty and clayey, give rise to the occurrence of highly yielded unconfined, semi confined and confined aquifers together with local perched ones.

The different hydraulic properties of the solid rocks and the loose pyroclastic and alluvial sediments, together with their aerial distribution make it possible to identify the occurrence of important hydrogeological units in the area.

4.2.2. Mojo

The aquifer materials found in this area are very fine-grained rocks of volcanic origin with some silty sand and pebble beds. Furthermore, the rocks are fractured and jointed. But, secondary fine mineral precipitates fill the joints. These two cases reduce yield of water bearing formations and wells.

It is evident that where fractured hard rocks are found there is a possibility to get good groundwater. But, here as stated above, the rocks are fine grained or cemented by fine-grained mineral precipitates where poor secondary porosities develop. The porosity of fine-grained rocks is low and permeability is low too.

Trachyte lavas, massive ignimbrites and lacustrine deposits

Huge mountains at the rift margin (e.g. Yerer trachitic volcano) have poor hydraulic conductivity due to absence of primary porosity, massive nature of exposure. In addition, bare and steep nature of these highly elevated morphological features have poor groundwater storage and low infiltration property for the absence of vegetation which can delay the immediate rushing water that comes from precipitation.

Lacustrine sediments cover most of the northwestern part of Mojo town (Fig 2.2). The thickness increases from northwest to southeast. These sediments are exposed in the study area with thin but extensive spatial distribution and consist of sands, silts, clays, tuffs, pumice, and ignimbrites. These sediments, in most places are mixed compositionally with Quaternary volcanic products and form a specific mixed volcano-sedimentary rock type.

Based on the visual observation on the field one can group the lacustrine deposits by its superficial water conductive nature. However, in terms of productivity of the unit since it deals with both vertical and horizontal extension of the unit classifying it by its superficial hydrogeological character is maybe misleading.

Tuff, diatomite and ignimbrite are partially interbeded in the lacustrine sediments and at some places form an extensive layer. Therefore, the permeability of this aquifer unit is some how reduced due to the intercalation of tuff layers which is visible around the gullies and banks of the Mojo River.

Fractured ignimbrites and rhyolitic ignimbrites

The ignimbrite and rhyolitic ignimbrite cover most part of the study area. In most cases the ignimbrites are well jointed and it has a moderate permeability and productivity. These faults and joints can serve as an important groundwater-recharging conduit in the absence of secondary filling material.

Alluvial and basaltic flows and domes

The alluvial cover mainly outcrops above the products of the western Rift margin complex and consists of regolith and alluvium. It is grouped under the highly permeable unit.

Basaltic lava flows that are found in the eastern and southern part of the study area are outcropping in scattered form. These basalts are highly fractured and in several places they are scoriaceous. Hence, they have high permeability and productivity.

4.2.3. NAZRET

Different lithologic units that are recognized in Nazret area are characterized by different hydraulic properties. These differences are also some times observed even with in the same unit. The main aquifers in the area are alluvial and lacustrine sediments, pyroclastic rocks, and weathered and fractured volcanic rocks.

In broad sense the aquifers found in the area can be sub divided in to two main categories; these are: -

A/ non-indurated sediments and fragmental or brecciated volcanic deposits. These aquifers have their permeabilities mainly attributed to the primary porosities and

B/ dense or massive volcanic rocks, which are characterized by permeability, associated with fractures, joints, and faults, zones affected by weathering and / or interbeds.

The non-indurated alluvial and lacustrine sediments in the area are composed of gravel, sand, silt, or clay size particles that are not hardened by mineral cementing. Those zones with the coarse sediments like sand and gravel form very important aquifers. While the clays, silts, or the loam are poor aquifers and form typical aquitards in different places in the area (Woldu Ameneshoa, 1994).

The fragmental or brecciated volcanic deposits are mainly constitute various pyroclastic rocks, which include brecciated basalts (scoria, cinder and spatter products), pumice falls, poorly welded or unwelded tuffs, ashes and volcanic sand. These deposits usually form very porous and permeable zones representing important aquifers in many places. However, some of these deposits like the volcanic ashes and unwelded tuffs (when composed of different sized particles) are characterized by high porosities but with low permeabilities.

Fractured, jointed, faulted and /or weathered zones mainly in the basalt and ignimbrites some times form important aquifers. The faults and fractures also serve as important conduits for groundwater movement and recharge. When dense and unfractured, however, these volcanic rocks are typical aquicludes.

Therefore, the rocks of the area were broadly classified in to five aquifer classes or permeability groups as follows: -

A/ very low permeability group: - rhyolitic flows and domes intensely welded unfractured ignimbrites and fresh unfractured aphanitic basalt, B/ Low permeability group: - unwelded tuffs (mainly composed of ash), lithic rich ignimbrites, fresh unfractured and /or unweathered vesicular basalts, diatomite, fine-grained sediments,

C/ Moderate permeability group: - ash flows and falls, moderately fractured vesicular and aphanitic basalt, weathered and/or jointed ignimbrites,

D/ High permeability group: - weathered vesicular basalts, weathered aphanitic basalts, alluvials, and

E/ Very high permeability group: - coarse grained lacustrine sediments, volcanic sand, scorias and cinders, pumice falls, highly fractured (jointed) vesicular basalt. The aquifer characteristics of different rock units are described as follows.

Alluvial and lacustrine sediments

The alluvial aquifers in the area are composite, and usually represent nonindurated deposits with materials ranging from gravels to clays. These are materials laid down by the action of the Awash River either on its channel or on the adjacent flood plains owing to channel flows and periodic over bank flooding. The Gravel and sands form important aquifers characters by high permeabilities, while the clay, silt and loam serve as aquitards or aquicludes forming semi-confined or confined conditions in some of the wells. The alluvials generally form multi-layer aquifer system along with the other aquifer materials (mainly pyroclastics and some basaltic flows).

On the surface, however, the alluvial sediments are often composed of fine gained materials (clay and silt) especially on the flood plains. This gives rise to a generally decreased infiltration capacity over those places and hence limited direct recharge from rain.

The lacustrine sediments in the study areas show different permeability due to the variation in their size composition both from place to place and in depth.

Porphyritic Vesicular Basalts

Vesicular basalts in general have high porosity due to the abundance of vesicles. But, since the vesicles are apparently not connected these basalts often show low permeabilities unless they are cris-crossed by fractures, cracks, joints and /or are heavily weathered.

In the study area, the vesicular basalt unit tends to have variable permeabilities in different places. Weathered vesicular basalt makes productive aquifer. The unit as a whole can be qualitatively considered as having a moderate permeability in the study area (Woldu Ameneshoa, 1994).

Aphanitic basalt

From hydrogeological point of view two extreme varieties of the aphanitic basalt can be identified. The first ones are those basaltic rocks which are relatively dense, unfractured and may be unjointed, and the second heavily weathered and /or fractured.

The fresh or poorly weathered and/or fractured basalts usually represent aquitards. The only surface out crop of this basalt is found on top of Kechema ridge (west of Nazret).

Weathered and/or fractured zones of the aphanitic basalt unit are considered to have high porosities. When interlayered between relatively impervious layers these basalts form aquifers that may store significant amount of water (Woldu Ameneshoa, 1994).

Loose Pyrolcastic Deposits

The main loose pyroclastic deposits occurring in the area include pumice falls, ash flows, surges, unwelded tuffs and volcanic sand.

The ash flows and unwelded tuffs are generally characterized by high porosities but with low permeabilities. Hence, they act as aquicludes or as leaky beds. On the other hand, the pumice fall and the volcanic sand horizons are the most important aquifers in the area, particularly at Melka Hida well fields.

The pumice falls consist of mostly lapilli sized pumice clasts, which gave the deposits very high primary porosity and usually form loose deposits.

Lithic rich Ignimbrites

The lithic rich ignimbrites unit, which covers the relatively low-lying area west of Nazret, is characterized by abundance of pumice clasts and scarce welding. While this (presence of pumice) gives the unit certain amount of porosity, it is generally characterized by low permeability mainly due to the low degree of pore interconnectivity.

Welded Ignimbrites

Intensely welded ignimbrite outcrops mainly to the west and southwest of Nazret.

The intensely welded ignimbrites which usually forms scarps to the west, southwest and northwest of Nazret is generally considered impervious having very limited permeability.

Rhyolitic Lava Flows and Domes

Rhyolitic rocks mainly form domes and ridge. They represent rhyolitic flows of different age with associated interlayerings of obsidian and they are generally considered to be very poor aquifers. The rhyolitic domes northeast and southeast of Nazret, neither show incision by faults (or fracturing) nor the rocks are weathered. They represent dense lava flows and therefore, are considered impervious.

4.3. Groundwater Potential

The climatic condition, geologic formation and topography of the area determine the volume of water discharges of surface of the area.

The ground water potential of a region depends on its geological structure and the characteristic distribution of its rock formations. In the rift system, internal drainage adds to underground water resources.

The lithology, stratigraphy and structure of the geologic deposits and formation control the nature and distribution of aquifers and aquitards in geologic systems. The geology, including the mineral composition, grain size, and grain packing of the rocks, is the main factor in the physical constraints of aquifer systems.

4.3.1. Debre Zelte

Scoriaceous and vesicular basalt, which are mainly concentrated in the vicinity of Debre Zeite, are classified as very good aquifers. Based on the well information collected, discharge can reach up to 70l/s (Adane Bekele, 1999). Transmissivity also reach to about 79.1m^2/day. These indicate that the aquifers near Debre Zeite have high potential. The geological log of the borehole in the area show that the aquifers exist under confined conditions.

4.3.2. Mojo

Most of the fractured and weathered ignimbrite and basalt make up good aquifer type.

Fine-grained alluvial deposit intercalated with ash material, massive rhyolitic and trachytic lava flows and fine-grained and well-compacted lacustrine deposits are all poor aquifers. They make most parts of the study areas. Most of the boreholes in these formations have yields less than 5 l/s.

Hence, aquifers character range from poor to moderate in potential.

4.3.3. Nazret

The general aquifer characteristics of the different lithologies in Nazret and the immediate vicinity vary from high to low permeability. The permeability of the volcanic rock is associated with faults, joints and open interconnected vesicles. In the lacustrine and alluvial deposits, high permeable zones are encountered in coarse-grained sediments like sand and gravel deposits. In these zones, ground water movement and storage is high. In fine textured sediments, ground water movement and storage is highly impeded, there fore they are poor aquifers.

CHAPTER 5: HYDROCHEMISTRY

5.1. Introduction

The chemical composition of natural water is derived from many different sources of solutes, including gases and aerosols from the atmosphere, weathering and erosion of rocks and soils, solution or precipitation reactions occurring below the land surface, and cultural effects resulting from human activities (Hem, 1992).

The major natural inorganic constituents of aerobic groundwaters are charged species, either anions or cations, silica and dissolved O_2, N_2, and CO_2. Major anions (concentration >1 mg/l are chloride (Cl^-), sulfate (So_4^{2-}), nitrate (No_3^-), carbonate (Co_3^{2-}), bicarbonate or hydrogen carbonate (HCO_3^-); major cations are sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}). The minor constituents include mostly metal cations and fluoride anions. Under anaerobic conditions, nitrite (No_2^-) and ammonium (NH_4^+) are formed by reduction of nitrate; similarly, sulfate is replaced by hydrogen sulfide.

The quality of water depends on the salinity, temperature, and other chemical contents of the water, the physical and chemical properties of the surrounding rocks, the volume and velocity of water in movement, human factors (industrial activity, changing agricultural practices and increasing urbanization) and biological processes (Tebbutt, 1998).

Many human activities have adverse consequences for the environment. As human population increases and civilization becomes more and more technologically developed, the adverse effects become obvious. Urban development produces large volumes of solid and liquid wastes which can pose major environmental difficulty in their disposal.

Rainfall, climate, geology, period of contact of water with rock, temperature and pressures are the major water quality controlling factors in the study areas.

5.2. Water Sample Collection and Analysis

Natural water is sampled in view of carrying out various analyses on it. Representative water samples were collected from existing water bodies, which were used to study hydrochemical property of the aquifers and to classify water types. Water quality and their use for certain purposes have been determined based on chemical analyses. To enrich the chemical information additional data were also collected from previous works.

The sampling points were selected to identify the influence of human activities and urbanization on the quality of surface and groundwater. About 27 water samples for physico-chemical analysis and 13 water samples for bacteriological analysis were collected (Fig. 5.1, 5.2 and Fig 5.3 and annexes 4, 5a, 5b and 5c). However, due to financial limitations, 20 of the collected water samples for physico-chemical analysis were analyzed depending on their distribution to pollution sources, geographic distribution and sound hydrogeological reasoning for the three towns. 13 samples from Rivers (1 from Shimbra Meda seasonal stream, 7 from Mojo River and other 5 from Awash River), 2 samples from boreholes (1 from Awash Melkasa Aluminum factory and 1 from Debre Zeite Shimbra Meda well field), 4 samples from Lakes (Hora, Kuruftu, Babogaya and Bushoftu lakes) and 1 sample from rainwater in Nazret town. Out of all the 20 samples analyzed about 16 are used as drinking water. The lakes waters are non potable. Samples were collected carefully to obtain reliable hydrochemical data and also care was taken to avoid contamination during and after sampling. The samples were collected in plastic bottles. In the field the bottles were cleaned by distilled and/or tap water and three times rinsed with the water to be sampled and then filled to the top in order to protect equilibration with the surrounding air. Samples were taken directly at the tap or wellhead, from the flowing rivers/streams and at the top edge of Lakes. During the time gap between the sampling and analyses, the samples have been kept at a temperature of about 4^0c.

Accordingly, as pointed above 13 samples were collected for bacteriological water examination. 3 samples were examined from boreholes (1 from Mojo water supply wells, 2 from Nazret Awash Melkasa Agricultural research center and Awash Melkasa Aluminum sulfate factory). 4 samples were from rivers (two from Mojo River and two from Awash River). 5 samples were from lakes (one from lake Koka and the others from crater lakes in Debre Zeite area such as Hora, Kuruftu, Babogaya and Bushoftu lakes) and one sample from hot spring at Sodere (Fig. 5.1, 5.2 and 5.3 annexes 5a,5b and 5c).

The inability to have samples from Nazret wells is because they were non-functional during the field trip time. Most wells in Nazret are non functional because of high fluoride content in subsurface water on the area and high pump running cost. The current water in distribution system is from Awash River, which is relatively free from high fluoride concentration and fresh. For the physico-chemical result analysis and hydrochemical characterization, the available past results have been used (annexes 6a, 6b, and 6c).

Hydrochemical data were collected from different institutions to fill the data gap. These data were collected from ministry of water resource, Ethiopian geological survey, water well drilling enterprise, Oromia Water Resource Bureau, and Oromia Water Works Construction Enterprise and from different MSC thesis. The geographic positions of some of these past data points were tried to be located. But, it was difficult to locate the position of most wells, as their location is unknown.

Lake Samples were collected from the top and at the edge of lakes. This may reduce the over all coverage of sampling to represent the whole lake water. The samples were analyzed in Oromia Water Resources Bureau, Central Laboratory. In addition to the laboratory water quality analysis a field kits that can measure EC, TDS, pH, Eh, temperature, salinity and turbidity were used. All the sampled water sources have got in-situ measurements of the above-specified parameters both in the wet except for turbidity and in the dry season.

Including the previous chemical analysis data a total of 202 water samples were considered for physico-chemical analysis from boreholes, hand-dug wells, lakes, rivers/seasonal streams, rainwater and spring.

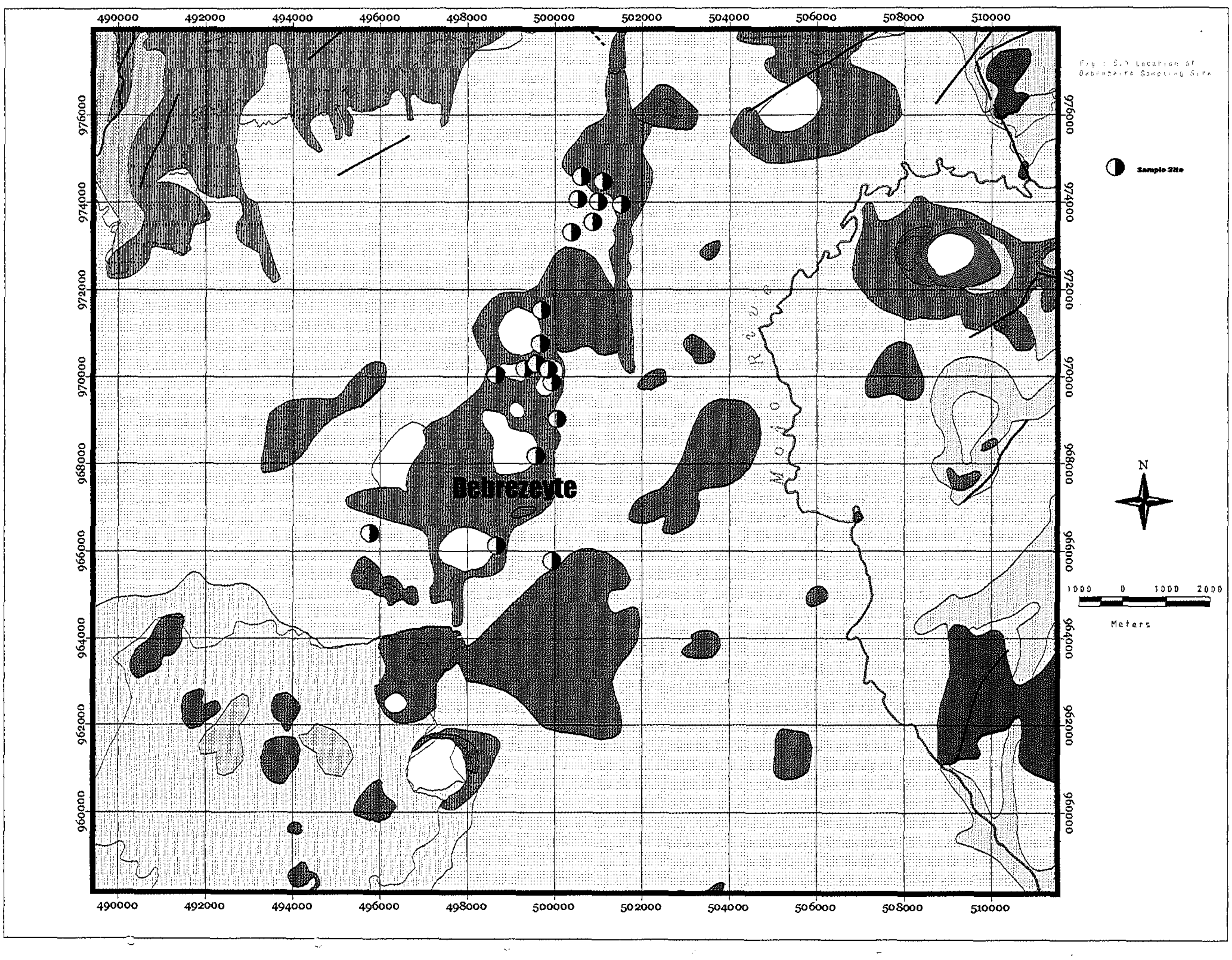


Fig : 5.1 Location of Debrezeite Sampling Site

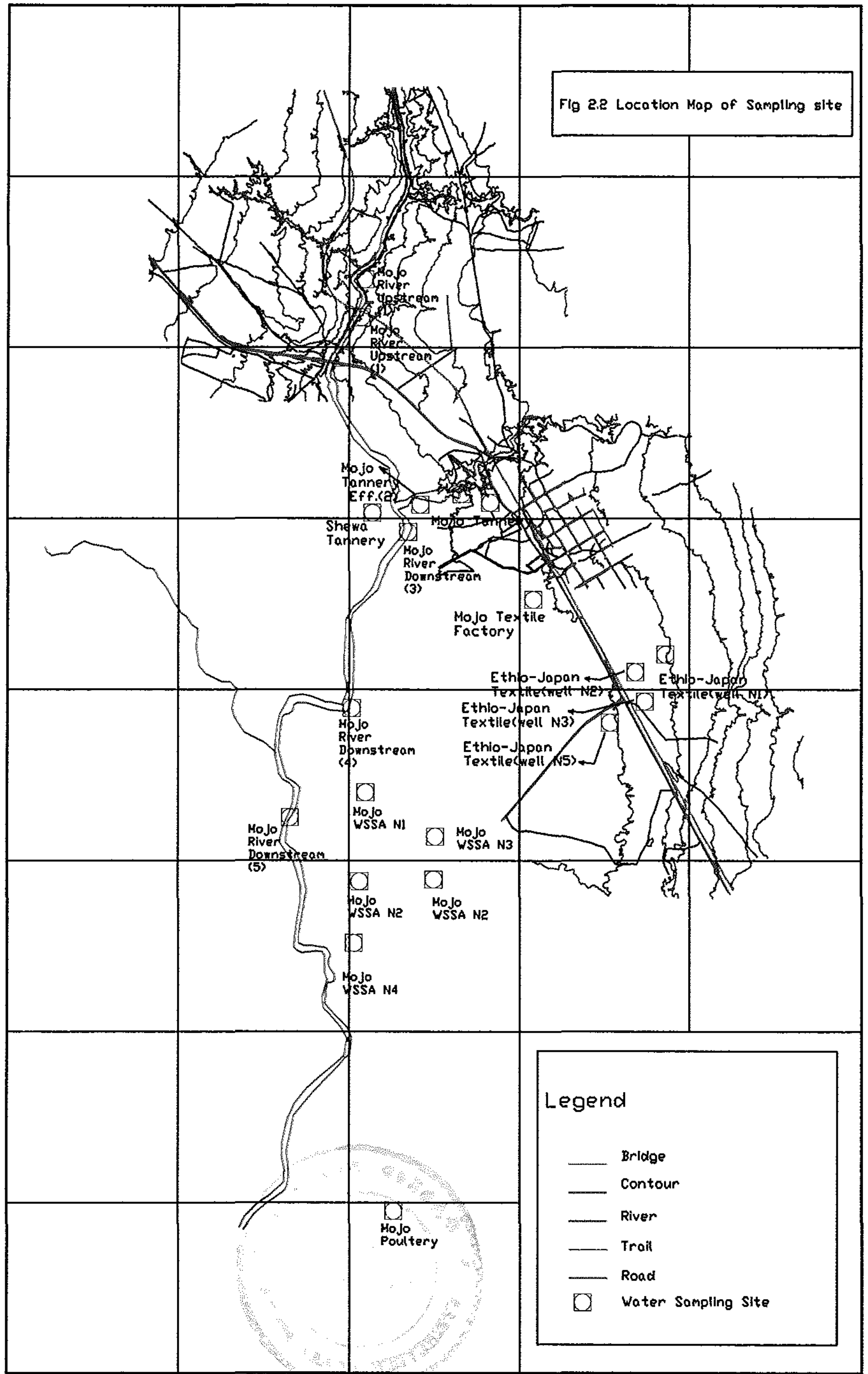


Fig 2.2 Location Map of Sampling site

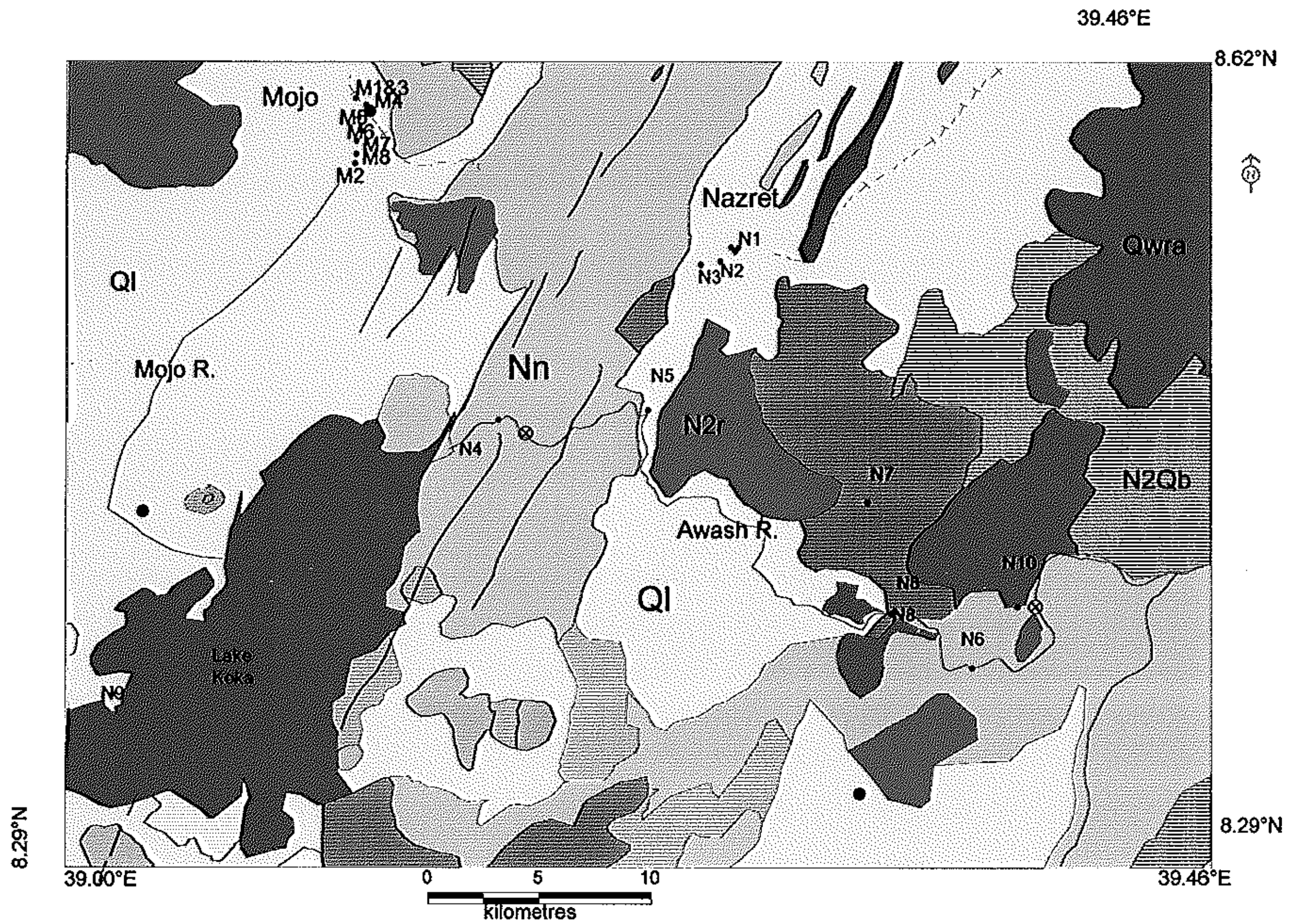


Fig. 5.3 Sample Location Map

Legend

- Lacustrine Sedments (Ql)
- Recent Aphyric Basalts (Qwb3)
- Pitchstone flows & domes (Qwp)
- Unwelded rhyolitic pumice & unwelded tuffs (Qwpu)
- Porphyritic basalts of Tulu Moye (Qwb2)
- Alkali & peralkali rhyolites, trachytes, domes & flows of Boset Weldoyi & Hadda mts.(Qwra)
- Pleistocene - subrecent basalts (Qwb1)
- Bofa basalts (N2Qb)
- Older alkaline & peralkaline rhyolite domes & flows (N2r)
- Ash flow tuffs, panteleritic ignimbrites & unwelded tuffs (Nazret Group) Nn
- fault
- River
- Sample Site
- Thermal Spring

5.3. Water Analysis Result

Water is never found in its pure state in nature. Essentially, all water will contain substances derived from the natural environment or from the waste products of man's activities. These constituents are basic criteria in the determination of water quality. In addition, the various properties of water imparted by the constituents serve further to define quality of water.

A complete chemical analysis of a water sample includes the determination of the concentrations of the inorganic and organic constituents. Physical analysis includes characteristics of water detectable by the senses of smell, taste, visual observation, and touch. Taste, odor, color, temperature, turbidity, TDS & EC and solids fall in to this category. Biological examination includes tests to detect the presence of coliform bacteria, which indicate the sanitary quality of water for human consumption. Hence, besides being chemically safe for human consumption water to be used in home should be free for undesirable physical properties and harmful microorganisms should be virtually absent.

5.4. Physical Parameters

5.4.1 Appearance, turbidity, color and odor

Data set of the physical parameters such as appearance, turbidity, colors and Odor of water samples were collected from lakes, boreholes and seasonal streams of surface waters. These samples were later analyzed in the laboratory. The results of analysis show that all the samples collected from four lakes (Bushoftu, Hora, Babogaya and Kuruftu) show higher values and above the standard colors unit.

The turbidity of all the lakes also shows lakes water is turbid. The turbidity values of lakes water are in the range of 17 FAU to 32FAU. The appearances of water analyzed are shown from pale yellowish to cloudy in appearance.

The physical characteristics of the sample collected from Shimbra Meda wells shows that the borehole water is colorless, clear appearance and odorless.

The water sample collected from surface water at Shimbra Meda well field analyzed shows that cloudy appearance high turbidity and a lot of suspended materials. High turbidity may be attributed to the erosion of sediments from agricultural farmland and slightly gentle hills around the area. The appearance of water samples from Mojo River upstream to downstream till the water get diluted by natural self-purification system is turbid. After the dilution processes of municipal and factories impurities taking place the water become clear in far downstream. The turbidity of the water is decreasing down the river having very high turbidity at the place where the factory effluents adjoining the river. The color of the water at all sampling points show above the limits for drinking water. It is caused by the absorption of particulate matter in the river water. The river water samples also show objectionable to pungent smell or bad smell odor. This objectionable character is attributed to pollution of the river.

The rainwater sample collected and analyzed from Nazret town shows all its physical properties (appearance, turbidity, color and odor) are low and non-objectionable below the standard limit. The water samples from seasonal streams in Nazret town indicate all the mentioned physical parameters have high value above the standard limit.

The turbidity of Awash River increases along its flow path from up to down stream. Very high color value (12450 Pt. Co.) and bad smell observed at Melka Hida might be an indication of local or point source contamination. The water sample collected and analyzed from Awash Melkasa Aluminum Factory well indicate all the physical parameters are below the standard limit and non objectionable.

5.4.2. Temperature

A number of parameters such as turbidity, color, odor, etc are affected by temperature directly or indirectly. Temperature also affects pH, electrical conductivity, the rate of chemical reaction as well as the concentration of the reactants and products, and solubility of gases in water. The temperatures of most natural waters fall between 0 and 50^0C. These temperatures fluctuate seasonally with minimal occurring during winter or wet periods, and maximal in the summer or dry seasons, particularly in shallow waters.

Based on the water temperature, the samples analyzed in all sites except, Sodere hot spring can be categorized in to the cold water having temperature values below 25^0C. The in-situ measured temperature at Sodere hot spring was 58°C.

5.4.3. Acidity- Alkalinity (pH)

Acidity- Alkalinity (pH) represents the negative common logarithm of hydrogen ion concentration and / or activity. Based on pH value, a solution can be acidic if pH is less than seven (pH < 7), basic if pH is greater than seven (pH > 7) or neutral if pH is equal to seven (pH=7) at room temperature. The extreme value is at pH=0 (extremely acidic) and pH=14 (extremely alkaline). The pH value of natural water has a profound effect on the mobility of many elements. Only few ions such as Na^+, K^+, $N0_3^-$ and Cl^- remain in solution through out the entire range of pH values found in normal groundwater, Fifield et al. (1996). In natural water, pH is mostly controlled by carbondioxide-bicarbonate-carbonate equilibrium of the system. The pH of most natural waters is between 6.0 and

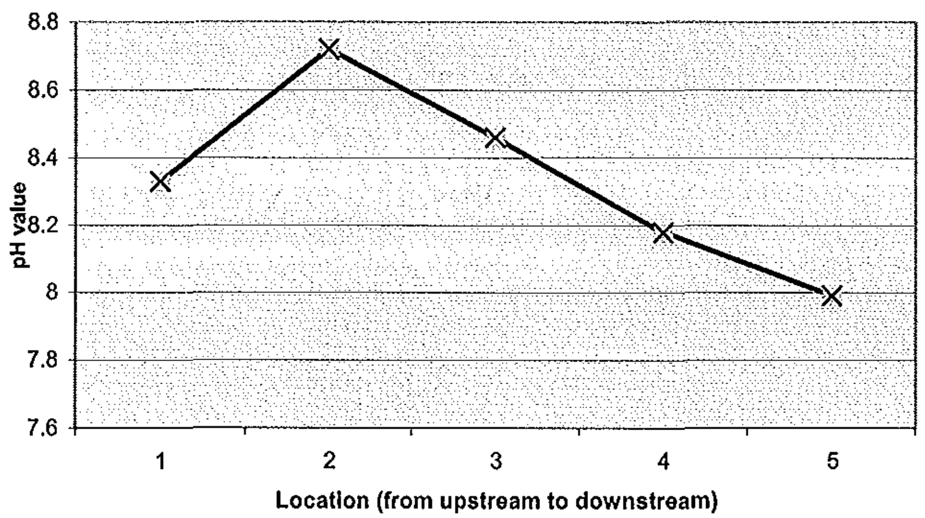
8.5. The pH is an important regulator in chemical and biological systems of natural waters. The hydrogen ion concentration of a raw water source for a domestic water supply system is important in that it can affect taste, corrosivity, and efficiency of chlorination, treatment processes and industrial applications. The pH value of the samples in Debre Zeite area ranges from 6.6 in lake Kuruftu to 9.2 in lake Bushoftu indicating that it ranges from acidic to alkaline including neutral water. However, the pH values of most waters in Debre Zeite area are greater than seven (pH >7).

The lower pH value was measured for surface and hand dug well (pH reading from one hand dug well from Debre Zeite area has 6.68), while the higher value was measured for the crater lakes especially lake Bushoftu which has 9.2 pH value.

The pH values of water samples analyzed in Mojo area ranges from 7.11 to 8.46. The value recorded in Mojo River down stream after all the effluents join the river. The value of pH is increased after factory effluents join the river and decreases further down the stream (Fig. 5.4).

The pH values of water samples collected from Nazret area ranges from

Fig 5.4 pH value along Mojo river



1= Mojo river upstream, 2=Mojo tannery effluent, 3-5=Mojo river down stream
The distance between 1 and 2 is approximately about 600m, 2 and 3 is about 500m, and 2 &5 is about 1.8km.

7.12 to 7.84 for all samples. This range lies with in the pH range of natural water. The value indicated in Awash River shows that there is a slight increment of pH down stream. The pH value of rainwater sample is nearest to neutral with slight alkaline range.

The rise in pH value at the middle of Fig 5.4 indicates that nearby Mojo tannery and Mojo edible oil factories effluents of alkaline wastes in nature are discharged to the river with out neutralization before they release to a natural river.

5.4.4. Total Dissolved Solids (TDS)

Total dissolved solids (TDS) refer to total concentration of inorganic solids. Ions like calcium, magnesium, sodium, potassium, bicarbonate, nitrogen, phosphorous, iron and sulfur including the non charged once like SiO_2 may comprise the TDS of water.

The total concentration of dissolved material in groundwater is determined from the weight of dry residue remaining after evaporation of the volatile portion of the water sample.

Based on TDS value, water can be grouped in to the following category.

Table 5.1 classification of water based on TDS values in water (other source).

Water type	Total dissolved solids (mg/l)
Fresh water	0-1000
Brackish water	1000-10,000
Saline water	10,000-100,000
Brine water	More than 100,000

Source: Freeze and Cherry (1979)

In Ethiopia TDS or salinity generally increases from the plateau volcanics, which is characterized by high rainfall and lower to region of lower rainfall and higher evaporation of the rift valley floor.

According to the TDS based water classification, most of the water in the study area belongs to fresh water groups including some of the crater lakes.

All waters collected and analyzed from study areas have a TDS value of less than 1000 mg/l except Lake Hora and Mojo tannery effluents. Lake Hora has TDS value of 1250 mg/l and a Mojo Tannery effluent has TDS value of 120,520 mg/l.

The elevated value of TDS in Lake Hora around the sampling point may be an indication of an anthropogenic influence. As the lake is used as a resort area, there is human activity at the beach; swimming and bathing are practiced, which may contribute to water contamination.

The highest TDS value investigated in Mojo Tannery effluents is obviously the results of uncontrolled factory wastewater disposal to the nearby Mojo River.

From the data collected and analyzed from different sources, it is shown that total dissolved solids generally increased from Debre Zeite area to wards Nazret area. Total dissolved solids of rivers/streams increase from the source or upstream towards water head or down stream.

5.4.5. Electrical Conductivity (EC)

Electrical Conductivity is a measure of the ability of a solution to carry electrical current and depends on the total concentration of ionized substances dissolved in the water.

Since the electrical conductivity of water is an indirect measure of its dissolved constituents it usually shows a strong correlation between EC and TDS values. When the value of TDS increases the value of EC also increases. The relation between TDS and EC can be given by the following formula:

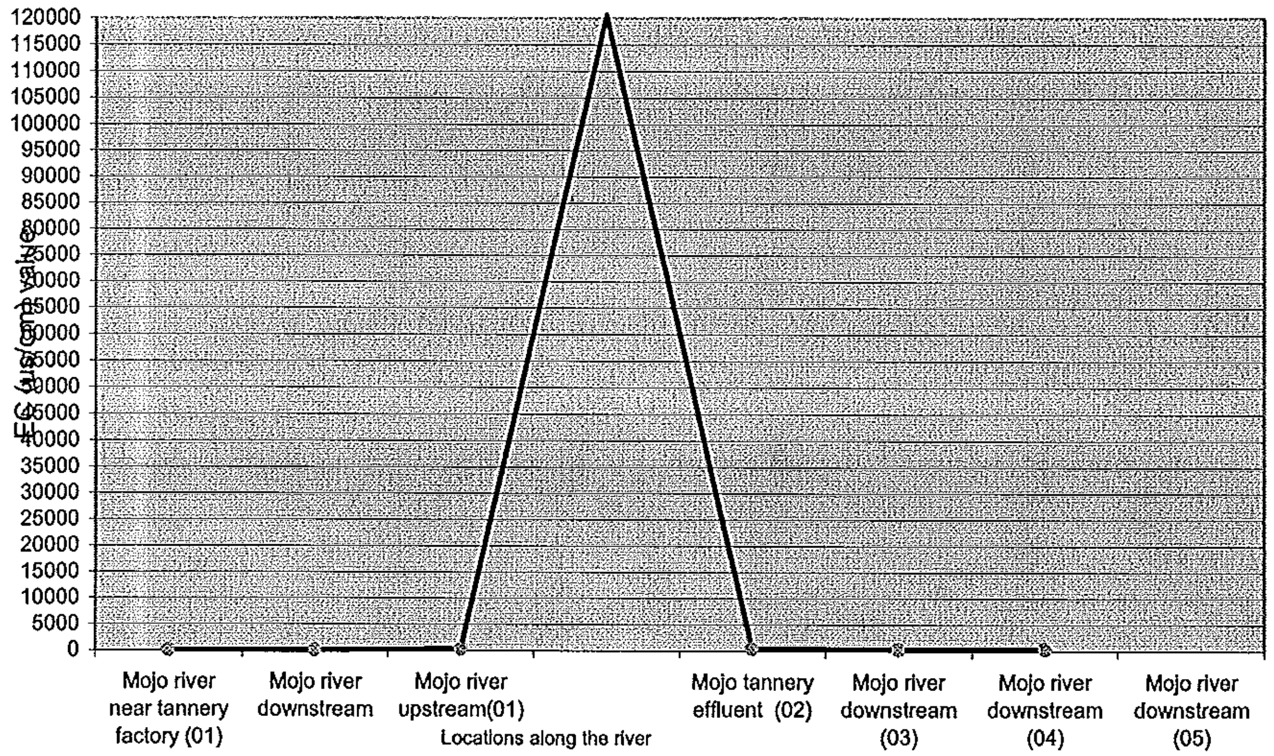
$$KA=S$$

Where; K is specific conductance in micro mhos/cm,

S is total dissolved solid in mg/l,

A is the value indicating the relation between conductivity and dissolved solids concentration. The value of A is mostly between 0.55 and 0.75.

Frg. 5.5 EC value along Mojo river



The highest value of EC was recorded both in the field and laboratory in some of the water samples collected. EC values measured from Mojo Tannery effluent is very high owing to a lot of suspended and dissolved solids carried in the tannery wastewater (Fig 5.5).

The value of EC increases after the river water contacts with the effluents from the factories.

5.4.6. Hardness

The hardness of natural waters depends mainly on the presence of dissolved calcium and magnesium salts. Calcium and magnesium dissolved in water are the two most common minerals that make water hard. The degree of hardness becomes greater as the Calcium and Magnesium content increases and is related to the concentration of multivalent cations dissolved in the water. The hardness value resulting is generally called "hardness as $CaCO_3$." Or "Calcium + Magnesium hardness" or "total hardness." Carbonate hardness, when reported, includes that part of the hardness equivalent to the bicarbonate + Carbonate (or Alkalinity). If the hardness exceeds the alkalinity (in milligram per liter of $CaCO_3$ or other equivalent units), the excess is termed "non carbonate hardness" and frequently is reported in water analyses.

The degree of hardness of drinking water has been classified in terms of its equivalent $CaCO_3$ concentration as follows.

Table 5.2 Classification of water based on hardness as $CaCo_3$ (other source).

Hardness range (mg/L of $CaCO_3$)	Description
0 – 60	Soft
61 –120	Moderately hard
121 –180	Hard
More than 180	Very hard

Generally the hardness of water is calculated from results of water sample analyses expressed in the form:

$$\text{Total hardness} = 2.5\ Ca + 4.1\ Mg$$

Although hardness is caused by cations, it may also be discussed in terms of carbonate (temporary) and non-carbonate (permanent) hardness. Carbonate hardness refers to the amount of carbonates and bicarbonates in solution that can be removed of carbonates and bicarbonates in solution or precipitated by boiling. Non- carbonate hardness is caused by the associations of the hardness causing cations with sulfate, chloride, or nitrate and is referred to as "permanent hardness" because it cannot be removed by boiling.

The principal natural sources of hardness in water are sedimentary rocks, seepage, and run off from soils. Hard water normally originates in areas with thick topsoil and limestone formations. Ground water is generally harder than surface water.

The two main industrial sources of hardness are the inorganic chemical and the mining industries. In the building industry calcium oxide is used in mortar, stucco, and plaster. It also finds use in tanning, as a water and wastewater treatment chemical.

Concerning health aspect, there is no evidence of adverse health effects specifically attributable to high levels of calcium or magnesium in drinking water. (WHO, vol.2 guidance for drinking water quality, 1988). But, hard water can cause both a nuisance and an economic burden to the consumer.

From the samples analyzed in the study areas the water samples are generally classified as hard to very hard in hardness.

The samples collected and analyzed from Debre Zeite lakes reveal that Lake Kuruftu lies with in hard water range; While lake Bushoftu lies with in very hard water range table 5-3 and (Fig. 5.6). As indicated on table 5.3 and annex 5a total hardness as $CaCO_3$ (170mg/l) exceeds the total alkalinity as $CaCO_3$ (110mg/l) in lake Kuruftu, which indicate the excess is noncarbonate hardness. But, total alkalinity as $CaCO_3$ in other crater lakes is much greater than total hardness as $CaCO_3$. Such variations might be due to lake Kuruftu has less contact with soil minerals and more contact with surface raw water than lake Bushoftu or other lakes. Water bodies which have less contact with soil minerals but have more contact with rain and surface waters are usually softer than those have more contact with soil minerals but have less contact with surface water bodies.

Table 5.3 Total hardness (as $CaCO_3$ mg/l), total alkalinity as $Caco_3$ and total acidity in the study areas (this work).

s/no	Area	Location (Site Name)	Source	Total hardness as CaCO3 (mg/l)	Total alkalinity as CaCO3 (mg/g)	Total acidity (mg/l)
1	Debre Zeite (Bushoftu)	Lake Bushoftu	L	250	900	520
2	,,	Lake Hora	L	235	1260	580
3	,,	Lake Kuruftu	L	170	110	480
4	,,	Lake Babogaya	L	185	500	550
5	,,	Shimira Meda	BH	175	484	190
6	,,	Shimira Meda	R	65	85	180
7	Mojo	Mojo river up stream (01)	R	132	381	136
8	,,	Mojo tannery effluent to river (02)	R	260	560	1140
9	,,	Mojo river down stream (03)	R	175	193	80
10	,,	Mojo river down stream (04)	R	170	381	120
11	,,	Mojo river down stream (05)	R	185	413	80
12	,,	Mojo river near bridge (tannery)	R	1460	704	410
13	,,	Mojo river downstream	R	352	107	61
14	Nazret	Awash Melekasa Aluminium factory	BH	265	425	550

15	,,	Adama rain water (near technical college)	rain water	1190	24	38
16	,,	Adama seasonal stream (near Frank Hotel)	R	130	470	248
17	,,	Adama seasonal stream (near Dumbbells Hotel)	R	220	85	94
18	,,	Awash river at treatment plant	R	80	115	166
19	,,	Awash river at Melka Hida	R	59.8	125	80
20	,,	Awash river at Melka Oba	R	1400	107	174

Fig. 5.6 total hardness, alkalinity and acidity

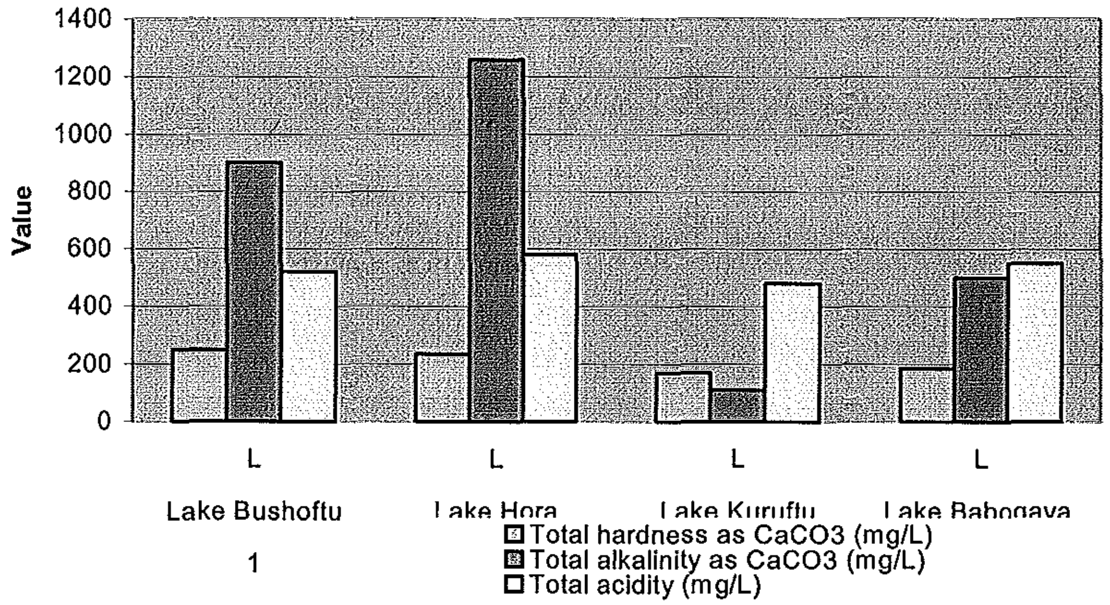
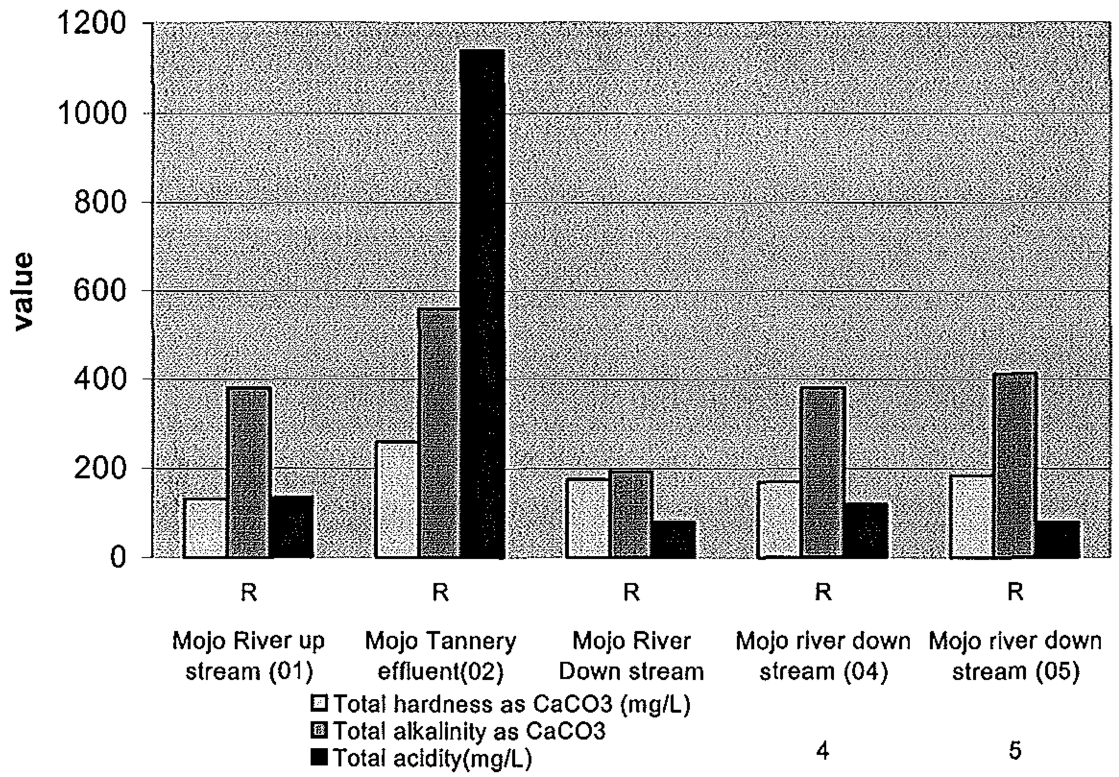


Fig 5.7 total hardness, alkalinity and acidity for Mojo river



The samples collected and analyzed from Mojo River show that the hardness increases down the stream with the exception of Mojo tannery effluent. The Mojo tannery effluent water analysis has shown that the hardness lies with in very hard water range (Fig 5.7). Generally the total hardness of water samples increases from the western margin of the study area (Debre Zeite) to the eastern margin of the study area (Nazret).

5.5. Major Cations and Anions

The major constituents of natural water occur mainly in ionic form and are commonly referred as the major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, HCO^-_3, Cl^-, SO^{2-}_4 and CO^{2-}_3). The total concentration of these eight major ions normally comprise more than 90% of the total dissolved solids in water, regardless whether the water is dilute or has salinity greater than seawater.

In the study areas water evolves from Ca-Mg-HCO_3 water in the volcanics of Debre Zeite area to Na-K-HCO_3 Water in acidic rock of the Nazret area.

The concentration of the different major ions in the water of the study areas were expressed in milligram per liter (mg/l) and milliequivalent per liter (meq/l) is depicted in annexes 5a to 5c and 6a to 6c.

The concentration of silica (SiO_2), which is the main non-ionic species in the water samples, is also given.

Cations

In the samples collected and analyzed some of the cations such as sodium and potassium were not completely analyzed due to the shortage of appropriate reagents and analyzing instruments for those samples collected in season one or wet period. To fill this gap data were collected from previously analyzed samples.

The chemical analyses carried out reveal waters from Debre Zeite area such as boreholes, lakes Kuruftu and Cheleleka show that the dominant cations in water samples are calcium and magnesium. The concentration of calcium varies from 10 mg/l in Shimbra Meda boreholes to 88 mg/l in hand dug well. The magnesium concentration also ranges from 7.2 mg/l in Shimbra Meda seasonal stream to 64 mg/l in hand dug well.

The concentration of these major cations decreases towards Nazret area with the maximum value of calcium observed 48.5 mg/l in Nazret municipality borehole.

The substantial high concentration of calcium and magnesium in Debre Zeite area than Mojo and Nazret areas might be attributed to the system in Debre Zeite area (except Lakes Bushoftu, Hora and Arengude) and geology of the areas. Calcium and magnesium concentrations decrease towards Nazret area, which attribute to these cations are depleted from acidic rocks that more abundant in Mojo and Nazret areas. Moreover, Debre Zeite is found closed to the high land with high rainfall and fast flushing system than Nazret. Nazret is found in the central part of rift floor, which is more characterized with closed system.

Anions

The predominant major anion in all the analyzed samples from all the areas is bicarbonate. Chloride and sulfate are also important constituents of both surface and groundwaters. The concentrations of both anions are increasing towards Nazret area.

When sulfide minerals undergo weathering in contact with aerated water, the sulfur is oxidized to yield sulfate ions that go into solution in the water (Hem, 1992).

The concentration of sulfate in waters of Debre Zeite area is ranging from 1 mg/l in Shimbra Meda boreholes to 362.5 mg/l seasonal stream. The concentration in lakes water ranges from 2mg/l in lakes Bushoftu and Hora to 4mg/l in Lake Kuruftu.

Sulfate concentration from Mojo River is ranging from nil for downstream of the river to 75mg/l at Mojo tannery effluent discharges to Mojo River. This peak value might be the result of runoff from different sources and industrial effluents.

Waters from Nazret areas have also a concentration ranging from nil in rainwater to 65mg/l in one seasonal stream flowing in the town.

5.6. Minor (trace) Ions

All the ions other than those mentioned under the Major ions obtained from the results of the chemical analyses of water samples are discussed in this category. Minor or trace ions constituents of water are actually or potentially of vital importance to human health, plant nutrition, or other areas of general interest (Hem, 1992). The determination of concentration of these ions is therefore very important. Some of the trace or minor ions in the drinking water may affect human health more seriously than other constituents. For instance, the determination of fluoride concentration in drinking water enables to understand the occurrence of tooth decay in drinking water of a particular area. The determination of other minor or trace ions in drinking water has received special attention. The minor or trace ions analyzed in this work includes fluoride, nitrate, nitrite, copper, iron, manganese, chromium, phosphate and others.

The concentration of fluoride in boreholes of Shimbra Meda of Debre Zeite is 1.7mg/l and in Shimbra Meda seasonal stream is 2.4mg/l. The concentration of this anion in Lakes water ranges from 0.5mg/l in Lake Kuruftu to 1.17mg/l in Lake Babogaya.

Fluoride in water is commonly associated with volcanic or fumarolic gases and in some areas these may be important sources of fluoride for natural water. Reference has been made to the occurrence of fluoride in volcanic rocks of rift valley floor.

What observed in the waters of Debre Zeite area is that as the concentration of fluoride increases in Shimbra Meda Boreholes and seasonal stream, the concentration of calcium decreases below the value of magnesium.

The fluoride concentration in Mojo river ranges also from 1mg/l at Mojo River downstream to 2.1mg/l near Mojo tannery or at the river gauging station.

The fluoride reading in water from Nazret area is also ranging from nil in rainwater to 3mg/l at Awash Melka Oba down stream of Awash Melkasa or near Sodere hot spring.

The concentration of nitrate in the analyzed waters from Debre Zeite area ranges from nil to 22mg/l in Lake Babogaya.

The waters from Mojo area indicate the concentration is ranging from nil to 539mg/l in Mojo tannery effluent to Mojo River.

The concentration of nitrate in waters from Nazret area also ranges from nil to 22mg/l in Awash Melkasa Aluminum factory borehole.

5.7. Sodium Adsorption Ratio (SAR)

The concentration of sodium in water is an important factor in determining its utilization for irrigation; because higher concentration of sodium in soil hardening by reducing permeability of the soil. These effects are caused by the replacement of calcium and magnesium ions by sodium ions on the soil clays and colloids. The extent of this replacement can be estimated by the sodium adsorption ratio (SAR), which is expressed by the following formula.

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \quad \text{--} (5.1)$$

Development of excessive sodium in soils will result from irrigation water that has high SAR values (18 or above). Values below 10 indicate little danger of sodium hazard. In general SAR value below 2 is classified as no hazard, 2 to 10 is classified as having little hazard, 7 to 18 medium hazard, 11 to 26 high hazard and over 26 as very high hazard (Fetter, 1994).

The SAR values computed for all collected Debre Zeite Lakes water samples range from 3.51 in Lake Babogaya to 17.8 in Lake Hora. Therefore, the lakes water are classified as little to medium hazard of sodium.

The boreholes in Debre Zeite area have values ranging from 0.86 to 1.06. Therefore, based on the above classification, all boreholes in Debre Zeite area are classified as no sodium hazard (table 5.4).

SAR for borehole waters from Mojo area ranges from 1.72 to 3. This indicates that some of the boreholes show little hazard (table 5.4).

The waters from Nazret area have values from 1.8 to 7.5. This also shows the value ranges from no hazard to little hazard (table 5.4).

From the table 5.4, one can observe that the concentration of sodium in groundwater is increasing from Debre Zeite area towards Nazret area. Therefore, the potential danger of sodium hazard as a reduction of soil permeability and hardening of the soil is relatively high at Nazret.

Another important classification of water for irrigation is with respect to electrical conductivity (EC) and soluble sodium percentage (also known as sodium percentage) which is defined by the following formula:

$$\%Na = \frac{(Na + K)}{Ca + Mg + Na + K} \quad \text{, ---} (5.2)$$

All ionic concentrations are expressed in milliequivalent per liter.

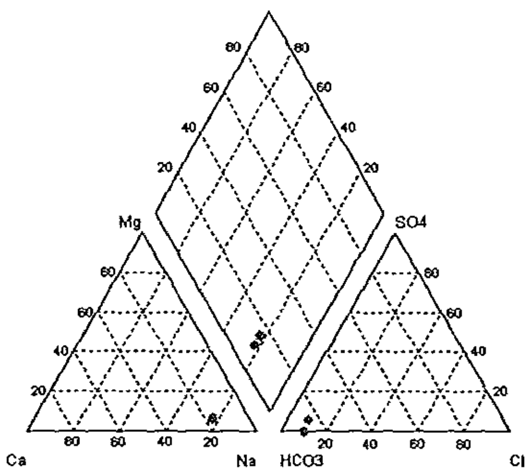
Table 5.4 SAR, % Na and EC value of certain waters from different sources in the areas (This work)

Area	Location(site name)	Water source	SAR	% Na	EC
Debre Zeite	Shimbra Meda	BH			526
,,	Bushoftu	L	5.51	69.2	1624
,,	Hora	L	5.4	68	2268
,,	Kuruftu	L	4.7	69.2	206
,,	Babogaya	L	3.51	57	854
,,	Babogaya Arm	L	17.8	72	844
,,	Debre Zeite WSSA well no 1	BH	1.06	29.1	390.3
,,	Debre Zeite WSSA well no 2	BH	0.9	25	449
,,	Debre Zeite WSSA well no 3	BH	0.95	29	418
,,	Debre Zeite WSSA well no 4	BH	0.95	27	444
,,	Debre Zeite WSSA well no 5	BH	1.01	29	456
,,	Debre Zeite WSSA well no 6	BH	0.86	26	475
Mojo	Ethio-Japan Textile well no 1	BH	1.74	43	876
,,	Ethio-Japan Textile well no 2	BH	2.06	48	878
,,	Ethio-Japan Textile well no 3	BH	1.72	43	871
,,	Ethio-Japan Textile well no 4	BH	2.6	53	1000
,,	Mojo Municipality well no 3	BH	2.7	53	544
,,	Mojo Municipality well no 4	BH	3	56	505
,,	Mojo tannery	BH	2.9	43	1565
,,	Mojo WSSA no 1	BH	1.82	45	403
,,	Mojo well no 3	BH	2.1	48	501
Nazret	Melka-Hida well no1	BH	1.8	45	611
,,	Melka-Hida well no1	BH	2.62	52	580
,,	Melka-Hida well no1	BH	7.5	76	927
,,	Melka-Hida well no1	BH	7.4	78	1011
,,	Dhaka Adi new well 1	BH	2.9	55	656
,,	Etage Hotel well no 1	BH	4.54	67	1076

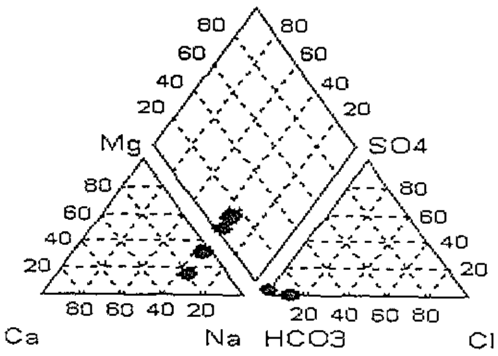
5.8. Water type classification.

The tabular presentation of chemical data is an ambiguous to understand and interpret, especially, if there are many samples. Hence, there exist various methods of graphical presentation of chemical analysis of surface and groundwater. The graph facilitates for easy understanding, interpretation, comparison and also classification of water samples. They can be either a single sample diagram or many samples diagram. One graphical method of presenting hydrochemical data that will be discussed here is the Piper tri- linear diagram. Piper tri-linear diagram is used to present more than one sample at a time. This method consider mainly the major cations (Ca^{2+}, Mg^{2+}, and N^{+}+K^{+}) and major anions (HCO_3^-, CO_3^{2-}, Cl^- and So_4^{2-}).

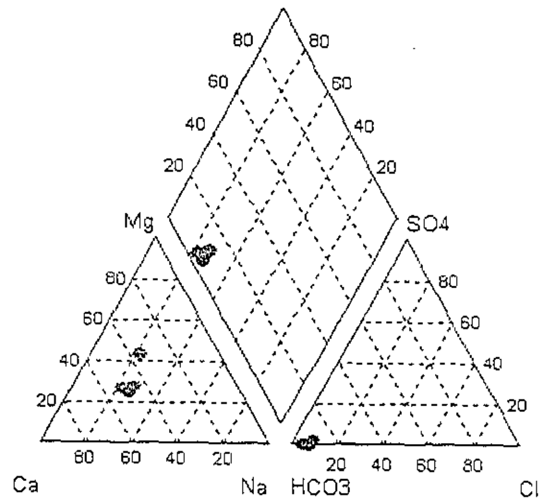
Fig. 5.8 Piper tri-linear diagrams to classify different water types from different sources are as follows.



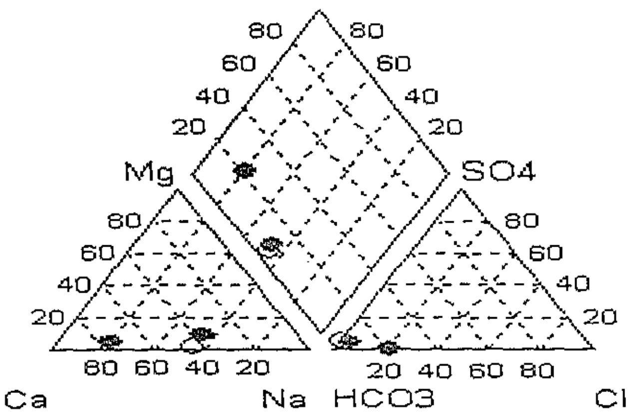
Piper tri- linear digragm for boreholes from Nazret area



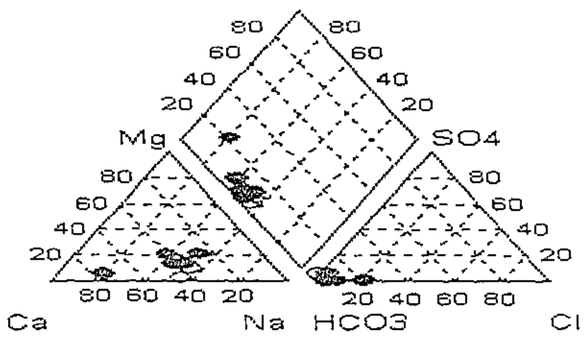
Piper tri-linear diagram for Debre Zeite Lakes



Piper tri-linear diagram for boreholes from Debre Zeite area



Piper tri-linear diagram for Mojo river



per tri linear digaram for Mojo Municipality

5.9. Interpretation and Classification of Water Samples

The water samples analyzed from crater Lakes in Bushoftu area; Lake Bushoftu, Babogaya, Hora and Arengude analyzed at arm, mid and bottom all show Na-HCO_3 type water. Cheleleka and Kuruftu lakes show Ca-HCO_3 type water. This indicates that Lakes Kuruftu and Cheleleka are fresh water type with shallow depth water circulation while the water of other Lakes show deep-water circulation with increased salinity and alkalinity.

The boreholes in Debre Zeite area are Ca-HCO_3 type water.

The water types in Mojo area are both Ca-HCO3 type water and Na-HCO3 type water. However, Na-HCO3 type water is the dominant type of water in the area.

The Na-HCO3 type water is increasing from Debre Zeite area towards Mojo area.

Nazret area is also characterized by Na-HCO3 type water. It is attributed to water chemical composition. The concentration of Na ion is increasing progressively from western plateau (Debre Zeite area) towards Nazret area or to the rift valley floor.

5.10. Bacteriological Analysis

The objective of bacteriological testing of water is to detect and determine the concentration of faecal bacteria in water in order to:

Check the supply is free from pathogenic (disease causing) organisms and to assess faecal pollution of supplies

The presence of bacteria and pathogenic (disease-causing) organisms is a concern when considering the safety of drinking water. Pathogenic organisms can cause intestinal infections, dysentery, hepatitis, typhoid fever, cholera, and other illnesses.

Human and animal wastes are a primary source of bacteria in water. These sources of bacterial contamination include runoff from feedlots, pastures, dog runs, and other land areas where animal wastes are deposited. Additional sources include seepage or discharge from septic tanks, sewage treatment facilities, and natural soil/ plant bacteria.

Older water systems, especially, dug wells, spring fed systems and river systems are most vulnerable to bacterial contamination. Any systems with casings or caps that are not watertight are vulnerable. This is particularly true if the well is located so close to surface run off and it might be able to enter the well.

There are two main methods used to detect and measure indicator bacteria in water. These are the membrane filtration method and the most probable number (MPN) multiple tube method.

From these two methods to detect and measure indicator bacteria, membrane filtration method was used for bacteriological examination of water in this study.

Membrane filtration method is the most useful method for testing faecal indicator bacteria in drinking water (P. John, 1991). This procedure involves filtering a measured volume of sample (100 ml), or an appropriate dilution of it, through a membrane filter which has a pore size of 0.45 μm-micro organisms are retained on the surface of the filter which is then placed on an absorbent pad soaked in a suitable selective growth medium (containing lactose) in a glass, plastic. It is then incubated at 44^0C for faecal coliform detection. Any bacteria able to grow will multiply to form visible colonies on the membrane filter surface. The number of colonies counted is expressed in terms of the number present per 100 ml of original undiluted sample.

Testing of bacteria (Coliform and E. coil) was done in field by Oromia water resources bureau central laboratory to avoid unnecessary delays and possibly a need for re-sampling if necessary. When we receive water samples, we give the samples a number and the time of collection. The samples were collected and examined from drinking boreholes, rivers, factory effluents, and lakes from the study area (table 5.5). It indicates E. coli bacteria contents, which varies from O (nil) to too numerous to count (TNTC) per 100 ml in water samples examined. The samples collected from boreholes show that E. coli bacteria count is nil i.e., boreholes are free from bacteria contamination. The values count from Sodere spring is 1 per 100 ml of sample; the values count from Lakes water ranges from 15 per 100 ml in Lake Babogaya to too numerous to count (TNTC) per 100 ml in lake Kuruftu. The samples collected and analyzed in Lakes waters are from the skirt of lakes at which anthropogenic influences are observed.

The values count from rivers waters show that the value ranges from 23 per 100 ml at Awash treatment plant at Koka to too numerous to count (TNTC) in other rivers. Therefore, human activities are the key factor for bacteriological contamination of these surface water bodies.

High counts of faecal Coliform and E. coli bacteria in water samples are a direct indication of the infiltration of water contaminated with wastes derived from humans and other warm blooded animals. Water samples collected from drinking boreholes show no E. coli count, which indicates boreholes are free of bacteriological contamination.

Table 5.5 Bacteriological examination of water around Debre Zeite, Mojo and Nazret areas (this work)

s/no	sampling points	Source	Date and time of sampling	Date and time of analysis	E-Coli per 100ml	Total coliform per100ml
1	Sodere (open spring	Sp	28/02/2004 4:00am	29/2/04 9:00am	1	5
2	Awash River (at Melekasa bridge, on the road to Arsi)	R	28/2/04 4:10am	29/2/04 9:00am	TNTC	TNTC
3	Awash at treatment plant (raw water)	,,	28/2/04 5:00pm	29/2/04 10:00am	23	52
4	Mojo River upstream (01)	,,	29/2/04 11:00am	1/3/04 10:00am	TNTC	TNTC

5	Mojo River downstream (02)	,,	29/2/04 11:50am	1/3/04 10:40am	TNTC	TNTC
6	Koka Lake (where people swim)	L	29/2/04 2:00pm	1/3/04 10:50am	31	82
7	Hora Lake (where people swim)	,,	29/2/04 4:00pm	1/3/04 1:00pm	22	68
8	Babogaya Lake (where people swim)	,,	29/2/04 4:30pm	1/3/04 2:00pm	15	49
9	kuruftu Lake (where people swim)	,,	29/2/04 4:40pm	1/3/04 3:00pm	TNTC	TNTC
10	Bushoftu Lake (where people swim)	,,	29/2/04 6:10pm	1/3/04 4:00pm	43	92
11	Debre Zeite Agricultural research centre	BH	29/2/04 11:00pm	1/3/04 4:30pm	Nil	Nil
12	Awash Melkasa Aluminium factory	,,	28/2/04 11:00pm	29/2/04 1:00pm	Nil	Nil
13	Mojo town water supply (from Tap water	,,	29/2/04 11:50pm	1/3/04 4:20pm	Nil	Nil

Remark: TNTC= too numerous to count

5.11. Water Quality

Water quality is a dominant factor in determining the adequacy of any supply to satisfy the requirements of these uses.

Water quality is determined by analytically measuring the concentrations of the various constituents and the effects, or properties, caused by the presence of these substances. In determining the quality of natural water supply source, the procedures used in sampling the supply are very important.

Each major type of water-supply source has certain water quality characteristics, which are valuable in the preliminary and formative phases of the development of the supply. The outstanding characteristics of surface waters, such as rivers, lakes, reservoirs, estuaries and ground water should be recognized.

Information about the water quality requirements for various beneficial used is important in the evaluation of a water supply source.

Water quality embraces the individual and combined effects of the substances present. The vitality of a supply to serve various uses is determined, to a large extent, by the constituents found in the water as well as its properties

When we are talking about water quality we are referring to the suitability of water for a proposed use. The three main classes of use are domestic, agricultural and industrial. A supply intended for municipal use may include all the three classes and accordingly required a standard of quality that is generally higher than that needed for any one class.

Water quality is closely linked to water use and to the state of economic development.

Guidelines set for drinking water, industrial water and agricultural (irrigation) water qualities.

5.11.1. Drinking Water Quality

The primary aim of the guidelines for drinking water quality is the protection of public health and thus the elimination, or reduction to the minimum, of constituents of water that are known to be hazardous to the health and well being of the community.

The quality of water defined by the guidelines for drinking water quality is such that it is suitable for human consumption and for all usual domestic purposes, including personal hygiene. However, water of a higher quality may be required for some special purposes.

In arriving at the guidelines for various substances in water, the total intake from air, food, and water for each substance is taken in to considerations. Guidelines values for both WHO and Ethiopian drinking water quality are mentioned in this work and the quality of water for the study areas are analyzed with respect to these guidelines. When guideline values are exceeded, it should only be a signal to investigate and take remedial action.

The guideline values for WHO and Ethiopian standard for selected water quality criteria are given in the following tables for microbiological and biological, inorganic constituents of health significance, and aesthetic water quality. This selection is based on the parameters or variables analyzed in this work.

Table 5.6 Microbiological and biological water quality guide values (other source).

S/no	Organism	Unit	Guide Values		Remarks
			WHO	Ethiopian	
1	Microbiological quality				
A	Piped water supplied				
A.1	Treated water entering the distribution system				Membrane filtration is recommended for low turbid water.
	-Faecal coliform	Number/100 ml	0	0	
	-Coliform organisms	”	0	0	
A.2	Untreated water entering the distribution system				
	- Faecal coliforms	Number/100ml	0		
	-Coliform organisms	Number/100ml	0		
	-Coliform organisms	Number/100ml	3		In an occasional samples but not in consecutive samples
A.3	Water in the distribution system				
	-Faecal coliforms	Number/100ml	0		
	-Coliform organisms	Number/100ml	0		
		Number/100ml	3		In an occasional

	-Coliform organisms				samples but not in consecutive samples
B	Unpiped water supplies				
	- Faecal coliforms	Number/100ml	0		
	-Coliform organisms	Number/100ml	10		Should not occur repeatedly

Table-5.7 Chemicals of Health Significance for Selected Water Quality Variables (other source).

No.	Substance	Guideline(G_N) (mg/l)		Remark (Health Effect)
		Ethiopian	WHO	
A	Inorganic constituents			
1	Chromium	0.10	0.05	Carcinogenicity suspect of chromium (VI) compounds
2	Copper	5	1	Acute gastric irritation & liver cirrhosis from long-term exposure
3	Fluoride	3.0	1.5	At low conc. prevent dental carries. At high conc. increase risk of dental fluorosis, & much higher conc. leads to skeletal fluorosis.
4	Manganese	0.8	0.5	Neurotoxicity and other toxic effects
5	Nitrate(as NO_3^-)	50	50	Causes methaemoglobinaemia in infants and suspect of certain form of cancer risk
6	Nitrite (as NO_2^-)	6.0	10	,, ,, ,, ,,

Table 5.8 Substances and Parameters that may Give Rise to Complaints from Consumers; (other source).

No.	Substance	Guideline Value (G_N) (mg/l)		Remark (Adverse Effect)
		Ethiopian	WHO	
A	Physical Parameters			
1	True Color	22 TCU	15 TCU	Unpleasing appearance
2	Odor	Non-Objectionable	Non-Objectionable	Unappealing to drink

3	Taste	Non-Objectionable	Non-Objectionable	Unappealing to drink
4	Temperature	Non-Objectionable	No guide value set.	High temperature may enhance growth of micro organisms & may increase test, odor, color & corrosion
	Turbidity	7 NTU	5 NTU	Stimulate after growth & cause objectionable appearance
B	Inorganic Constituents			
1	Ammonia	2	-	Objectionable odor
2	Chloride	533	250	Undesirable taste
3	Copper	2	1	Increase corrosion of GI & steel fittings, staining laundry & sanitary ware and give rise taste problem.
4	Hardness	392	500	Based on 300 as Reference WHO recommendation
5	Iron	0.4	0.3	Cause reddish-brown color, promote iron-bacteria & stain laundry & plumbing fixtures
6	Manganese	0.13	0.1	Stain laundry & plumbing fixtures and give rise to undesirable taste to beverages. Deposited as black precipitate in pipes. Certain micro organisms concentrate to give taste, odor, & turbidity problem.
7	pH	6.5 – 8.5	6.5-8.5	High pH imparts taste & soapy feel, while low pH cause corrosion. Preferably <8.0 for effective disinfection
8	Sodium	358	200	Undesirable taste
9	Sulfate	483	400	Causes noticeable taste & corrosion of pipes
10	TDS	1776	1000	Undesirable taste

Source: Ministry of Water Resources

5.11.2. Industrial Water Use (Quality)

Quality requirements for industrial waters vary widely according to potential use. For example, salt and brackish waters are commonly used as cooling water, particularly when they are used only once (not recycled) and can be disposed of without polluting the environment.

Industrial process waters must be much higher quality than cooling waters. Municipal supplies are generally good enough to satisfy the quality requirements of most process waters, with the exception of those waters used in boilers. About 60 percent of the water used by industry must be treated to meet quality standards. Sanitary requirements for waters used in processing milk, canned goods, meats and beverages exceed even those for drinking water.

In many cases, groundwater may be desirable for particular uses because of its low relatively constant temperature. In other cases, ground water may be suitable because of its natural hardness, because distilleries, bakeries, and breweries prefer hard water. The following table lists some typical quality tolerances for industrial process water.

Table 5.9 Industrial water quality (other source).

Industry	Turbidity	Color	hardness	Alkalinity (as $CaCO_3$) mg/l	Fe + Mn, mg/l	Total solids mg/l
Food products						
Backed goods	10	10	+	--	0.2	--
Beer	10	--	--	75-150	0.1	500-1000
Canned goods	10	--	25-27	--	0.2	--
Confectionery	--	--	--	--	0.2	100
Ice	5	5	--	30-50	0.2	300

Laundering	--	--	50	--	0.2	--
Manufactured products						
Leather	20	10-100	50-135	135	0.4	--
Paper	5	5	50	--	0.1	200
Paper pulp	15-50	10-20	100-180	--	0.1-1.0	200-300
Plastics, clear	2	2	--	--	0.02	200
Textiles, dyeing	5	5-20	20	--	0.25	--
Textiles, general	5	20	20	--	0.5	--

5. 10 Influence of water quality on the potential for clogging problems in localized (Drip) irrigation systems (other source).

Potential problem	units	Degree of restriction on use		
		None	Slight to moderate	Severe
Physical				
Suspended solids	Mg/l	<50	50-100	>100
Chemical				
pH		<7.0	7.0-8.0	>8.0
Dissolved solids	Mg/l	<500	500-2000	>2000
Manganese [2]	Mg/l	<0.1	0.1-1.5	>1.5
Iron[3]	Mg/l	<0.1	0.1-1.5	>1.5
Hydrogen Sulphide	Mg/l	<0.5	0.5-2.0	>2.0
Biological				
Bacterial populations	Maximum number/ml	<10 000	10 000-50 000	>50 000

5.11.3. Agricultural Water Quality

The future of farming depends on our ability to maintain our natural resources, such as soil, water and air. This water quality matters publication provides information on the potentially negative impacts that agriculture can have on soil and water quality, and some of the farming practices that can be minimize these impacts.

Water quality problems for irrigation

Water quality, soil types, and cropping practices all play a role in successful irrigation. Good quality water permits maximum yields consistent with proper soil and water management.

Sodium Adsorption Ratio (SAR):- Water quality problems in irrigation include salinity and toxicity. Excessive salinity occurs when there is an accumulation of slats in topsoil. Sodium has far-reaching effects on soils. Most sodium in natural water originates with the release of soluble products during the weathering of plagioclase feldspars. In addition minor amounts of sodium may come from the mineral halite (NaCl).

The particular consequence is the ratio of sodium to calcium and magnesium. When sodium-rich water is applied to soil, some of the sodium is taken up by clay; the clay gives up calcium and magnesium in exchange. This reaction, called base exchange alters the physical characteristics of soils and can even lead to growth retardation. Clays that takes up sodium becomes sticky and slick when wet and has low permeability. When dry, the clay shrinks in to hard clouds and that are difficult to cultivate. The formula describes SAR is given in equation 5.1.

The United States Department of Agriculture has developed a classification with reference to the sodium adsorption ratio as an index for sodium hazard and specific electrical conductance (EC) as an index of salinity hazard.

Water class	EC in us/cm	Alkali hazard (SAR)
Excellent	less than 250	up to 10
Good	250-750	10-18
Medium	750-2250	18-26
Bad	2250-4000	Greater than 26
Very bad	Greater than 4000	---

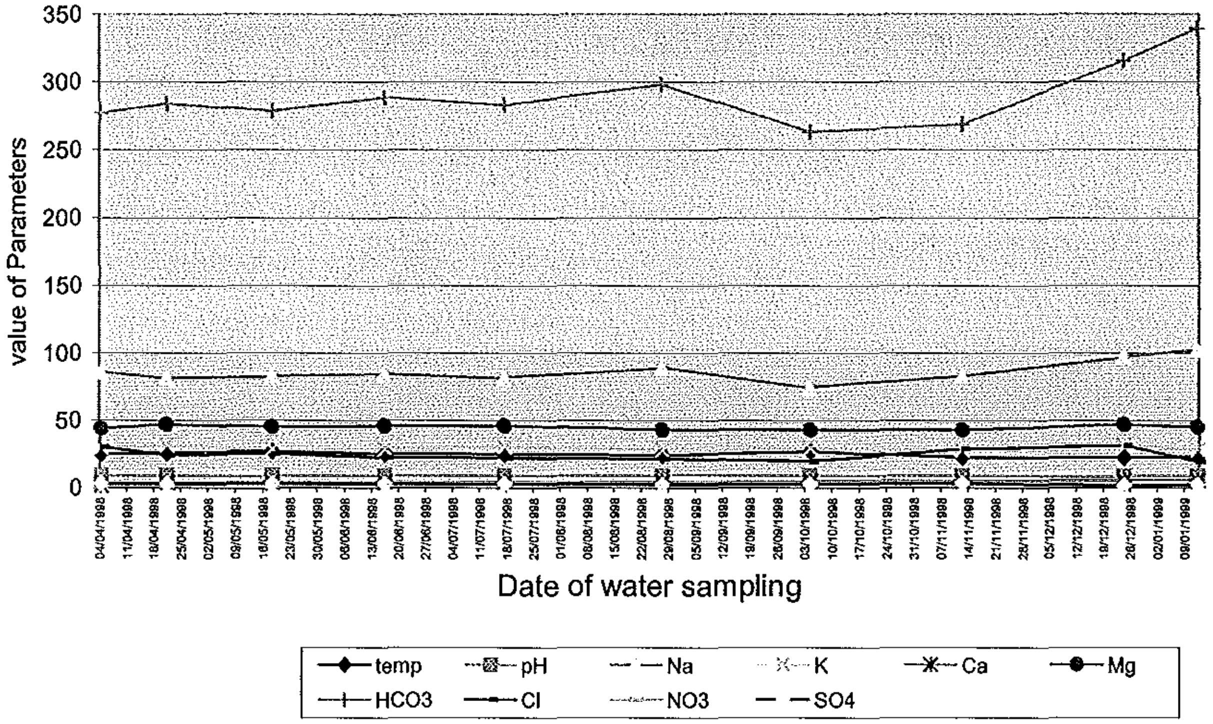
Considering the sodium hazard it is also possible to classify water for irrigation according to the formula given equation 5.2 and EC values of water.

Water class	EC in us/cm	%Na
Excellent	less than 250	<20
Good	250-750	20-40
Permissible	250-2250	40-60
Doubtful	2210-4000	60-80
Unsuitable	Greater than 4000	>80

5.12. Temporal Variations

The concentration of some ions increases from time to time in lake Babogaya as shown in figure below (Fig. 5.9). Bicarbonate anion shows substantial increment in one year's duration. Sodium ion also shows a considerable increment in the same Lake from 1998 to 1999. These increments of ions in this lake might be attributed to both natural variations and anthropogenic influences on the lake.

Fig. 5.9 Temporal Chemical variations of Lake Babogaya



CHAPTER SIX: SOURCES OF WATER POLLUTION

6.1 General

Pollution is the presence of matter or energy whose nature, location or quantity produces undesired environmental effects. Under the clean water act, for example, the term is defined as a man-made or man induced alteration of the physical, biological and radiological integrity of water. Pollutant is any substance introduced in to the environment that adversely affects the usefulness of the resource.

Water pollution is the degrading of the natural quality of water. Such pollution is usually thought of in the context of human activities, but it also can be naturally occurring. When determining the degree of pollution, both the presence of a substance and its concentration must be considered. The level at which a substance could be harmful is different for each substance.

Pollution can be divided in to two general sources; point and non point sources.

Point sources are any discernible, confined and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, animal feeding operation, or vessel or other floating craft, from which pollutants are, or may be, discharged.

Non point source of pollution is caused by diffuse sources that are not regulated as point sources. In practical terms, non point source pollution does not happen at a specific, single location (such as a single pipe), but generally results from land run off, precipitation, air borne particles, or water percolating through contaminated materials. Examples of non point sources include run off from agricultural land, forestry activity, urban areas, and construction sites. Such pollution results in the alteration of the chemical, physical, biological, or radiological quality of the water.

Ground water pollution occurs, or can occur, when ground water in the zone of saturation is recharged with polluted water or other liquid pollutants, or when a pollutant is placed or buried in the saturation zone. For example, ground water pollution may result from rainwater passing through sediment polluted with industrial or agricultural chemicals. Water polluted while on the surface of the ground, such as run off polluted with different chemicals applied for various activities, can also percolate in to groundwater and pollute it. Pollution may also result from wells, improperly sealed or abandoned, that allow polluted surface water to reach an aquifer. These same wells may also transmit water from one aquifer to another if the well is drilled through more than one aquifer.

Many causes of pollution including sewage and fertilizers contain nutrients such as nitrates and phosphates. In excess levels, nutrients over stimulate the growth of aquatic plants and algae. Excessive growth of these types of organisms consequently clogs our water ways, use up dissolved oxygen as they decompose, and block light to deeper waters. Pollution is also caused when silt and other suspended solids, such as soil, wash off plowed fields, construction and logging sites, urban areas, and eroded riverbanks when it rains. Under natural conditions, lakes, rivers, and other water bodies undergo eutrophication, an aging process that slowly fills in the water body with sediment and organic matter. When these sediments enter various bodies of water, fish respiration becomes impaired, plant productivity and water depth become reduced and aquatic organisms and their environments become suffocated. Pollution in the form of organic material enters waterways in many different forms as sewage, as leaves and grass clippings, or as run off from livestock feedlots and pastures.

The pollution of surface water bodies such as lakes, rivers and streams with chemical and biological contaminants has become one of the most crucial environmental problems in the study areas.

The major sources of water pollution can be classified as municipal, industrial and agricultural sources. These include industrial establishments, agricultural activities, municipal wastes, and garages, fuel stations and health centers.

6.2. Industries

The characteristics of industrial wastewater can differ considerably both with in and among industries. The impact of industrial discharges 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. Three options are available in controlling industrial waste water control can take place at the point of generation in the plant; waste water can be pretreated for discharge to municipal treatment sources; or waste water can be treated completely at the plant and either reused or discharged directly in to the receiving water bodies.

As indicated above industrial wastes are variable in nature. They may contain toxic heavy metals, oils, solvents and pesticides /herbicides. Effluents from textile processing are characteristically alkaline, high suspended solids and high BOD, industrial processing of the raw products of agriculture, i.e., food and fiber, produced potentially contaminating effluents generally high in BOD and colloidal and dissolved organic substances odor and suspended solids, Tannery waste water contain high concentrations of dissolved chlorides high BOD, total solids, hardness, sulfides and chromium. Food and drink process wastes commonly give rise to taste and odor problems if allowed to contaminate water supplies.

In the study area there are a number of mostly small and medium scale industries.

Waste waters discharged from these industries and factories are often stored in basins, pits, ponds, or lagoons and /or directly discharged in to the near by water bodies. Different tanneries found in Mojo towns are the best example, which directly discharge their wastewater in to Mojo River with out any prior treatment.

In the processes of impounding waste water for natural purification, if the site is unlined, and the probability of the soil is high water seeps down ward to contaminate groundwater. This is a threat especially where the underlying rocks are permeable and shallow groundwater table.

The discharge of untreated tannery effluent in to receiving water bodies in the study areas has become a major causes (source) of water pollution, especially, in Mojo river.

Different industries use different chemicals, which in turn lead to the production of different effluents, which have different impact on the environment. The chemicals discharged from various industries in the area are tabulated as follows.

Table 6.1 Chemical discharge from different industries (other work)

No	Type of industries	Chemicals
1	Leather/Tannery industry	Cr, Cacox, ca$(OH)_2$, S, H_2SO_4, NaHs, Nacl, $(NH_4)2SO_4$,
2	Tesxtile industry	Na (OH), H_2O_2, HCOOH, Na_2CO_3, CH_3 COONa, Nacl, NH_4 OH, $Al_2(SO_3)_2$, Na_2 SO_4, Cr_2O_7
3	Meat industry	NaOH, HCl
4	Edible oil factory	CO2, chemicals for washing and heavy oil,
5	Plastic factory	Thermal and waste water

All industries produce and discharge waste waters from some stage in their process. Most of the effluents contain bacteriological pollutants, which could find their way in to a river or lake, either directly or through a treatment plant.

Industry as a source of pollution can be divided in to three broad categories. These are gaseous waste, liquid waste, and solid waste. Table 5.10 gives an over view of various types of wastes those industries generate in the study area and as whole.

Many industrial wastes eliminate organic and inorganic substances, i.e., carbondioxide, and nitrous oxide, phosphorous compounds, chromium compounds and heavy metals. They can be very complex in their physical and chemical characteristics.

Table 6.2 source characteristics and treatment of some industrial wastes (other work).

S/No	Waste producing industries and materials	Origin	Characteristics	Treatment disposal methods.
1	Food bakeries	Washing and greasing of pans	High BOD, grease, floor washings, sugars flour, detergents.	Amenable to biological Oxidation
2	Meat and poultry	Stockyards, Slaughtering of animals, rendering of bones and fats, residues in condensates, grease and wash water, picking chickens	High in dissolved and suspended organic matter, blood, other proteins, and fats	Screening, setting or Flotation, tricking Filtration.
3	Hospital	Washing, sterilization of facilities, used Solutions spills	Bacteria, various chemicals, Radioactive materials	Discharge to municipal Sewers holding and Biological aeration in large facilities
4	Leather	Un haring, soaking, Deliming, and Bating of hides	High total solids, hardness, Salt, Sulfides, chromium, PH precipitated lime and BOD	Equalization, sedimentation and biological treatment
9	Textiles	Cooking of fibers, De sizing of fabric	Highly alkaline, colored, High BOD and temperature, High suspended solids	Neutralization, chemical precipitation, biological treatment, aeration.

Parameters of Industrial Pollutions

Although there are many parameters of industrial pollution known to exist, only the following parameters are seen here due to lack of complete chemical analysis result.

Acidity, Alkalinity and pH: - One of the most damaging characteristics of many industrial wastes, particularly from the inorganic industries, is their acid or alkali content. Either a high or a low pH may be damaging, causing fish kills and general sterility in natural streams, and inactivating the essential micro-organisms in sewage treatment processes. Wastes of low pH are corrosive to steel and concrete structures in waterways or sewerage systems.

Suspended solids:-The suspended solids test is a measure of the amount of undissolved and colloidal suspended matter (organic and inorganic) in the water bodies. This parameter is as important as the Biological oxygen demand (BOD). In stream pollution control since the degree of pollution also increases with the amount of suspended matters discharged in to the streams.

Chlorides:-Due to considerable amount of chlorides contained in both domestic and some industrial wastes, such as tannery the measure of chloride in receiving waters indicate the level of salt pollution and thus the degree by which the beneficial use of water for agriculture can be affected.

Nitrate and Phosphate: - Nitrate and phosphate are the principal constituents, which are responsible for the amount of plant growth in rivers and lakes. They are the main causes for development of algae, some of which are poisonous to livestock. Decay of algae causes death of fish, high turbidity, color and taste in water. The discharge of phosphate and nitrate bearing wastes from both domestic and industrial sources, in to lakes and impounded reservoirs also induce the biological productivity in the water bodies and thus leads to their ageing

6.3. Municipal Wastes.

Municipal sewage is a major source of water pollution. Domestic wastewater collects on the streets and in low-lying areas. The situation is further aggravated by the addition of untreated wastes from small and medium scale industries.

Untreated wastewater from domestic sewage and commercial estate discharge their wastewater in to different seasonal streams and rivers. This discharged wastewater pollutes surface and then ground water.

Municipal wastes can be categorized in to the following groups.

Septic tanks and cesspools: - septic tanks and cesspools are to be designed to discharge domestic wastewater in to the subsurface above the water table. Water from toilets, sinks, and showers, dishwashers, and washing machines passes from the home in to a septic tank, where it undergoes setting and some anaerobic decomposition. It is then discharged to the soil via a drainage system. Septic systems discharge a variety of inorganic and organic compounds. These compounds include biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), fecal coliforms, ammonia, nitrate, phosphorous compounds and others.

In the study area, however, there are not much septic tanks constructed; only few houses have septic tanks. Most of the urban dwellers use dry pit latrines and open field to dispose their waste excreta. Fore example in Nazret town there are only six public latrines constructed by the city council (DEVECON, 1992).

Land fills: - landfills are designed to minimize adverse effects of waste disposal (miller 1980). However, many were poorly designed and are leaking liquids, generically termed leachate, which are contaminating groundwater. Landfills can contain non-hazardous municipal waste, non-hazardous industrial waste or hazardous wastes

Materials placed in landfills include such things as municipal garbage and trash, demolition debris, sludge from wastewater treatment plants, incinerator ash, toxic and hazardous materials. Leachate is formed from the liquids found in the waste as well as by leaching of the solid waste by rainwater.

As there is no known landfills investigated in the study area no potential danger of groundwater pollution from these sources has been investigated.

Open dumps: - open dumps are typically unregulated. They receive waste mainly from households but are used for almost any type of waste. Waste is frequently burned and the residue is only occasionally covered with fill. Such dumps do not have liners and Leachate collection systems and by their nature are highly likely to cause groundwater pollution.

Residential disposal: - homeowners who are not served by a trash collection service must find alternative ways of disposing of their house hold waste. Included in the house hold waste are hazardous substances, pesticides, unused paints, and used paint thinner.

In the study areas these type of waste disposal method is occurring in the residential areas. They also pour waste liquids in to ditches or the sanitary sewer. These are undesirable practices that can easily result in environmental pollution including groundwater pollution.

Surface impoundments: - pits, ponds and lagoons are used by industries and municipalities for the storage and/or treatment of both liquid non hazardous and hazardous waste and discharge of non hazardous waste. Impoundments are used to treat wastewater by such processes as setting of solids, biological oxidation, chemical coagulation and precipitation, and pH adjustment. Water from surface impoundments may be discharged to a receiving watercourse such as streams or lakes.

Unless a discharging impoundment is lined, it will also lose water by seepage in to the subsurface. Non-discharging impoundments release water either by evaporation or seepage in to the ground or a combination of both. Evaporation ponds are occurring in some of the industries (Hora tanneries in Debre Zeite and Nazret edible oil factories) in the study areas. But the areas are classified as more arid with high evaporation exceeding precipitation. Therefore, potential threat of ground water pollution is less especially in Nazret area where ground water is found at depth and overlain by less permeable formations.

Impoundments are used for wastewater treatment by municipalities and industries such as metal industry, and chemical manufacturing. Lagoons and waste disposal ponds used in some factories such as; - Nazret edible oil factory and Hora Tannery in Debre Zeite town.

Urban runoff: - precipitation over urban areas typically results in a great proportion of runoff and less infiltration than that falling on nearby rural areas because of the greater amount of impervious land surface in the urban area. In addition, the urban runoff contains high amounts of dissolved and suspended solids from auto emissions, fluid leaks from vehicles, home use of fertilizers and pesticides, refuse, and pet feces. The water samples collected and analyzed from two ephemeral streams in Nazret town reveal these facts.

The samples analyzed shows that its total suspended solids, Turbidity, and appearance indicate high values beyond the permissible level.

This urban runoff get recharged to the subsurface and carried in to the surface receiving waters, such as Awash and Moji rivers. Though its great potential danger for ground water pollution is minimum due to depth watertable (Nazret town) and less permeable covering soil it contribute to the degradation of surface and groundwater.

Ground water surface water interactions: - some aquifers are recharged naturally from surface water if the stream stage is higher than the water table (Fetter, 1994). If the surface water body becomes contaminated, then the aquifer being recharged by that water could also become contaminated.

Accordingly, groundwater recharged from Mojo River can be contaminated. Mojo River is one of the most polluted surface water in the study area due to industrial and municipal waste disposal. It is a solid and liquid waste receiving water body, which in return recharge groundwater. An exception to this might occur if the surface water contamination is by a material that could be adsorbed or precipitated or removed by filtration when it passes through the alluvium under the stream. Wells located near a stream can induce infiltration from the stream in to the groundwater reservoir by development of a cone of depression. Contaminated surface water can thereby be drawn in to an aquifer.

Natural leaching: - Dissolved minerals occur in groundwater due to natural leaching from rocks and soil naturally occurring groundwater may have total dissolved solids in excess of several thousands milligram per liter and may contain undesirable concentrations of various anions and cations. Human activity that results in acid rain may enhance the ability of infiltrating rainwater to leach naturally occurring substances from rock and soil.

Generally, in the study area garbage solid waste is collected by few municipality trucks and dumped in an open field at the out skirts of the towns. The dwellers have no solid waste collection containers.

Since the municipal collections are not effective the majority of house holds in the towns dispose garbages in their compounds or in the open field and the streets. Sometimes the garbage is burned when accumulated. For instance, the sample survey on dry waste disposal conducted by DEVECON in Nazret town shows that 115 house holds or 46% dispose solid wastes in the open field, 90 households (36%) use municipality trucks and 44 (17.6%) garbage pits.

This figure indicated that most part of the solid waste disposed from the town is in an open field while only small percentage (17.6%) has a garbage pit. Although there is no surveyed figure shown for other towns in this work similar trend is anticipated.

6.4. Agricultural Activities

Agriculture is among the numbers of activities that are associated with man's introduction of foreign chemical and biological material in the subsurface environment. In the long run the most potentially hazardous of agricultural activities may be the use of chemical pesticides. But it is possible that the tremendous use of chemical fertilizers as plant nutrients may be a more significant problem, causing an increasing buildup of nutrients in some surface waters and groundwaters. The increasing mineralization of groundwater due to natural leaching processes and irrigation practices is the pressing groundwater quality problem. Agriculture for the most part can be characterized as diffused regional or non-point sources.

The principal contaminant is nitrate, derived both from fertilizers and as a result of the transformation of organically bound nitrogen in the soil to inorganic forms by bacteria.

Increased sulphate and chloride concentrations derived from the use of ammonium sulphate and potassium chloride fertilizers may also occur in drainage water from farmland. The condition of high concentration of sulphate recorded at Shimbra Meda seasonal stream in Debre Zeite area reveal this fact.

The major agricultural activities being practiced in the study areas are animal husbandry, crop farming and dairy developments.

The liquid and solid waste generated from livestock, feaces, urine, livestock yards and related activities are the sources of water contamination in the study areas.

The problems particularly associated with the farming activities are the farmers use large quantities of chemical fertilizer and pesticides for better crop production. When fertilizers are applied to agricultural land, a portion usually leaches through the soil and to the water table. The primary fertilizers are compounds of nitrogen, phosphorus, and potassium. Phosphate and potassium fertilizers are readily adsorbed on soil particles and seldom constitute a pollution problem. But nitrogen in solution is only partially used by plants or adsorbed by the soils, and it is the primary fertilizer pollutant (Todd, 1980).

In the same way that a weed is a plant in the wrong place, a contaminant is a chemical compound in the wrong place. Compounds that are necessary for successful farming may be unwanted in fresh water. For example, phosphorous is essential to plant growth, but too much of it can cause problems in water. The most common contaminants from agricultural practices include the following.

1. Sediment is mineral or plant material suspended in water and wind. It can fill in waterways, ruin fish spawning areas, and contribute to the transport of plant nutrients, which are bound to soil particles and greatly increase the costs of water treatment.

2. Nutrients are minerals required for plant growth. They are present in chemical fertilizers, manure and other organic fertilizers such as compost or plant residues. Nutrients can be transported from agricultural lands to surface and ground water. They can produce unwanted growth of algae and aquatic plants and accelerated "aging" of lakes and streams.

3. Pesticides are organic compounds deigned to kill specific plants and animals. They have become an important part of modern agriculture but pose a potential threat to non-target organisms, including us.

4. Disease-causing microorganisms are present in manure and animal carcasses. They may contaminate run off water from livestock facilities and become a health concern for humans and other animals.

5. Miscellaneous compounds such as fuels, solvents, paints, heavy metals and waste products may be sources of agricultural pollution. Sediments, nutrients and pesticides may be washed from agricultural land to surface runoff water. Surface and ground water can be contaminated by agricultural activities how do contaminants move from farms? Contaminants can move in to surface water bodies if they are attached to eroding sediments, suspended in air or dissolved in runoff water. Both wind and water can transport sediments. Wind also moves odors, which are considered to be a special class of pollutant. Dissolved compounds can leach in to ground water supplies. What is a best management practice? Not all farms create pollution problems. As well, not all pollution problems are serious. However, the potential for environmental problems to arise due to agricultural activities is well documented. There are practical ways to ensure that risks to the environment are minimized with out sacrificing economic productivity. These pollution-prevention-farming methods are known as Best management practices.

Contaminants can move in to surface water bodies if they are attached to eroding sediments, suspended in air or dissolved in runoff water. Both wind and water can transport sediments, which are considered to be pollutant.

CHAPTER SEVEN: POLLUTION IDENTIFICATION AND EXTENT OF POLLUTION

The possible pollutants in water are virtually limitless. From a public health or ecologic view, a pollutant is any biological, physical, or chemical substance in which an identifiable excess is known to be harmful to other desirable living organisms (Botkin and Keller, 1987). Thus excessive amounts of heavy metals, certain radioactive isotopes, faecal coliform bacteria, phosphorous, nitrogen, sodium and other useful (even necessary) elements as well as certain pathogenic bacteria and viruses, are all pollutants.

There are many different materials that may pollute surface water and ground water. The identification of pollutants is limited to the results of chemical analysis of inorganic constituents and bacterial analysis of water samples. Therefore, in this section the possible pollutants identified in the area under consideration has been summarized under surface and ground water sources.

7.1. Surface Water

The primary causes for the deterioration of surface water quality are municipal and domestic wastewater, industrial and agricultural (organic, inorganic, thermal), and solid and semisolid refuses.

Surface water ecosystems fall in to two categories. Standing systems, such as lakes and ponds, are usually more susceptible to pollution because water is replaced at a slow rate. Thus pollutants can build up to hazardous levels. Flowing systems include rivers and streams. Because water flows more quickly in them, they tend to purge their pollutants.

However, this purging effect is useless if the supply of pollutants is constant or spread evenly along its banks, as is common along many rivers. The surface water bodies (river and lake) in the study areas are recipient of the different types of wastes generated in the town either partly or fully. The following section presents the amount and type of pollutant in surface water bodies of the area.

7.1.1 Physical Characteristics

Characteristics of water evaluated in a physical analysis include color, turbidity, odor and taste. From the chemical analysis result Shimbra Meda seasonal stream in Debre Zeite area has turbid appearance, high values of turbidity and color. These elevated values are attributed to the leaching of agricultural field and sediments in the running water. These artificially induced polluting sediments come from disruption of the land surface for farming and some related activities. It is the result of human use of the environment. On the other hand the lakes waters around Debre Zeite are also objectionable in the physical properties mentioned above. The source of physical pollution of lakes in the study area can be resulted from leaching of organic debris, agricultural farms, and industrial wastes and due to natural constituents of water such as iron and manganese.

Mojo River water physical characteristics have shown objectionable nature. The water along the flow line shows clear to black appearance, high turbidity and color values of which the highest is observed from the tannery effluent and odorless to pungent smell. The turbidity values decreases from upstream to downstream, which is the result of dilution or self-purification of river water. The values of these physical characteristics at tannery effluent adjoining the river are extremely high. A pungent smell odor is a typical characteristic of industrial effluents to the Mojo River. These figures of physical characteristics are an indication of serious pollution of the river.

The physical characteristics of surface waters in and around Nazret also show pollutants in the water. The seasonal streams analyzed in Nazret town indicate sewer systems combine with storm- water flow with municipal wastes. During the heavy rains, urban storm runoff exceeds the capacity of the sewer system, causing it to back up and over flow. It may deliver pollutants to the nearby Awash River. Turbidity and color are main physical pollutants of Awash River. They result from leaching of agricultural lands, vegetations and other organic and inorganic materials.

7.1.2. Nutrients

Rivers and streams contain many organic and inorganic nutrients needed by the plants and animals that live in them. If higher than normal concentration they become pollutants (Chiras, 1991). The two important nutrients that cause pollution problems are phosphorous and nitrogen, both of which are released from a variety of sources (Botkin and Keller, 1987). In the environment, inorganic nitrogen occurs in a range of oxidation states as nitrate (NO^-_3), and nitrite (NO^-_2), ammonium ion (NH^+_4) and molecular nitrogen (N_2).

The concentration of phosphate a fully oxidised phosphorus above the permissible limit (5mg/l, Ethiopian standard) is found at Lake Babogaya, Mojo tannery effluent to Mojo river, Adama seasonal stream1 (near Frank Hotel) and Adama seasonal stream 2 (near Dembela Hotel). Bushoftu, Hora, and Kuruftu lakes have also a considerable phosphate concentration though it is below the standard value. On the other hand the phosphate value in other surface waters (river samples) is below the permissible limit. But, its concentration in Mojo river water is also a considerable value next to the above lakes.

The nitrate concentration in Mojo tannery effluent to Mojo River is extremely high above the permissible limit. The concentration recorded was 539mg/l, whereas the nitrate concentration in all other analysed surface water samples has a value below the permissible limit (50mg/l of Ethiopian guide value). This is the major cause of pollution of Mojo River. Moreover, Excessive nutrient inputs are the main causes of eutrophication.

7.1.3. Inorganic Constituents

Inorganic water pollutants encompass a wide range of chemicals, including metals and acids. The inorganic constituent described below includes major, minor and trace elements. The concentrations of these inorganic constituents in water is controlled by the availability of the elements in the soil and rock through which the water has passed, by geochemical constraints such as solubility and adsorption, by the rate of geochemical process and by the sequence in which the water has come in contact with the various minerals occurring in the geologic materials along the flow path and the residence time. It is becoming increasingly common for the concentration of dissolved constituents to be influenced by man's activities. In some cases contribution from man made sources can cause some of the elements listed as trace elements to occur as contaminants at concentration levels that are orders of magnitude above the normal ranges (Freeze and Cherry, 1979).

The ability of water body to support aquatic life, as well as its suitability for other uses depends on many trace elements. Some metals such as manganese, zinc and copper present in trace concentration are important for the physiological functions of living tissue and regulate many biochemical processes. The same metals, however, discharged in to natural waters at increased concentrations in sewage, industrial effluents or from other human activities can have sever toxicological effects on humans because of their tendency to accumulate in the body and the aquatic ecosystem. According to UNESCO (1992) water pollution by trace metals resulting from anthropogenic impact are causing serious ecological problems in many parts of the world. This situation is aggravated by the lack of natural elimination processes for trace metals. On the other hand the effect of major ions (Ca, Na, Mg, K, HCO_3. SO_4 and Cl) on health are not as such serious as trace elements. In the samples analysed from study areas, some of the inorganic constituents are above the maximum permissible level. The presence of ammonium in Shimbra Meda seasonal stream, Mojo river at different spots, Mojo tannery effluents, different seasonal stream samples analysed from Nazret town are an indication of water pollution. Iron concentration in Kuruftu Lake, Mojo River at different spot, seasonal stream in Nazret town, and Awash River at different localities are above the Ethiopian and WHO drinking water quality.

The concentration of manganese in the analysed surface water samples is also a little bit elevated above the standard value in some localities. Kuruftu, Hora and Babogaya lakes in Bushoftu area have manganese concentration above the standard value. The concentration of manganese in Mojo river at different localities around the factories located is also above the guidance value. The river samples analysed from Nazret seasonal stream near Dembela Hotel and Awash River at treatment plant have high concentration of manganese. This higher level of manganese in freely flowing river water might be associated with industrial and/or municipal pollution in the area.

On the other hand, the concentrations of other major ions in the analysed surface water samples are all below the permissible limit, even if there is a considerable contribution from different anthropogenic sources.

7.1.4. Bacteria

Faecal contamination is still the primary water quality issue in rivers, streams and lakes especially in many developing countries where human and animal wastes are not yet adequately collected and treated. The situation is probably more critical in fast growing cities where the population growth rate still far exceeds the rate of development of waste water collection and treatment facilities.

Human and animal wastes are a primary source of bacteria in water. These sources of bacterial pollution include runoff from feedlots, pastures, and other land areas where animal wastes are deposited. Additional sources include seepage or discharge from septic tanks, sewage treatment facilities, and natural soil/plant bacteria.

Bacteriological examination of water samples identified the presence of excess coliform organisms, which indicates the pollution of rivers/streams and lakes water. Moreover, the presence of Escherichia coli further confirms the high level contamination of the rivers/streams and lakes waters by bacteria from man made sources. Examination of water samples for the presence of faecal bacteria is a sensitive technique indicating recent faecal contamination. The higher the coliform count, on the other hand indicates, the more likely the water is to contain some pathogenic agent from faecal contamination.

Faecal coliform (E. coli) of water samples examined from lake Kuruftu, Mojo river at both up and downstream, Awash river at Melkasa bridge (on the way to Arsi) show the faecal coliform counted was too numerous to count. This indicates that anthropogenic influences at these localities are intensive and surface waters are highly polluted. Moreover, all surface waters analysed indicate that the waters are all polluted having a value above the permissible level.

In general the presence of coliform bacteria, inorganic and organic constituents, distribution of fauna and flora together with the physical characteristics (colour, taste, odour and turbidity) reflects the impact of anthropogenic activities on the quality of rivers/streams and lakes of water of the areas.

Plates 7.1. Mojo tannery effluent discharging to Mojo river and the polluted river.

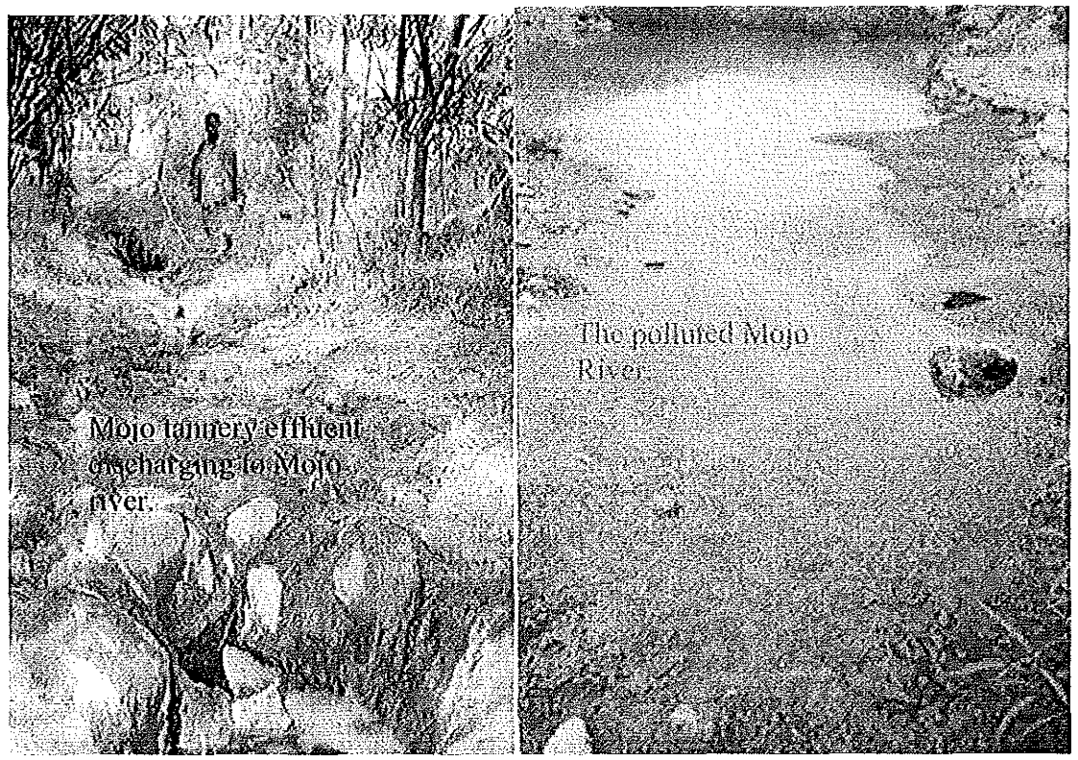
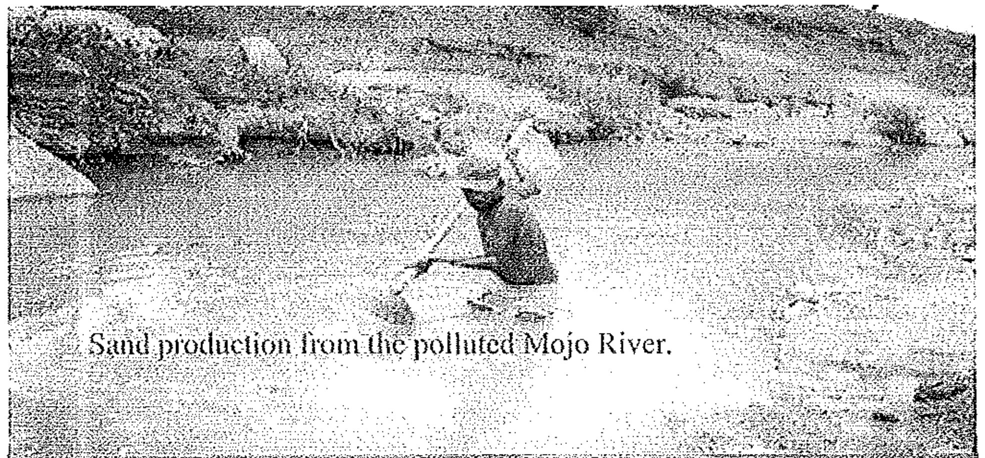
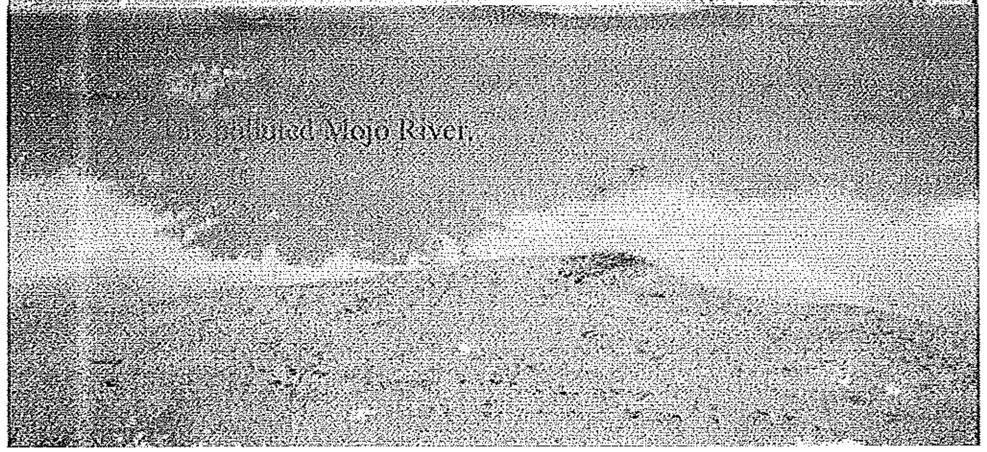


Plate 7.2. The polluted Mojo river from discharging of factory effluents.



Sand production from the polluted Mojo River.



The polluted Mojo River.

7.2. Groundwater

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 cannot be easily introduced 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 expansive.

The data collected and analysed from groundwater in this work are very limited to characterise groundwater pollutant well. Therefore, previous chemical analysis results have been used.

7.2.1 Nutrients

Potential contaminants of the nutrients group include those inorganic or organic compounds containing nitrogen and phosphate. Nitrate occurs naturally in groundwater as a result of soil leaching but in areas of high nitrogen fertilizer application it may reach very high levels.

The concentrations of nitrate in some groundwater are above the standard limits. Debre Zeite Air force boreholes, Blue Nile Plastic Factory, Hora Tannery, Almaz Doro, CIM-Mission, Kalehiwot boreholes, Ada Pasta and Macaroni, Debre Zeite management institute from Debre Zeite area all have high nitrate concentration above the standard limit.

One hand dug well in the town is also highly contaminated (62.1meq/l) nitrate concentration.

The entry of high concentration of nitrate into these boreholes might be through direct discharge of sewage or recharge from waste surface water bodies.

The high concentration of nitrate in shallow hand dug and boreholes indicate the interaction of surface water with groundwater.

The concentration of nitrate in boreholes from Mojo area is below the standard limit. However, some boreholes like Defence construction well numbers 5 and 9, Mojo Ethiopian Food Corporation wells and some shallow wells show considerable concentration of nitrate.

The concentration of nitrate in Melka Hida well field in Nazret area reached to 41.5mg/l.

The other important nutrient that contributes for the degradation of water quality is phosphate. The amount of phosphate concentration is insignificant in most ground waters and generally below the permissible limit.

7.2.2. Inorganic Constituents

The chemical data collected from different sources indicate that the inorganic constituents in groundwater are mostly below the standard limit for drinking water. But, there is a relative enrichment of some of the inorganic constituents like sodium, calcium and others in groundwater compared to surface water bodies. Of course, their concentrations in Debre Zeite crater Lakes are higher.

7.2.3. Bacteria

The bacteriological examinations carried in some of the boreholes in the study areas indicate that there is no bacterial contamination for groundwater. All the values show no coliform organisms and faecal coliforms (E.coli) reading from the sample collected and analyzed. The results from all samples indicate nil value per 100ml of water sample. However, as indicated in other section the surface waters bodies (lakes and river) are rather highly polluted especially the rivers/streams.

CHAPTER EIGHT: COMPARISON AND DISCUSSION (SYNTHESIS)

It is evident that water forms an indispensable constituent of the living environment for man and for all the other eco- systems. The water particularly intended or used for human consumption must be free from chemical substance and micro- organism, or must be within the normal range in amount that would not provide a health hazard.

Supply or source of water for drinking should not only be safe and free from dangers to health but should also be aesthetically as attractive as possible. Absence or within the standard limit of physical parameters of water, chemical parameters and biological parameters are very important.

Pertaining to these facts the potential source of pollution of waters in Debre Zeite, Mojo and Nazret areas were assessed.

The significance of the different chemical and biological parameters used to investigate the pollution of the surface and groundwater bodies can be evaluated as follows.

Turbidity: - Attributable to suspended and colloidal matter the effect of which is to disturb clearances of diminishes the penetration of light. According to Ethiopian and WHO drinking water quality standard the highest desirable level being 7 and 5 respectively and the maximum permissible limit is 25 units. In the samples analysed for turbidity reading in the study areas, seasonal stream of Shimbra Meda and lake Kuruftu have turbidity value above the maximum permissible limit from Debre Zeite area.

The samples analysed from Mojo River near by factories and town have also above the maximum permissible limit. But the value of turbidity far away from the town along the Mojo river is below the permissible limit.

The values of turbidity reading from Nazret seasonal streams and Awash River at different localities are also far beyond the maximum permissible limit. Awash River shows an increment of turbidity along its flow line. i.e., the turbidity increases substantially from upstream to down steam.

The maximum turbidity values recorded were 5375 NTU from Shimbra Meda seasonal stream in Debre Zeite area, 10,010NTU from Mojo river near Mojo tannery and Mojo Edible oil share company and 4 325 NTU from Nazret seasonal stream.

The highest turbidity value recorded in Awash River was 386 NTU at Awash Melka Oba (near Sodere) down Awash Melkasa Bridge. The water samples analyses results from other surface and ground water sources are all below the maximum permissible level. The high value of turbidity value can be associated with the highest number of micro-organisms which would be involved in bio-degradation that changed the state of the water. Leaching of municipal wastes and irrigation of the surrounding area especially Awash River could also be another factor.

Colour: - the borehole waters are clear and colourless, their colour readings are nil. Hence, they are in good condition. But, the colours of surface waters are high and in some rivers or streams far beyond the maximum permissible limit. The colour in these water bodies may be of natural mineral origin, caused by metallic substances such as iron and manganese compounds and organic compounds as well.

The highest reading of colour obtained in Debre Zeite area was from Shimbra Meda seasonal stream (101000pt.co) and from Lake Bushoftu (103pt.co), in Mojo area from Mojo river near river gauging station (near Mojo Tannery and Edible oil factories, 17,300pt.co) and Mojo tannery effluent to river the 10,750pt.co and in Nazret area from seasonal stream near Dembela Hotel, 72,500 pt.. Co and from Awash River at Melka Hida which is 12,450pt.co.

These highest intensity of colours at water sampling points are as a result of the impact of multiple factors, such as minerals, organic and inorganic soluble wastes from industries and municipal wastes.

*PH:-*It is the measure of potential pollutant. Not only is hydrogen ion a potential pollutant in itself. It is also related intimately to the concentration of many other substances, particularly the weakly-dissociated acids and bases. Conversely, the concentration of weakly dissociated acids and bases markedly affects the pH value and the case with which it can be altered.

The finding of pH in river water around Debre Zeite is 7.26; in borehole is 7.1 and the lakes value ranges from 6.6 in lake Kuruftu to 9.21 in lake Bushoftu.

From pH of these water bodies, one can observe that the value of river and boreholes are with in the range of natural water while the lakes water pH range from slightly acidic (lake Kuruftu) to strongly alkaline (lake Bushoftu). The high pH reading observed could be due to natural pollutant.

The pH value of Mojo River ranges from 7.71 to 8.29. The pH values upstream and far down stream is low relative to the middle one. It indicates alkaline condition. The relative high pH reading observed at the intermediate shows that there is an industrial effluents and municipal waste disposal to the river which contribute to high pH.

The pH value of rainwater analysed from Nazret town is 7.14 that is closer to neutral value. pH values of all seasonal streams and Awash river ranges from 7.12 to 7.84 and pH value of bore hole at Awash Melkasa Aluminium factory has 7.3. From these analyses we can observe that rain water has relatively low pH value nearest to neutral water

Generally the pH values of all waters analysed from surface and groundwater in and around Nazret area is 6.5 and 8.5 i.e., similar to the value of most natural waters.

Total dissolved solids: - This is mainly due to the concentration of different salts in water with trace of iron, manganese and other substances. All salts in the solution change the physical and chemical nature of the water.

The highest readings of TDS above maximum permissible level of WHO standard were observed from samples in lake Hora of Bushoftu and Mojo tannery effluent. All the TDS of other water samples have lower TDS below the standard level. The highest reading of TDS observed at Mojo tannery effluent to Mojo River is due to high concentration of ammonia, ammonium, nitrate, sulfate and chloride originated from discharging tannery and textile factories.

Total hardness: - the total hardness effect is excessive scale formation. Hardness in water may be caused by the natural accumulation of salts from contact with soil and geological formation or it may enter from direct pollution by industrial wastes such as from tanneries.

All the samples analysed show that the water in the study areas ranges from hard to very hard. Moreover, some samples indicate high value beyond the permissible limit. The highest value of hardness observed in Mojo River near river gauging station and Mojo tannery due to an accumulation salts from contact with soil and industrial discharge.

Ammonia (NH_3):- all waters collected and analysed show a considerable concentration of ammonia. Some of the samples have ammonia concentration greater than the maximum permissible limit. The maximum reading of ammonia in water samples were observed in Shimbra Meda seasonal stream (25.01mg/l), which might be due to ammonia fertilizer from the surrounding agricultural activities.

High ammonia concentration in Mojo river at different spots and Mojo tannery effluent to Mojo river are due to industrial discharge from Mojo tannery, edible oil factory and Mojo town domestic wastes.

High ammonia concentration in Nazret seasonal streams is due to municipal wastes. The high concentration of ammonia observed in Awash River might be due to agricultural activities in the surrounding area.

Ammonium (*NH_4*): - ammonium is an indication of water pollution from some of the waters analysed in the study area. The high value of ammonium (NH_4) in Shimbra Meda stream is may be the result of agricultural field leaching (contribution from fertilizer). The presence of NH_4 in large amount in Mojo river at different spot, and ammonium in water samples analysed from Nazret different seasonal stream are an indication of pollution through disposal of sewage and organic wastes to these receiving water bodies.

Iron:- the presence of iron in some surface water in the study areas such as Lake Kuruftu, Mojo River, Awash River and Nazret seasonal streams can be attributed to land fill leachates, sewage and more is from the dissolution of rocks and minerals. The concentration of iron in drinking water is normally less than 0.3mg/l. Iron is an essential element in human nutrition in this low amount concentration. It is contained in a number of biologically significant proteins. E.g. Haemoglobin and also in many oxidation-reduction enzymes.

Iron ingestion in large quantities results in a condition known as haemochromatosis (normal regulatory mechanisms do not operate effectively) where in tissue damage results from iron accumulation.

The presence of iron in drinking water supplies is objectionable for a number of reasons unrelated to health. Under the pH conditions existing in drinking water supplies, iron salts are unstable and precipitate as insoluble ferric oxide, which settles out as a rest coloured silt. Such water often taste unpalatable and stains laundry and plumbing fixtures. Iron also promotes the growth of iron bacteria.

Therefore, it would be prudent to maintain its levels below the mentioned values.

The concentration of manganese in surface waters on the study area ranges from nil to 10mg/l. But the Ethiopian and WHO guide value for manganese is 0.13mg/l and 0.1mg/l respectively. Water samples having concentration grater than these standard values are an indicator of effect on manganese pollution. The source of concentrated manganese in the sampled water might be acid drainage from the runoff of municipal and industrial wastes.

Nitrate: - Nitrate presents health hazards to infants and adults if it is present in drinking water at a concentration of greater than 50mg/l (according to Ethiopian standard) because of the relationship between high nitrates or nitrites in water and infant methemoglobinemia.

The concentration of nitrate from the water chemical analysis result shows that some boreholes and hand dug wells especially around Debre Zeite, Mojo ternary effluent to Mojo river, have concentrations above the standard limit set by Ethiopian and WHO guide line values. The concentration of nitrate in Mojo tannery effluent to Mojo River is 539mg/l, which is extremely higher than the maximum permissible limit. It is one of the largest point source of pollution to Mojo River. Though the value is decreasing downstream, Mojo River has considerable concentration at all sampling points. The concentration of nitrate in some boreholes and hand dug well is also greater than the maximum permissible limit.

The concentration of Nitrate in Awash Melkasa Aluminium Factory is relatively higher than other groundwater samples on the area.

This can be explained by the fact that the water is in contact with industrial effluent and/or residential wastes that could contribute for higher concentration in nitrate, otherwise generally in all the analysis made the nitrate concentration is lesser than the amount set as the maximum permissible limit.

Fluoride: - The concentration of fluoride in natural water that has total dissolved solids content of less than 1,000mg/L is usually less than 1mg/l (Hem, 1992).

Fluoride is a biologically important constituent of teeth and bones in lower concentrations.

The concentration of fluoride in all water samples analysed from Debre Zeite area is 2.4mg/l and lower.

The concentration in Shimbra Meda bore holes and stream water are a little bit higher when compared to the WHO standard, however below the Ethiopian standard limit. The maximum concentration of fluoride in Mojo River is 2.1mg/l. The concentration in water from Nazret area is ranging from nil in rainwater to 3.0mg/l of Awash River at Melka Oba.

The concentration of fluoride along the Awash River is increasing from upstream to down stream. The reason for the increment along the river flow path is due to the geological processes such as volcanic and geothermal activities on the area. Volcanic and geothermal activities are characterized by high fluoride concentration.

The effect of high fluoride concentration in drinking water in Nazret area is common. Fluoride in excess of the standard limit eventually causes endemic cumulative fluorosis with resultant skeletal damage in both children and adults. The mottling of teeth is also another health problem of fluoride.

Acidic igneous rocks, hot spring or geothermal activities and industrial waste disposal are the sources of fluoride.

Calcium; - calcium salts are common in water. These salts may result from leaching of soil and other natural sources, or they may occur in sewage and industrial wastes.

The effect of calcium in drinking water is formation of concentration in the body such as kidney or bladder stones and excessive scale formation on cooking utensils and water heaters. According to WHO, international standard for drinking water, the guide line value is 75mg/l and the maximum permissible limit is 200mg/l.

The water samples collected analyzed from Debre Zeite area show the concentration of calcium is below the guide lines value.

The water samples analysed from Mojo river show very high calcium concentration reaching up to 436mg/l. The river water samples collected at different points show relatively high concentration.

This high concentration of calcium in the river water might be due to leaching of soil by river water as natural source and sewage and industrial wastes as an anthropogenic influence.

The concentration of calcium in most sampled natural waters from Nazret area is below the WHO standard limit. However, rainwater collected near Adama Technical College has 280mg/l and Awash River at Melka Oba down to Awash Melkasa Bridge has 288mg/l calcium concentration. These values are above the values set by WHO (200mg/l) as a maximum permissible limit. These high values of calcium in water samples also show natural and human influence on the waters analysed.

Magnesium (Mg): - Magnesium is an essential mineral element for human beings; the daily requirement is about 0.7gm. However, at high concentrations magnesium salts have laxative effect up on the new users. The undesirable effects that may produce include hardness, taste, and gastrointestinal irritation in the presence of sulphate.

The guide line value for magnesium set by WHO is 50mg/l and the excessive limit is 150mg/l for drinking water.

The chemical analysis results of magnesium from the water samples show different magnesium concentration.

The magnesium concentration of crater lakes in Debre Zeite area is relatively higher than other surface water bodies. The magnesium concentration in lakes Bushoftu, Hora, and Babogaya and Shimbra Meda borehole is greater than the calcium concentrations in these water bodies. But, under normal conditions magnesium levels in fresh water are generally less than those in calcium, probably because of the lower geochemical abundance of magnesium (Matthess, 1982).

The concentration of magnesium in shallow wells and surface water bodies are higher than deep boreholes.

Chloride: - chloride is present in all natural waters, but mostly the concentrations are low. In most surface streams, chloride concentrations are lower than those of sulfate or bicarbonate. Exceptions occur where streams receive inflows of high chloride ground water or industrial waste or are affected by oceanic tides (Hem, 1992).

The most common type of water in which chloride is the dominant anion is one in which sodium is the predominant cation.

Due to taste considerations and possible corrosion of hot water system, chloride concentration in domestic water should not exceed 200mg/l. the concentration of chloride in all sampled and analyzed from Debre Zeite area ranges from nil in lake Kuruftu to 140mg/l in lake Hora.

The concentration of chloride in Bushoftu and Hora lakes are relatively higher when compared to other water samples.

The concentration of chloride in Mojo River is generally below the standard limit. However, its concentration in Mojo tannery effluent to Mojo River is the highest when compared to other sampled waters from the area.

The concentration is higher near and around the town. When we go further from the town its concentration is decreasing.

Although the maximum concentration is below the standard limit the significant concentration around the factories shows that the effluents of factories waste water have contribution for relatively higher concentration near the establishments.

The water samples analysed from Nazret area also show their maximum value is generally below the standard level. However, the concentration observed at Awash Melka Oba downstream of Awash Melkasa Bridge closer to Sodere Hot spring is relatively higher than the other water samples from the area. This influence on the concentration from other samples is probably due to addition of human and industrial wastes to the water.

Phosphate: - phosphates are produced by natural processes, but major man-influenced sources include; partially treated and untreated sewage, run off from agricultural sites and application of some lawn fertilizers.

Phosphorus is one of the key elements necessary for growth of plants and animals in lake ecosystems it tends to be the growth limiting nutrient.

Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate.

Phosphate will stimulate the growth of plankton and aquatic plants, which provide food for larger organisms.

Excessive nutrients inputs usually phosphate and nitrogen, have been shown the main causes of eutrophication.

The guide line value set by Ethiopian standard for drinking water for phosphate is 5mg/l.

The sample collected and analysed from boreholes and surface water at Shimbra Meda indicate the phosphate concentration is very low.

The concentration in lakes water ranges from 2.3mg/l in lake Kuruftu to 5.7mg/l in lake Babogaya. The concentration in Lake Babogaya is above the standard limit set by Ethiopian standard, which may be attributed to human influence or impact of waste disposal and contamination with lake water. The concentration in lakes Bushoftu and Hora are also a little bit an elevated value but below the standard limit.

The concentrations of phosphate in Mojo area sampled waters are below the standard limit except Mojo tannery effluent to Mojo River. The concentration of phosphate in Mojo tannery effluent to Mojo River is 14.5mg/l, which is very high; beyond the limit.

Obviously this very high concentration is attributed to man influenced source.

The concentrations of phosphate in waters from Nazret area are ranging from 0.01mg/l in rainwater to 19.7mg/l in seasonal (ephemeral) stream near Frank Hotel. The water samples collected from ephemeral streams from Nazret town show high value due to untreated sewage or partially treated sewage in solution with water.

The high concentration (7.3mg/l) recorded from Awash Melkasa Aluminium factory is also due to human influenced to the borehole water.

Chromium: - most rocks and soils contain small amounts of chromium in its naturally occurring state is in a highly insoluble form, however, weathering, oxidation and bacterial action can convert it in to a slightly more soluble form. Most of the more soluble forms in soil, especially any hexavalent chromium, are mainly the result of contamination by industrial permissions. Some contamination arises from the use of sewage sludge added to land. Contamination of air, water, and food has occurred as a result of man's use of chromium;

The harmful effects of water borne chromium in man are associated with hexavalent chromium; trivalent chromium, which is regarded as a form of chromium essential to man, is considered practically non-toxic and no local or systematic effects appear to have been reported.

Hexavent chromium in high does have been implicated as the cause of digestive tract cancers in man. The chemical analysis made in this work is for hexavalent chromium (Cr^{6t}) for the toxic one. The guide line value set for chromium in drinking water is 0.1mg/l and 0.05mg/l for Ethiopian and WHO standards respectively. According to Ethiopian standard all the waters collected and analysed from all water sources are below the standard limit setted. However, some water sources have higher concentration above the standard setted by WHO drinking water quality.

Lake Babogaya having a value of 0.06mg/l has higher concentration than WHO standard. The chromium concentration in Mojo River near the Edible oil, tannery and textile factories effluents to the river show high value, which is greater than the WHO standard. The exceptional high value that observed at these localities might be the result of industrial emissions of wastewater.

Bacteriological assessment: - it is a parameter used for biological assessment of the degree of organic pollution since high bacterial count occurs where the degree of self-purification decreases. The greatest danger associated with drinking water is that it may recently have been contaminated by sewage or human excreta, even the danger of animal pollution must not be over looked.

The organisms most commonly used an indicators of pollution are E. coli and the coli form groups as a whole.

Drinking water should not contain any micro-organisms known to be pathogenic. It should also be free from bacteria indicative of pollution with excreta.

The methodology involved in membrane filtration technique gives the presumptive number of coliform and E. coli in the 100ml water sample. The standard sets for coliform organism and faecal coliform or E. coli bacteria count number per 100ml is zero. But, bacterial examination of the samples from all surface waters (Lakes and Rivers) indicated faecal pollution having the value above and beyond the standard limit.

CHAPTER NINE: CONCLUSION AND RECOMMENDATION

The study areas are found in the upper Awash River basin situated in the central part of the country. Today the area encompasses the most densely populated and most industrialised regions of the country. The study areas (Debre Zeite, Mojo and Nazret) are the selected urban centres from the upper Awash River basin. The town of Debre Zeite is located at $8^0$45'N Latitude and $38^0$58'E Longitude; Mojo is located at $8^0$34'N latitude and $39^0$05'E longitude and Nazret is located at latitude $8^0$32'and $39^0$16'.

According to the 1994 population and Housing census result, the total urban population residing in Nazret town was 127,842, in Bushoftu (Debre Zeite) was 73,372 and in Mojo was 21,997.

Debre Zeite, Mojo and Nazret are located in the main Ethiopian rift (MER). Plateaux bound the main Ethiopian rift from western and eastern sides. The western side is the Ethiopian plateau and the eastern is the Somalian plateau.

Various factors affect the pattern and density of drainage in the study areas. Among these; rainfall, rock types and tectonics are the most important ones.

The lacustrine deposits of the rift floor area shows pattern of regional parallel drainages. These patterns are very widely spaced and usually are not very deep.

The average altitude of the plateaux on both sides of the rift is about 2500m a.s.l., while the floor of the rift valley gently decreases from the west to an altitude of 1350m a.s.l. to the east of Nazret.

The physiographic variation results to a difference in precipitation of the areas. The areas get the highest rainfall during the four months of June, July, August and September, with the highest rainfall in the months of July and August and lower rainfall is recorded in the months of November and December.

The annual average temperature recorded for 20 years in Debre Zeite was 19.35^{0}C, for 21 years in Mojo was 20.04 ^{0}C and for 20 years in Nazret was 21.24 ^{0}C. It indicates that temperature increases as altitude decreases from Debre Zeite area towards Nazret area.

The region, like most of the main Ethiopian rift has had extensive Pliocene- Quaternary vulcanicity and the geomorphology is one characteristic of a volcanic area, modified somewhat by lacustrine deposition during the pluvial periods.

The rocks of the study areas consist of consolidated volcanic rocks, lacustrine and loose alluvial deposits. Volcanic rocks consists of different types of basalts (scoriaceous and vesicular), rhyolite, trachytes, ignimbrites and welded and unwelded tuffs of varying ages. The lacustrine sediments are compact and fairly welded tuff ashes, slits, clay and diatomaceous sediments. The alluvial deposits are unconsolidated and consist of sand, slit and clay beds with brown, red or black colour and showing variation in thickness from place to place. The study areas, which are part of the northern portion of the Main Ethiopian Rift, have number of faults sub- parallel to the main Ethiopian Rift axis which is characterised by normal fault.

The volcanic rocks in the areas namely, basalt, trachytes, ignimbrite and welded tuff exhibit a wide range of hydrologic properties. Basalts range from fresh, dense and massive types to highly fractured, jointed or vesicular types. Ignimbrite and tuff also range from massive, dense to highly weathered and fractured type. Alluvial and lacustrine sediment differ in grain size distribution and thickness from place to place, which contribute to the variation in their hydrologic properties. The interconnection of pore space and highly fracture system caused scoriaceous and scoria to be highly permeable and productive aquifer in the area (especially Debre Zeite area). Well-developed fracture system also provided ignimbrite and basaltic unit to be high to moderate permeability. Rhyolite and trachytes have low permeability due to massive nature. Fine-grained materials and compaction caused low permeability in alluvial and lacustrine deposits.

The physical parameters such as appearance, turbidity, colour and odour of the ground water in the study areas are in good condition. But, surface waters like Shimbira Meda seasonal stream, Bushoftu, Hora, Kuruftu and Babogaya Lakes have values greater than high turbidity and colour values.

Mojo River has turbid appearance, high values of turbidity and colour and objectionable odours in most cases due to direct discharge of industrial and domestic wastes into it.

Rainwater collected in Nazret town shows good conditions of physical properties, which in turn show air pollution in the town from industrial source is minimal.

Seasonal streams from Nazret town and Awash River collected from different spots show high values of turbidity and colour and also turbid appearance due to discharge of agricultural products.

The pH values of both ground water and surface water in the areas ranges from 6.6 in Lake Kuruftu, which is slightly acidic to 9.21 in Lake Bushoftu, which is strongly alkaline nature. Except Lake Kuruftu, pH values of all other surface and groundwaters are alkaline with pH ranging up to 9.21.

The conductivity and TDS values of all groundwaters in the study areas are lower than 1000mg/l. i.e., ground water is classified as fresh water. But, the conductivity and TDS values of certain surface water bodies are greater than 1000mg/l. The high values were recorded in Bushoftu and Hora of crater lakes from Debre Zeite area and the polluted Mojo River from Mojo area. However, salinity measured as electrical conductivity show a progressive increase from western margin Debre Zeite area towards eastern margin Nazret area within the same system or origin of water.

The ground and surface waters of the areas can be classified as dominantly as very hard water types.

From the available water chemical analyses results of Debre Zeite area lakes Bushoftu, Hora, Babogaya and Arengude are all sodium-bicarbonate type water and lakes Kuruftu, Cheleleka, boreholes and hand dug wells show calcium- bicarbonate type water.

On the basis of these major chemical constituents, it can be concluded that the chemical composition of the waters are continuously enriched by calcium and magnesium cations and bicarbonate anion due to the effect of the interaction between waters and the geological environment through which they reside and move.

The waters from Mojo area show both Calcium and Sodium- bicarbonate type water. However, Sodium- bicarbonate type water is the dominant water type on the area.

The chemical analysis results of water from Nazret area also show the dominant waters are sodium- bicarbonate type water.

Concerning the major anion constituents the waters of the areas are characterised by a relatively higher content of bicarbonate and chloride. The concentration of chloride is increasing in crater lakes of Debre Zeite area and towards the east.

The higher concentration of sodium in lakes Bushoftu, Hora and Arengude than other lakes in the area is an indication of these lakes is found in a closed system in addition to the geological formation prevailing on the area. Lakes Kuruftu and Cheleleka on the other hand reveal open system in which their water circulation is fast with low residence time.

Generally sodium in combination as sodium- bicarbonate is a very important constituent of the most ground waters and some lakes waters in the study areas. The rhyolite-obsidian- tuff-ignimbrite rock suite, which is typical of the rift valley volcanic centres which, is rich in two elements, which are abundant in the ground waters. The effects of all other ions content are minimal.

Bacteriological analyses for the boreholes show no indication of total coliform and E.coli or faecal pollution. But, all the samples collected from surface waters (Lakes and Rivers) are charged with bacterial contamination which might be various origins (soil, animal excreta and others). Faecal pollution was shown in all the examined river waters and some lake waters. Bacteria count from all rivers show, all rivers are extremely polluted with the value too numerous to count the colony. Therefore, these waters are unfit for human consumption according to the standard set by Ethiopian and WHO standard limit.

From the data collected, it is indicated that industrial effluent and domestic sewage pollution are serious in Mojo River.

Pollution of the Mojo and Awash Rivers are becoming a serious as a consequence of discharging of raw sewage, industrial wastes directly discharged to the rivers. The water pollution of these surface waters indicated that organic and faecal pollution is a major threat to the safe use of the water for drinking and other purposes.

Water carries pollutants from the air and land in to surface and ground water.

Point source of pollution has a known discharge point, such as a pipe or sewer. Here are some examples of typical point sources identified in the study areas; municipal sewage treatment; combined sewer overflow and industrial wastewater.

Non point sources pollution refers to water pollution in run off soil erosion, agriculture, urban run off and land development are some of the sources of polluted urn off. Non point sources are often challenging to identify, measure and control. Here are some examples of typical non point sources agricultural activities; urban storm water runoff; construction activities and land disposal (landfills and land application of sewage sludge). Pollution is not always visible. A river or lake may seem clean, but still be polluted. In ground water, on which the population of Debre Zeite and Mojo rely for their water supply, discern of all types of pollution is difficult. But the effects of pollution on the rural area of Mojo River are obvious.

When pollution makes water unsuitable for drinking, recreation, agriculture and industry, it eventually also diminishes the aesthetic quality of lakes and rivers. Even more seriously, when contaminated water destroys aquatic life and reduces its reproductive abilities, it eventually menaces human health. Nobody escapes the effects of water pollution.

Finally, based on the above investigations, discussions and analyses the following recommendations are made.

- In the ultimate consideration of River waters for the water supply of local people, the temporal variation in the water quality should be known. A complete chemical, physical and bacteriological analysis should be carried out at a specified period for the water supply. i.e., water quality appraisal should be made both during the dry and the rainy seasons.

- To minimize the effect of pollution each industry should have appropriate treatment plant and should treat its effluents before discharging it to the rivers. Similarly domestic liquid wastes of the towns should be intersected and collected by a network of sewage systems and be conventionally treated before it is released to the rivers. To effect this water pollution control regulation is important and should be made available so that a person or institution who acts in contradiction to these regulations be prosecuted.

- Water quality requires a continuous monitoring and control and assesses the impact of development on the water quality to the standard set.
- The establishment of an inventory and licensing of significant dischargers should be made, to provide details of the nature, composition, flow and discharge points for the effluents concerned. The inventory should be updated on a regular basis and new industry should be required to provide details of its proposed discharges before being licensed to operate. Such licenses should be reviewed periodically.
- For each major discharger the provision of some form of effluent treatment should be mandatory.
- No pollution control programme can be effective without some form of policing. It there fore recommended that a small pollution inspectorate be established operating on regional lines.

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Annex 1a

Element: Monthly Rainfall — Lon.38°57' Lat.8°44' — Alt.1900m
Region: Shoa
Station: Debre Zeite Air Force

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total	Max	Min
1980	20	10.1	32.3	24.2	69.4	76.1	242.4	215.5	58.1	40.7	0	0	788.8	242.4	0
1981	0	20.5	164.2	62.1	7.1	35.8	294.6	151.8	162.8	4.2	0	1.2	904.3	294.6	0
1982	20.8	75.4	34.5	47.3	57.7	91	123.9	233.6	46.1	25.5	9.4	0	765.2	233.6	0
1983	0	10.2	62.8	105.2	209.5	149.4	128.8	344.8	88.6	23.4	0	0	1122.7	344.8	0
1984	0	0	19.3	0	108.7	80.7	220.5	217.3	85	0	0	3.6	735.1	220.5	0
1985	3.5	0	14.5	63.6	111.4	74	307.3	292.7	130	1.1	0	0	998.1	307.3	0
1986	x	x	x	x	x	x	81.8	116.9	130.6	11.3	0	0	340.6	130.6	0
1987	0	61.4	138.2	90.1	164	65.5	83.3	155.9	80.9	4.6	0	0	843.9	164	0
1988	8	15.9	6	44.6	36.8	100.6	145.9	236.8	121.4	16.6	0	0	732.6	236.8	0
1989	1.5	12.2	35.1	47	0.4	59	183.7	171.5	135.2	21.2	0	3.3	670.1	183.7	0
1990	0	123.2	58.2	86.4	36.5	76	224	173.2	102.4	0	0	0	879.9	224	0
1994	x	0	29.2	19.5	19.6	74.5	232.8	187.3	86.6	0	10.2	0	659.7	232.8	0
1995	0	2.4	7.8	33.9	5.5	92.5	188.4	169.6	175.1	0	0	11.9	687.1	188.4	0
1996	16.4	0	103.1	55.3	105.4	291.5	164.1	275.6	90	0.1	5.9	0	1107.4	275.6	0
1997	27.8	0	26.7	74.8	13.6	121.7	235.8	171.8	71.4	99.9	10.9	0	854.4	235.8	0
1998	32	51.4	13.9	77.2	41.8	77.7	206.3	293.5	97.6	93.3	0	0	984.7	293.5	0
1999	0.5	0	36.6	0	10	176.8	298.7	258.6	48.7	90.9	0	0	920.8	298.7	0
2000	0	0	8.6	50.4	65.4	77.4	244.3	181.4	139.4	40	23.4	3.4	833.7	244.3	0
2001	0	4.6	165.6	21.8	104	79.5	252.3	142.8	64.3	37.2	0	0	872.1	252.4	0
2002	8.6	0	48.2	34.6	11	102.3	194.3	181	58.4	0	0	21.3	659.7	194.3	0
Average	7.7278	20.3842	52.8842	49.3684	61.9895	98.5263	202.66	208.58	98.63	25.5	2.99	2.235			

Annex 1b

Monthly Rainfall | Lon. 39°07' | Lat. 8°370' | Alt.1870m
Region: Shoa
Station: Mojo

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total	Max	Min
1983	4	31	112	95	68	12	143	282	40	43	28	0	858	282	0
1984	0	0	14.2	0	81	64.4	238.6	190	114.8	46	0	7	756	238.6	0
1985	0	0	6	52	83	10	304	287	128	2	0	0	872	304	0
1986	0	56.2	34	59.2	32.7	182.2	132.2	65.1	72.6	3.1	0	0	637.3	182.2	0
1987	0	22.8	377.9	75.7	200.3	8.9	154.3	233.6	53.3	14.5	0	0	1141.3	377.9	0
1988	20.5	4.5	6.8	29.7	10.7	124.8	255.4	300.5	243.3	62.8	0	0	1059	300.5	0
1989	0	14.9	125.1	84.9	0.2	77	175.5	385.3	116.4	22.5	0	1.8	1003.6	385.3	0
1990	0	131.1	48.2	54.6	x	20.6	291.8	228.9	125.4	0.4	0	0	901	291.8	0
1991	0	31.1	147.1	4.3	13.8	55.2	329.9	205	92.2	0	0	0	878.6	329.9	0
1992	41.2	5.4	9.9	48.5	18	86.2	182.9	287	82.9	27.4	10.7	1.9	802	287	1.9
1993	2	19.5	0	82.5	73	59.6	286.5	216.6	82.1	5.4	0	0	827.2	286.5	0
1994	x	x	22.6	39.7	x	87.2	251	117.5	127.3	0	40.1	2.5	687.9	251	0
1995	x	44.6	37	60.5	31.4	32.7	180.8	143.7	70.9	2.5	0	0	604.1	180.8	0
1996	x	0	97.5	72.2	127	214.9	221.3	220.9	79.8	0	3	0	1036.6	220.9	0
1997	30.4	0	37.6	16.8	16.1	130.6	216.1	158.6	77.8	55.3	21	0	760.3	216.1	0
1998	32.3	7.6	50.7	46	46	112.1	161.3	274.8	149	154.1	0	0	1033.9	274.8	0
1999	x	0	18.4	0	4.2	90.9	541.5	362	67.4	87.4	0	x	1171.8	541.5	0
2000	0	0	12	10.1	33.2	128	285.9	230.8	114.1	12.6	25.4	0	852.1	285.9	0
2001	0	28.5	79.4	22.5	111	131.5	184.7	175.6	54.9	0	0	0	788.1	184.7	0
2002	0	0	8.9	13.7	6.5	62.4	193.5	168.2	90.2	0	0	14.7	558.1	193.5	0
2003	40.6	55.9	74.9	84.3	23.2	129	x	x	x	x	x	x	407.9	129	x
Average	10.0588	22.655	62.87	45.343	51.542	86.78	236.51	226.655	99.12	26.95	6.4	1.47		236.51	1.47

Annex 1c

Element: Monthly Rainfall Lon.$39^{0}17'$ Lat.$3^{0}33'$ Alt.1622m
Region: Shoa
Station: Nazret

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total	Max	Min
1983	x	43.4	33.8	79.3	188	24.7	214.8	221.3	72.4	14.3	0	0	892	221.3	0
1984	0	0	4.3	0.4	173.1	84.6	202.7	148.3	66.9	0	0	19.8	700.1	202.7	0
1985	3	x	23.1	183.4	67.3	8	405.4	327.1	169	0	0	0	1186.3	405.4	0
1986	0	96.5	41	6.2	54.4	152.4	263.3	95	20.4	0	0	0	729.2	263.3	0
1987	0	11.2	80.2	81.1	259.6	0	161.6	243.4	30.8	0	0	0	867.9	259.6	0
1988	34	31.3	6.8	50.9	9.4	50.3	155.4	171.4	186.9	52.9	0	0	749.3	186.9	0
1989	0	29.9	21.7	95.4	0	54.7	182.5	251.2	80.3	5.7	0	3.5	724.9	251.2	0
1990	0.7	183.9	83	114.7	13.3	12	337.8	168.7	153.7	10.8	0	0	1078.6	337.8	0
1991	0	x	84.2	13.5	22.3	74.4	322	232.8	89	13.1	0	1.7	853	232.8	0
1992	41.2	27.8	0	46.3	8.6	65.9	232.8	210	160.3	43.9	0	3.5	840.3	232.8	0
1993	15.4	51.9	0	102.6	72.7	64.1	345.2	142.4	79.3	20	0	0	893.6	345.2	0
1994	0	0	2.6	49.1	26.5	70.1	229.6	171.5	173.8	13.8	35.6	51	823.6	229.6	0
1995	0	36.5	46.7	127.2	33	46.5	203.1	251.4	88.2	14.7	0	2.8	850.1	251.4	0
1996	27.2	0	111.3	65.1	115.2	120.2	220.2	250	93.9	0	7.9	0	1011	250	0
1997	14.4	0	75.3	28.5	6.9	94	193.1	240.9	75.5	116.5	31.5	0	876.6	240.9	0
1998	11.8	25.6	105.2	19.8	79.3	55.3	196.5	220.6	144.7	132.8	0	0	991.6	220.6	0
1999	8.7	0	22.6	1.2	18.6	68	283.2	194.4	66.3	164.7	3.1	0	830.8	283.2	0
2000	0	0	20.2	16.1	51.5	60.8	352.7	271	133.6	85.7	64.8	12.9	1069.3	352.7	0
2001	0	6.2	108.3	28.7	177	51.2	253.8	145.3	107.8	1.7	0	0.3	880.3	253.8	0
2002	20.9	11.1	21.4	51.3	22.5	50.2	129.9	205.7	65.3	1.1	0	34.5	613.9	205.7	0
Average	9.33	30.85	44.585	58.04	69.96	60.37	244.28	208.12	102.905	34.585	7.145	6.5		244.28	6.5

Annex 2a

Region: Shoa
Station: Debre Zeite Air force
Element: Monthly mean Max temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	26.2	28.2	29.1	28.6	29.2	27.2	24	23.9	25	25.7	25.9	26
1981	27.1	27.3	25.9	25.7	28.8	29.1	24.4	23.9	23.2	25.4	25.5	25.6
1982	25.9	26.1	27.9	26.8	27.6	27.5	24.6	23	25	24.6	25.3	25.3
1983	25.9	27.1	28.2	26.9	27.6	26.8	25.5	23.5	24.8	25.6	26.4	26
1984	26.3	27.4	29.1	30.1	28	26	24.1	x	25	26.6	26.5	25.4
1985	26.5	26.8	28.5	26.7	27	27.3	23.2	22.9	24.4	25.9	26.2	25.7
1986	x	x	x	x	x	x	24.2	24.6	25	26.5	26.6	25.9
1987	25.7	27.1	26.7	26.9	27	26.3	26.3	25.3	26.8	27.5	26.8	26.4
1988	26.5	28	29.8	28.9	29.4	27.3	23.1	23.7	24.3	25.2	25.6	25.8
1989	24.5	26.5	28	26.5	28.9	27.7	23.3	22.4	24.6	25.2	26.1	25.2
1990	26.5	26.3	26.7	26.5	29	27.6	24.6	23.9	24.8	26.8	26.8	26.2
1991	x	x	x	x	x	x	x	x	x	x	x	x
1992	x	x	x	x	x	x	x	x	x	x	x	x
1993	x	x	x	x	x	x	x	x	x	x	x	x
1994	x	27.8	28.4	28.9	29.6	26.9	23.8	23.1	24.4	26	25	25.5
1995	26.4	28.7	28.5	27.8	29.9	29.2	24.4	23.7	25	26.2	26.1	26.4
1996	26	28.7	28	27.8	27.2	24.2	24	24.2	25.5	26.5	25.7	25.7
1997	26.1	27.4	29	27.2	29.7	27.7	24.9	25.2	26.9	25.9	25.3	25.9
1998	26.6	27.8	28.6	30.1	29.6	28.9	24.6	23.6	25.3	25.8	25.7	25.4
1999	26.9	28.8	27.8	29.7	30	28	23.7	24.3	x	x	25.1	25.4
2000	26.7	28.2	29.7	29.4	29.1	27.5	24.8	23.7	24.9	25.1	25.5	25.8
2001	26.5	29.2	27.7	29.1	28.4	26.7	24.6	24.1	26.9	27.6	26.9	27.6
2002	27	29.9	29.3	30.4	31.4	29.1	26.8	25.3	26.4	27.9	27.3	26.2
Max Ave.	26.3	27.75	28.26	28.11	28.81	27.45	27.45	23.91	23.91	26.11	26.02	25.87

Annex 2b

Region: Shoa

Station: Mojo Lon.39°07' Lat.8°37' Alt.1870m

Element: Monthly mean Max temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	x	x	x	x	x	28.5	26.7	25.4	26.5	27.4	27.2	26.2
1984	27.1	28	30.8	31.1	29.5	27	25.7	26.3	27.5	27.7	28.2	27.7
1985	28.7	28.9	31.4	30.8	30.6	31.5	25.9	24.6	26.6	28	28.6	28.9
1986	28	30.4	x	x	29.7	26.5	25.3	25.3	26	27.6	26.6	26.5
1987	27.2	28.7	28.5	28.5	27.9	27.8	27	25.7	28.1	28.9	28.7	28.3
1988	28.1	30.1	31.3	30	31.5	28.3	23.8	24.4	25	28.2	27.3	27.1
1989	27	30	30.1	27.5	31.3	28.6	24.2	24.7	25.3	27.6	28	27.5
1990	28.2	27.8	28.3	29.2	x	29.3	25.1	24.5	25.9	27.4	28	26.5
1991	29.4	29	29.7	30	31.3	30.7	24.5	24.3	26.3	28.4	27.6	27.5
1992	28	29	31.6	31.8	32.2	29.9	24.8	23.5	25.7	27.1	27.2	27.9
1993	27.8	27.5	31.6	29.8	29.3	28.6	26.7	25.9	26.2	28.6	28.7	28.5
1994	x	x	32	31.8	33	28.4	24.8	23.9	25.2	27.2	26.5	26.2
1995	27.9	29.2	29.1	29.1	30.7	30	24.5	24.8	26	27.9	28.2	28.2
1996	x	28.7	29.1	29.9	29.9	29.3	26.6	24.9	26.9	27.5	27.5	27.2
1997	28	28.5	30.9	29.1	30.7	28.6	25.2	26.3	28.1	28.5	27.5	28.6
1998	29.2	30.4	31.1	32	31.9	32.3	26.9	24.5	25.7	27	26.7	27
1999	x	30.8	30.5	31	30.9	30	29.4	28.9	28.8	28.6	29.3	x
2000	28.5	29.7	30.9	30.6	30.6	20.3	24.3	23.7	26.4	27.5	28.4	28.2
2001	28.1	29.6	29.5	30.9	30.1	28.3	26.3	26	27.8	29.7	29.5	29.6
2002	29.2	30	29.4	29.9	30.5	29.4	28.1	27.5	28.8	28.4	29.3	27.7
2003	28.6	29.3	29.9	29.6	32.1	30	x	x	x	x	x	x
Max Ave.	28.18	29.24	30.3	30.14	29.03	28.73	25.79	25.25	25.25	27.96	27.95	27.65

Annex 2c

Region: Shoa

Station: Nazret Lon.39°17' Lat.3°33' Alt.1622m

Element: Monthly mean Max temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	x	x	x	x	x	x	x	x	28.2	29.1	28.9	28.1
1981	29.6	29.6	28.4	27.6	x	33	28.3	25.7	25.8	27.9	28.1	27.5
1982	28.2	29.1	31.3	30.4	30.3	31.5	27.3	25.2	27.2	25.7	26.2	26.5
1983	x	28.1	30.7	29.5	30.4	29.8	27.8	25	27.5	28.6	28.5	27.7
1984	x	x	x	x	x	x	x	x	x	x	x	x
1985	29.9	x	32.1	29.4	30.8	32.4	28.8	25.3	28	29.1	30.3	29.3
1986	29.7	31.2	29.7	32.7	34.3	29.6	27.5	28.4	30.8	27.8	28.9	29.8
1987	25.1	31.7	31.2	29.8	30.4	30.1	29	27	29.8	31.1	30.7	30.6
1988	31	32.9	32.3	33.1	33.1	31.7	25.2	27.1	27.5	27.2	25.2	27.3
1989	29	29	28.5	27	32	30.3	24.3	24.7	26.9	28	28.3	28
1990	26.8	27.5	26.1	26.8	30.3	30	25.6	27.5	26.1	31.4	27.3	25.9
1991	27.7	x	28.9	29	30.1	30.1	25	24.8	26.6	27.5	27.1	26.6
1992	25.8	26.1	29.7	29.7	30.7	30.1	25.3	24.3	25.3	25.9	26.4	25.9
1993	25.3	24.9	29.5	27.9	28.1	28.6	24.8	25.1	26.5	27.5	x	x
1994	x	x	x	x	31.2	26.6	26.4	25.2	25.9	27.1	25.5	25.1
1995	26.9	29	28.7	28.3	30.9	31.6	25.9	25.6	26.5	27.9	27.4	27.5
1996	26.8	29.6	29.5	29	29.2	26.5	26.2	25.5	26.9	27.9	27.5	26.2
1997	28	28.3	30.3	28.5	31.2	29.7	26.1	26.3	28.3	27.3	25.6	25.9
1998	26.9	29.3	28.8	31.6	31.6	32.2	26.1	24.9	26.3	26.8	26.5	25.8
1999	27.1	29.9	28.2	31.1	31.5	30.5	24.7	25.2	27	25.6	25.9	25.4
2000	27.3	28.3	30	30.2	30.8	29.8	25.9	25.7	26.8	25.8	25.7	25.4
2001	24.7	27.8	28.5	29.8	29.6	28.2	25.8	25.3	27.4	28.7	27.3	26.8
2002	26.2	29.2	29.9	31	32.8	30.9	29.7	26.6	28.2	29.8	28.6	26.5
Max Ave.	27.47	28.97	29.62	29.62	30.95	30.15	26.46	25.73	27.25	27.9	27.42	27.04

Annex 3a

Region;Shoa

Station ; Debere Zeyite Monthly Min Temp.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	9	10.3	12.9	13	12.2	12.3	13.3	12.3	11.9	10.8	9.8	7.6
1981	9.8	11.2	13.6	13.3	12.5	11.7	12.9	12.6	12.2	9.5	8.4	6
1982	9.7	11.3	10.8	11.6	13.1	11.8	12.3	13.1	12.3	10.8	10.8	10.6
1983	9.8	12.7	13.8	13.6	14.3	12.4	13.3	13.9	12.6	10.7	9.1	8.2
1984	7.8	7.8	12.1	13.9	13.4	13	12.8	x	12	9.6	9.5	8.1
1985	8.5	9.8	12.4	12.8	12.3	11.6	11.8	11.9	11.3	9.2	9.2	8.9
1986	x	x	x	x	x	x	13	13.4	12.3	10.8	10	10
1987	9.8	11.3	13.7	13.2	14.6	12.9	13.9	13.7	12.8	12.3	9.9	10.3
1988	11.6	13.9	14.1	15.3	13.6	13.5	14.6	13.6	13	11.1	7.6	8.3
1989	9.2	11.4	13.1	13.7	11.9	12.7	13.5	12.4	12.7	10.1	9.7	12
1990	10	13.8	12.9	13.2	12.6	11.2	13.5	13.6	13.2	10.4	9.8	8.6
1991	x	x	x	x	x	x	x	x	x	x	x	x
1992	x	x	x	x	x	x	x	x	x	x	x	x
1993	x	x	x	x	x	x	x	x	x	x	x	x
1994		10.8	13.5	14.5	13.9	13.2	13.7	13.3	12.4	10.4	9.8	9.1
1995	9.2	12.2	13.9	14.7	14	12.6	13.6	13.9	12.1	11.6	9.8	11.5
1996	11.8	11.4	14.3	13.7	13.7	13.9	13.3	13.7	12.6	10.7	9.8	9
1997	11.9	10.3	13.9	13.9	13.8	14.1	13.8	13.8	13.3	13.3	12.6	9.8
1998	12.8	14.2	14.7	15.2	14.5	13.8	14.5	14.3	13.5	12.2	8.4	7.6
1999	9.8	10.2	13.5	14.3	13.7	13.2	13.4	13.5	x	x	8.1	8.5
2000	9	10.3	12.5	14.3	13.3	12.9	13.6	13.2	13.3	11.5	10.5	9.9
2001	10.2	11.1	13.7	13.8	14.1	13.3	13.9	14.5	12.6	11.8	9.8	11.1
2002	11.4	11.8	14.3	14.4	13.7	14.2	14.3	14.1	13.3	12.2	10.8	12.6
Min Ave.	10.07	11.36	13.35	13.81	13.43	12.86	13.45	13.41	12.6	11	9.67	9.39

Annex 3b

Element Monthely Minumum Temp. Lon Lat Alt.
Region Shoa
Station Mojo

Year	jan	Feb	Mar	Apr	May	jun	July	Aug	Sep	Oct	Nov	Dec
1983	x	x	x	x	x	15.7	12.5	14.3	13.9	11.8	9.7	9.8
1984	8	9.1	13.8	15.6	16.1	16	14.4	15.1	14	11.3	11.3	8.7
1985	8.5	11	13	13.5	13.5	12.7	12.6	12.7	12	9.7	9.3	7.9
1986	6.3	13.6	x	x	14.4	14.7	13.3	8.7	7.7	4.2	4.2	10.5
1987	11.4	11.3	15.3	13.9	14.5	15	15.1	14.7	14.6.	13.1	10.3	10.3
1988	11.9	14.5	14.8	15.3	15.4	14.2	15.3	14.7	14.2	11.5	7.3	9.9
1989	8.6	11.7	x	x	x	x	x	x	x	x	x	11.9
1990	10.4	14.1	13.1	13.3		12.9	13.9	14.1	13.2	10.4	9.6	7.5
1991	11	13.6	14.5	14.3	14.2	14	14.4	13.9	13.1	11.8	8.7	10.1
1992	11.5	12.7	14.7	14.3	13.6	13.1	13.5	13.9	11.9	10.4	10.6	11.3
1993	11	11.5	11.3	13.8	13.9	13.5	13.9	13.9	13.2	12.2	9.5	8.6
1994	x	x	13.7	14.5	15.1	13	15.2	14.7	14	11	9.7	9.3
1995	8.4	12.6	14.2	15.2	14.8	14	14.5	14.8	14	13.6	10.4	11.4
1996	x	11	13.3	13.3	13.5	13.2	15	14.4	13	10.2	10	8.1
1997	11.5	9.7	14.6	13.3	13.4	15.1	14.6	14.6	12.6	11.7	13.3	9
1998	11.5	11.1	12.6	13.8	13.1	13	14	15.4	14.5	13	8.4	6.8
1999		11.9	14.2	13.1	12.5	12.7	12.9	12.7	12.9	12.7	13.3	x
2000	9.4	10.1	13.3	14.7	14.7	13.6	14.4	13.9	13.4	11.7	9.5	7.7
2001	7.7	10.3	12.6	13.1	13.9	13.6	13.5	14	12.4	10.7	10.4	7
2002	9	8.7	12.3	12.6	12.4	12.9	14	14.5	.12.3	10.6	9.2	9.4
2003	9.7	10.7	10.8	12.7	13.4	12.4	x	x	x	x	x	x
Min Ave.	9.75	11.54	13.45	13.91	13.28	13.77	14.05	13.95	11.58	11.14	9.72	9.22

Annex 3c

Region Shoa
Station Nazerth
Monthly Min. Temprature

Year	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	x	x	x	x	x	x	x	x	15.1	12.1	11.6	9.3
1981	12.1	13.7	15.9	15.1	x	17.9	15.6	16	15.2	11.6	10.6	10
1982	13.9	14.7	15.1	16.2	16.2	17.9	16.1	15.5	15.4	11.9	12.9	12.6
1983	x	15.5	16.7	16.4	16.8	17.6	16.7	16.4	16.6	12.5	10.8	10.6
1984	x	x	x	x	x	x	x	x	x	x	x	x
1985	11.1		14.9	15.7	15.8	17.3	14.6	15	15	10.6	8.9	10.8
1986	11.5	14.7	13.3	13.5	14.8	16.1	15.7	14.2	15.8	11.2	10.7	16.2
1987	12	14.7	15.1	14.1	14.2	18	15.3	16.2	14.9	11.9	9.7	8.2
1988	11.5	15.1	12.7	12.6	14.8	16.2	11	14.4	15	10	7.6	8.2
1989	8.5	15.6	16.2	14.1	16.7	14.8	12	15.7	14.6	10.7	10	13.7
1990	12.7	15.1	14.5	14.4	16.5	17.8	15.7	15.6	15.1	14.1	12.5	11.6
1991	14.4		15.1	14.8	14.5	18	15.7	15.6	14.8	13	12.1	11.3
1992	13.6	15.4	16.1	16	15.9	17	15.4	15.5	14	11.8	12.2	13.9
1993	13.7	13.6	13.8	15.1	15.6	16.4	15.4	14.9	14.8	12.7	x	x
1994	x	x	x	x	15.8	16.8	15.7	15.5	13.7	11.2	12.5	11.1
1995	10.5	14.3	14.4	14.8	13.2	15.3	15.6	15.2	13.5	18	12.7	14.1
1996	14	14.1	15.4	14.6	14.7	16.6	15.8	15.7	14.6	12.1	13.2	12.1
1997	12.7	15.3	15.7	x	x	x	15.5	15.9	15.1	15.5	14.7	12.5
1998	14	16.2	16.1	16.3	17	18	16.4	16	15	13.5	12.9	10.6
1999	12.9	13.1	14.9	14.6	16.3	16.9	15.4	15.7	14.8	14.5	9.8	7.9
2000	9.2	13	15	16	16.7	17.8	15.9	16.1	15.1	13.6	12.5	11.5
2001	12.2	13.3	15	15.3	17.1	17.3	16.1	16.5	13.9	13.5	12.9	13
2002	14.4	13.9	15.9	16.3	18	18.3	17.3	16.4	15	13.6	13.3	15
Min Ave.	12.36	- 13.75	15.09	15.05	15.82	17.1	15.38	15.62	14.86	12.71	11.62	11.63

Annex 4a

Field Measured Parameters (season-1)

S/No	Area	Site Name	Water sources	Longitude	Latitude	Altitude (M)	TDS (mg/l)	EC (μS cm)	Salinity (mg/l)	Temperature (^{0}C)	pH	Eh (mv)
1	Nazret	Awash treatment plant	R	519795	937325	1558	122.4	188.3	122.4	24	5.61	0.1
2	,,	Awash at Melka Hida (up stream)	,,				133.4	205.2	133	23.6	6.84	0.1
3	,,	Awash at Melka Hida (downstream)	,,				138.8	223.7	134.5	24	7.03	
4	,,	Awash at Melka Oba (near Sodere)	,,				143.9	231.1	143.7	25.2	5.98	0.34
5	,,	Nazret seasonal stream near Frank Hotel	,,			1620	185.3	298.9	185	17.8	6.39	
6	,,	Nazret seasonal stream near Dembela Hotel (kebele 09)	,,	528279	943572	1628	65.3	107.9	65	18	6.69	
7	Mojo	Mojo River near Mojo tannery	,,	512611	952025	1756	182.5	294.4	180	16.2	6.5	
8	,,	Mojo river(Down stream)	,,	512265	946949	1793	122.8	204			6.9	
9	Debre Zeite	Shimbra Meda boreholes	BH				340	565	340	24.5	6.7	
10	,,	Shimbra Meda seasonal stream	R	500378	973310	1905	48.4	80.9	48	25.1	6.47	0.23

Annex 4b
Field Measured Parameters (season-2)

S/No	Area	Site Name	Water sources	Date of sampling	Longitude	Latitude	Altitude (M)	Time of Sampling	TDS (mg/l)	EC (μS cm)	Salinity (mg/l)	Temperature (^0C)	pH	Eh (MV)	Turbidity
1	Debre Zeite	Hora	L	29/02/2004	499575	968166	1872	4:15PM	1250	2120	1260	22.2	8.9	-153	
2	..	Kuruftu	..	..	499933	925769	1597	4:30PM	85.4	141	85.6	22.7	8.28	-83	33.75
3	..	Babogaya	..	..	499685	971531	1891	4:50PM	457	763	458	22.8	8.82	-118	13.94
4	..	Bushoftu	..	..	498671	966118	1875	5:30PM	897	1494	895	22.8	9.13	-138	7.1
5	Mojo	Mojo river upstream (01)	R	..	512611	952025	1756	9:15AM	323	534	325	20.4	8.33	-87	74
6	..	Mojo tannery effluent (02)	Effluent	..	512424	951081	1759	10:30AM	12400	20400	12490	22.2	8.72	-112	
7	..	After tannery effluent adjoing the river(03)	R	..	512353	950921	1746	10:50AM	497	829	496	19.4	8.46	-93	90
8	..	Mojo river downstream (0	..	..	512017	949890	1736	11:55AM	344	579	345	20.2	8.18	-77	37.18
9	..	Mojo river downstream (0	..	..	511654	949251	1734	12:20PM	383	636	384	20.8	7.99	-64	20.05
10	..	Mojo water supply wells	BH	..	512471	949128	1762	12:48PM	320	532	331	24.7	7.04	-27	0
11	..	Koka dam	L	..	501262	925767	1597	3:00PM	326	536	326	25.4	8.19	-80	>1000
12	Nazret	Nazret technical college well 003	BH	28/02/2004	530690	947272	1670	11:10AM	299	499	298	30.1	7.32	-29	0
13	..	Sodore	SP	..	542873	928836	1350	2:30PM	1527	2560	1490	58	6.88	0.04	0
14	..	Awash river at Melkasa bridge	R	..	537180	928545	1530	3:15PM	152.4	248	154.5	22.6	8.51	-98	
15	..	Awash Melkasa Agr. Research center	BH	..	535994	930146	1549	3:35PM	691	1153	691	29.2	7.37	-26	
16	..	Awash Melkasa Aluminum Sulfate Factory	..	..	536348	930881	1533	4:00PM	482	800	481	29.4	7.79	-53	
17	..	Awash river at treatment plant (raw water)	R	..	519795	937325	1558	6:15PM	135	237	242	19.3	8.37	-88	

Annex 5a

Water Chemical Analysis result (Collected in two seasons)

Debre Zeite Area

	Location	Shimbra Meda	Shimbra Meda	Bushoftu	Hora	Kuruftu	Babogaya	Ethiopian standard	WHO standard	
	Code	DZ1	DZ2	DZ3	DZ4	DZ5	DZ6			
	source	BH	R	L	L			Guidevalue	Guidevalue	Max. permissible limit
	Longitude		500378	498671	499575	499933	499685			
	Latitude		973310	966118	968166	925769	971531			
	Altitude		1905	1875	1872	1597	1891			
1	Variable									
2	appearance	clear	turbid	pale yello.	pale yello.	Cloudy	Cloudy			
3	Turbidity(NTU)	nil	5375	24	17	32	24	7	5	
4	Color (Pt.Co)	nil	101000	103	71	122	79	22	15	
5	Odour	odorless	odorless					non objectionable	non objectionable	
6	pH	7.1	7.26	9.21	8.7	6.6	8.06	6.5-8.5	6.5-8.5	
7	Temp.(°C)	22.2	19.4	19.6	19.6	19.5	19.1	non objectionable	non objectionable	
8	EC (us/cm)	526	74	1624	2268	206	854			
9	TDS (mg/l)	263	37	812	1134	103	427	1776	1000	
10	NH_3 (mg/l)	0.1098	25.01	0.6776	0.336	0.6776	1.1132	2		
11	Br_2 (mg/l)	0.04	nil	0.12	0.13	0.2	0.11			
12	Total Hardness as $CaCo_3$ (mg/l)	175	65	250	235	170	185	392	500	500
13	Total alkalinity as CaCo3 (mg/l)	484	85	900	1260	110	500			
14	Total acidity as CaCo3 (mg/l)	190	180	520	580	480	550			
15	Cl_2 (mg/l)	0.02	nil	0.02	0.01	0.08	0.01	5		
16	I_2 (mg/l)	0.12	nil							
17	NH_4 (mg/l)	0.116	26.02	0.722	0.3612	0.7224	1.1868			0.645
18	Na^+ (mg/l)			200	190	140	130	358	200	
19	K^+ (mg/l)			99	63.9	62	43.2			
20	Ca^{++} (mg/l)	10	14	11.6	15.2	38.4	15.2		75	200
21	Mg^{++} (mg/l)	36	7.2	53.04	47.28	17.76	53.04		50	150
22	Cu^{++} (mg/l)	0.06	0.25	0.08	0.03	0.08	0.08	2	1	
23	Fe^{++} (mg/l)	0.04		0.21	0.24	0.98	0.32	0.4	0.3	1
24	Mn^{++} (mg/l)	nil	nil	0.03	0.2	0.5	0.4	0.13	0.1	0.5
25	Cr^{6+} (mg/l)	nil	nil	0.05	0.04	0.04	0.06	0.1	0.05	
26	OH^- (mg/l)	nil	nil	nil	nil	nil	nil			
27	Cl^- (mg/l)	55	19	80	140	nil	16	533	250	600
28	No_3^- (mg/l)	10.56	nil	10.12	8.36	3.52	22	50	45	45
29	No_2^- (mg/l)		x					6	10	
30	F^- (mg/l)	1.7	2.4	0.64	0.93	0.5	1.17	3	1.5	1.6
31	HCO_3^- (mg/l)	590.48	103.7	1098	1537.2	134.2	610			
32	CO_3^{--} (mg/l)	nil	nil	nil	nil	nil	nil			
33	SO_4^{--} (mg/l)	1	362.5	2	2	4	3	483	400	400
34	PO_4^{3-} (mg/l)	0.07	0.65	3.4	3.9	2.3	5.7	5		
	Bacteriological Quality									
1	Coliform organisms (No. per 100ml)			92	68	TNTC	49	0/100ml	0/100ml	
2	Faecal Coliforms (E.Coli) No. per 100ml			43	22	TNTC	15	0/100ml	0/100ml	

Annex 5b

Water Chemical Analysis result (Collected in two seasons)

Mojo Area

	Location	Mojo river near gauging station	Mojo river downstream near Abu-diyab est.	Mojo river upstream (01)	Mojo tannery effluent(02)	Mojo river downstream (03)	Mojo river downstream (04)	Mojo river downstream (05)	Mojo water supply tap water	Ethiopian standard	WHO standard	
	Code	M1	M2	M3	M4	M5	M6	M7	M8			
	source	R	R	R	R	R	R	R	BH		Guidevalue	Max. permissible limit
	Longitude	512611	512265	512611	512424	512353	512017	511654				
	Latitude	952025	946949	952025	951081	950921	949890	949251				
	Altitude	1756	1793	1756	1759	1746	1736	1734				
1	Variable											
2	appearance	turbid	turbid	turbid	Black	turbid	clear	clear				
3	Turbidity(NTU)	10010	1140	95	3666	62	9	8		7	5	
4	Color (Pt.Co)	17300	2300	361	10750	225	47	28		22	15	
5	Odour	odourless	odourless	fishy&stale	Pungent smell	Bad smell	odourless	odourless		non objectionable	non objectionable	
6	pH	7.71	7.11	8.27	7.11	8.18	8.29	8.07		6.5-8.5	6.5-8.5	
7	Temp.(°C)	17.4	18.9	19	19.3	19	19.1	19.4		non objectionable	non objectionable	
8	EC (us/cm)	156	154	600	241040	880	620	700				
9	TDS (mg/l)	78	77	300	120520	440	310	350		1776	1000	
10	NH_3 (mg/l)	8.0215	1.0527	0.3751	305.525	4.114	3.3033	4.356		2		
11	Br_2 (mg/l)	3.76	0.13	0.28	1.44	0.06	0.14	0.08				
12	total Hardness as $CaCo_3$ (mg/l)	1460	352	132	260	175	170	185		392	500	500
13	total alkalinity as $CaCo_3$ (mg/l)	704	107	381	500	193	381	413				
14	total acidity as $CaCo_3$ (mg/l)	410	61	136	1140	80	120	80				
15	Cl_2 (mg/l)	1.64	0.04	0.14	0.72	0.03	0.07	0.04		5		
16	I_2 (mg/l)	6	0.81	0.42	2.16	0.09	0.21	0.12				
17	NH_4 (mg/l)	8.48175	1.1223	0.3999	235.725	4.386	3.5217	4.644				0.645
18	Na^+ (mg/l)			70	90	85	89.6	78.4		358	200	
19	K^+ (mg/l)	56	53	48	36	59	52	26				
20	Ca^{++} (mg/l)	436	126.24	50	57.6	280	53.6	61.3			75	200
21	Mg^{++} (mg/l)	88.8	8.736	1.68	27.84	12	8.64	7.68			50	150
22	Cu^{++} (mg/l)	4.93	nil	0.27	0.35	0.37	0.1	0.06		2	1	
23	Fe^{++} (mg/l)	0.5	1.06	0.41	3.3	0.39	0.11	0.03		0.4	0.3	1
24	Mn^{++} (mg/l)	8.7	nil	0.71	0.92	0.8	0.3	0.1		0.13	0.1	0.5
25	Cr^{6+} (mg/l)	nil	nil	0.09	0.08	0.09	0.07	0.05		0.1	0.05	
26	OH^- (mg/l)	..	nil	nil	nil	nil	nil	nil				
27	Cl^- (mg/l)	31	20	nil	137	36	10	20		533	250	600
28	No_3^- (mg/l)	nil	nil	1.32	539	11	8.36	9.24		50	45	45
29	No_2^- (mg/l)			0.0297	0.264	0.0363	0.0792	0.0297		6	10	
30	F^- (mg/l)	2.1	1	1.38	1.24	1.2	1.72	1.58		3	1.5	1.6
31	HCO_3^- (mg/l)	858.88	130.54	464.82	683.6	235.46	464.82	503.86				
32	CO_3^{2-} (mg/l)	nil	nil	nil	nil	nil	nil	nil				
33	SO_4^{2-} (mg/l)	9	nil	22	75	2.3	21	31		483	400	400
34	PO_4^{3-} (mg/l)	0.088	0.07	0.09	14.5	0.5	0.36	0.3		5		
	Bacteriological Quality											
1	Coliform organisms (No. per 100ml)			TNTC	TNTC				nil	0/100ml	0/100ml	
2	Faecal Coliforms (E.Coli) No. per 100ml			TNTC	TNTC				nil	0/100ml	0/100ml	

Annex 5c

Water Chemical Analysis result (Collected in tow season)

Nazret Area

	Location	Adama near technical college	Seasonal stream near Frank Hotel	Seasonal stream near Dembela Hotel	Awash river at treatment plant	Awash river at Melka Hida	Awash river at Melka Oba	Awash Melkasa Aluminum Factory	Awash river at Melkasa bridge	Koka Lake	Sodere spring	Ethiopian standard	WHO standard	
	Code	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10			
	source	Rain water	R	R	R	R	R	BH	R		sp		Guidevalue	Max. permissible limit
	Longitude			528279	519795			536348	537180	501262	542873			
	Latitude			943572	937325			930881	928545	925767	928836			
	Altitude			1628	1558			1533	1530	1597	1350			
1	Variable													
2	appearance	clear	Turbid	Turbid	Turbid	Turbid	Turbid	clear						
3	Turbidity(NTU)	8	370	4325	333	375	386	nil				7	5	
4	Color (Pt.Co)	11	2040	72500	4110	12450	2880	nil				22	15	
5	Odour	odourless	Bad smell	odourless	odourless	Bad smell	odourless					non objectionable	non objectionable	
6	pH	7.14	7.63	7.83	7.43	7.12	7.84	7.3				6.5-8.5	6.5-8.5	
7	Temp.(°C)	20.2	21.8	19.3	17	18.9	17.6	19.9				non objectionable	non objectionable	
8	EC (us/cm)	80	320	118	190	198	218	882						
9	TDS (mg/l)	40	160	59	95	90	109	441				1776	1000	
10	NH_3 (mg/l)	0.0244	8.54	9.196	2.4644	1.5488	2.684	0.0242				2		
11	Br_2 (mg/l)	nil	nil	nil	0.1	0.05	0.05	0.12						
12	total Hardness as $CaCo_3$ (mg/l)	1190	130	220	80	59.8	1400	265				392	500	500
13	total alkalinty as $CaCo_3$ (mg/l)	24	470	85	115	125	107	425						
14	total acidity as $CaCo_3$ (mg/l)	38	248	94	166	80	174	550						
15	Cl_2 (mg/l)	nil	nil	nil	0.04	0.03	0.01	0.08				5		
16	I_2 (mg/l)	0.04	nil	nil	0.09	0.13	0.05							
17	NH_4 (mg/l)	2.58	9.03	9.804	2.6058	1.6512	2.838	0.0258						0.645
18	Na^+ (mg/l)											358	200	
19	K^+ (mg/l)				42			11						
20	Ca^{++} (mg/l)	280	35.6	67.2	28.8	16.88	288	57.2					75	200
21	Mg^{++} (mg/l)	117.6	9.84	12.48	1.92	4.224	163.2	29.28					50	150
22	Cu^{++} (mg/l)	0.07	3.65	2.5	0.55	nil	0.12	0.05				2	1	
23	Fe^{++} (mg/l)	0.04	1.88		0.58	0.76	1.34	0.43				0.4	0.3	
24	Mn^{++} (mg/l)	0.05	0.05	10	1.1	nil	nil	0.2				0.13	0.1	
25	Cr^{6+} (mg/l)	0.01	nil	nil	nil	nil	0.02	0.00				0.1	0.05	
26	OH^- (mg/l)	nil	nil	nil	nil	nil	nil	nil						
27	Cl^- (mg/l)	22	38	19	23	14	89	nil				533	250	600
28	No_3^- (mg/l)	4.4	nil	nil	nil	nil	nil	22				50	45	45
29	No_2^- (mg/l)											6	10	
30	F^- (mg/l)	nil	0.65	2	1.8	2.2	3	1.5				3	1.5	1.6
31	HCO_3^- (mg/l)	29.28	573.4	103.7	140.3	152.5	130.54	518.5						
32	CO_3^{2-} (mg/l)	nil	nil	nil	nil	nil	nil	nil						
33	SO_4^{2-} (mg/l)	nil	nil	650	nil	2	30	66				483	400	400
34	PO_4^{3-} (mg/l)	0.01	19.7	7.9	0.08	0.05	0.3	7.3				5		
	Bacteriological Quality													
1	Coliform organisms (No. per 100ml)				52			nil	TNTC	82	5	0/100ml	0/100ml	
2	Faecal Coliforms (E.Coli) No. per 100ml				23			nil	TNTC	31	1	0/100ml	0/100ml	

Annex 6a

Chemical anlysis Result : Debre Zeite

unit in meq/l , conductivity in ns/cm and T in°C

s/no	Site Name	Date of sampling	Temperature	Longitude	Latitude	Altitude(m)	TDS	EC	pH	Hardness	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}	Sio_2	Hco_3^{-}	Co_3^{2-}	Cl^{-}	No_2^{-}	No_3^{-}	So_4^{2-}	NH4	Mn	F^{-}	Po4	Fe^{2+}
1	Babogya -Arm	04-Apr-98	24.8						9.09		85.8	29.7	1.8	44		277.14		30.44		0.86	3.19					
2	Babogya -Mid	"	21.1						8.17		87.3	31.6	6.9	47		239.64		21.77		62.04	24.74					
3	Babogya -Bott	"	21.6						7.73		88.8	30.9	8.3	48		306.37		22.07		6.22	2.38					
4	Babogya -Arm	21-Apr-98	25.8						9.09		81.3	31.6	3.6	47		283.77		24.1		1.37	3.12					
5	Babogya -Mid	"	21.4						7.69		84.3	30.4	6.8	49		302.12		20.28		1.02	1.92					
6	Babogya -Bott	"	21.2						7.59		88.8	30.9	8.8	50		317.54		20.31		1.03	2.03					
7	Babogya -Arm	18-May-98	26.9						8.95		82.8	28.9	3.9	45		278.79		25.41		1.5	3.25					
8	Babogya -Mid	"	21.3						8.26		81.3	29.4	6.3	47		286.76		20.91		2.68	2.59					
9	Babogya -Bott	"	20.7						7.7		88.8	30.9	8.1	50		314.65		20.64		2.88	1.9					
10	Babogya -Arm	16-Jun-98	25.1						8.87		84.3	28.7	4.2	46		288.49		22.24		2.54	2.91					
11	Babogya -Mid	"	21.6						7.92		85.8	30.2	6.1	48		302.67		20.97		0.98	2.44					
12	Babogya -Bott	"	21.6						8.17		85.8	29.2	8.3	47		300.82		20.73		2.21	2.11					
13	Babogya -Arm	17-Jul-98	24.8						9.11		81.3	30.4	4.5	46		282.82		22.02		3.5	2.99					
14	Babogya -Mid	"	21.2						7.73		78.4	30.9	7.5	49		285.54		21.27		1.52	2.1					
15	Babogya -Bott	"	21.6						7.55		81.3	31.4	8.3	51		297.05		20.41		2.56	3.92					
16	Babogya -Arm	27-Aug-98	24.2					714	8.91		88.8	28.2	4.5	43		297.92		21.4		2.24	2.52					
17	Babogya -Mid	"	20.1					798	7.6		77	30.9	6.5	49		277.72		20.65		5.81	2.69					
18	Babogya -Bott	"	20.3					782	7.91		78.4	30.2	6.4	48		286.68		18.53		1.85	2.2					
19	Babogya -Arm	04-Oct-98	26.8					614	8.96		74.2	29.2	4.9	43		263.18		19.68		3.04	2.72					
20	Babogya -Mid	"	21.7					807	8.02		77	32.1	6.4	50		280.94		22.04		3.3	2.48					
21	Babogya -Bott	"	23.4					910	7.04		74.2	30.4	20	48		264.61		22.62		16.79	1.87					
22	Babogya -Arm	12-Nov-98	22.5					817	8.83		82.8	28	5.1	43		268.75		28.73		2.75	3.48					
23	Babogya -Mid	"	22.7					892	8.14		84.3	28.9	6.1	47		292.25		21.59		3.04	2.56					
24	Babogya -Bott	"	20.8					951	7.35		84.3	29.7	8.3	48		298.49		20.39		3.29	1.87					
25	Babogya -Arm	24-Dec-98	22.4					844	8.63		97.5	31.4	5.5	47		315.5		31.28		1.89	1.59					
26	Babogya -Mid	"	21.7					884	7.84		88.8	29.7	6.6	47		305.58		22.79		1.22	2.48					
27	Babogya -Bott	"	21.4					965	7.42		104.9	30.2	8.8	49		388.99		2.93		0.21	0.13					
28	Babogya -Arm	12-Jan-99	23.1						8.77		102.2	28.4	5.8	45		339.43		19.59		3.32	2.28					
29	Babogya -Mid	"	21.1						8.41		100.7	28.2	5.8	45		333.52		9.55		20.61	8.14					
30	Babogya -Bott	"	20.6						7.25		110.9	32.4	8.5	52		378.77		21.11		1.72	1.99					
31	Hora-Arm	27-Aug-98	24					2290	8.5		433.9	46.1	3.4	69		589.24		345.24		42.04	281.18					
32	Hora -25m	"	22.4					2210	7.84		420.3	49	4.1	74		907.59		156.31		103.31	33.65					
33	Hora-int	13-Nov-98	23.5					2440	8.25		454.8	47.3	3.7	73				112.3		15.19	88.33					
34	Hora-Arm	14-Jan-99	24.3						8.33		403.6	48.2	4	74		990.06		140		10.51	6.11					
35	Arenguade,shor	13-Nov-98									8578.6	217.4	4.8	8				829		492	158					
36	west/north Cheleleka.	"	20.6					149	7.12		6.7	3.4	10.6	3		25.87		5.22		0.14	0					
37	East Chelel.s	"	19.7					147	7.95		3.1	2.9	23	4.8		28.93		3.42		1.36	0.91					
38	East Chelel.	24-Dec-98	18					246	7.45		4.6	3.4	30	7.7		47.69		0.39		1.72	0.39					
39	East Chelel.	13-Jan-99	20.7						7.53		5.6	3.9	35	9		57		0.44		1.28	0.17					
40	Kuruftu shore	"	21.4					191	7.8		4.5	3.9	24	5		37.44		2.95		0.15	0.1					
41	Kuruftu sw shore	25-Dec-98	26.7					232	8.4		5.1	4.4	24	5.6		35.35		3.16		5.12	0					
42	Kuruftu sw shore	16-Jan-99	22.2						8.25		5	4.5	25	5.8		43.48		0.42		2.35	0.67					
43	Mac. Factory	18/10/83		496376	967575	1935			7.4		25.4		56.1	41.8	59	439.2		11.3		0.5				0.3		
44	"	29588		496072	966751	1920					19	14	54	34	57	380		9						0.6		

	...continued.																									
s/no	Site Name	Date of sampling	Temperature	Longitude	Latitude	Altitude(m)	TDS	EC	pH	Hardness	Na^+	K^+	Ca^{2+}	Mg^{2+}	Sio_2	Hco_3^-	Co_3^{2-}	Cl^-	No_2^-	No_3^-	So_4^{2-}	NH4	Mn	F^-	Po4	Fe^{2+}
45	Defence Eng.	14/6/88							7.7		30.6	11.9	40.1	36.2		408.7		14		2						
46	Air ForceBW	17/8/87							8.6		44.2	9.6	51.3	20.4	82	316.8		14.2		7.1				0.8		
47	Air ForceBW	17/8/87							7.8		64.6	11.9	44.9	29.2	75	402.6		28.4		8.9				0.8		
48	Air ForceBW	22/8/88							7.8		47.6	12.4	73.7	15.6	71.5	390		21.3		11.2				1		
49	Air ForceBW	32569							7.2		44.2	11.2	64	30	84	366		35.5		5.9				0.97		
50	Air ForceBW	30/8/89							7.5		50	8.9	32.2	25.3	70.5	341.6		14.2		0.9				0.57		
51	SlaughteryBH	1974		495554	966073	1931	607		7.6		60	11	38.8	32.6	45	403		15.6						1.3		
52	Vetmary school	1974							7.4		67.5	9.5	42.6	32.5	63.7	442		15.6						0.75		
53	Blue Nile pl.Fa.	1996		495769	966401	1920			7.09		34	9	44	36	57	392		7		5				0.62		
54	Hora Tannery	1993		498650	970038	1915			7.4		57.8	5.6	43.3	26.3	67.5	380.6		12.8		6.7				0.68		
55	Almaz Doro	17-Jul-98	21.1	499309	970182	1897			7.04		24	6.8	24	33		140.3		5.99		5.68	33.68					
56	CIM-mission	,,	23.7						7.04		66	12.3	66	28		66.3		36.22		50.98	13.11					
57	Almaz Doro	,,		499309	970182	1897					24	7.3	24	31		166.71		2.81		0.17	0.13					
58	CIM-mission	04-Oct-98									58	13	58	31		217.73		3.5		13.66	2.26					
59	Hora Tannery	,,	23.1	498650	970038	1915		590	7.12		46	5.8	46	28		221.18		7.36		2	4.61					
60	Kalehiwot BW	,,	23.6	499666	970754	1914		687	7.44		36	11.1	36	34		237.68		14.77		5.1	2.59					
61	Almaz Doro	,,		499309	970182	1897					13.3	6.5	13.3	29		82.38		25.81		26.51	11.18					
62	Kalehiwot,south	,,	24.2	499934	969874	1880		585	7.4		34	10.7	34	26		171.77		4.21		7.99	4.04					
63	Almaz Doro	,,	24.7	499309	970182	1897		784	7.51		26	8.4	26	33		180.05		11.74		5.43	7.82					
64	Hora Tannery	25-Dec-99	24.4	498650	970038	1915		784	7.15		47	6.5	47	28		176.45		27.08		24.06	7.18					
65	Elfora	14-Jan-99	21.7						6.86		47	5.5	47	1.6		69.47		8.08		20.83	7.23					
66	Hora Tannery	13-Jan-99	23.9	498650	970038	1915			7.4		42	6	42	28		150.48		33.43		25.4	8.45					
67	Ada pasta&Maca	14-Jan-99	21.3	496072	967510	1920			6.97		42	10.9	42	28		144.72		4.8		4.99	4.97					
68	Management Inst.	,,		499956	968969	1905					36	12.1	36	28		186		8.47		9.77	8.66					
69	Blue Nile pl.Fa.	15-Jan-99	25.8	495769	966401	1920			7.45		34	9.1	34	43		155.99		8.71		11.95	4.66					
70	Almaz Doro	13-Jan-99	22.7	499309	970182	1897			7.5		26	7.5	26	29		163.66		11.7		3.84	7.4					
71	SlaughteryBH	15-Jan-99	25.6	495554	966073	1931			7.5		30	8.7	30	43		134.8		23.02		53.46	22.47					
72	Kalehiwot west	,,	22.7	499569	970304	1913			7.5		41	6.5	41	21		144.8		5.74		9.12	4.08					
73	Kalehiwot east	,,	21.4	499840	970165	1891			7.64		36	9.8	36	24		167.17		3.8		7.02	4.47					
74	Ato Gizaw HD		24.4						6.68		88	29.4	88	64		159.48		68.95		62.07	50.71					
	Unit: mg/l																									
75	Debre Zeite WSSA # 1	17/31/84		500602	974578	1910	323	390.3	8.4	208	34.9	6.9	51.3	19.3	72.7	292.8	24	15.6	nil	1.8	5.6	nil	nil	0.5	nil	0.08
76	Debre Zeite WSSA # 2	01/01/1985		500983	974004	1908	382	449	7.2	272	34	11.9	48	37	65	414.8	nil	11.3	0.03	1	nil	nil	nil	0.3	0.31	0.02
77	Debre Zeite well no2	,,					426	500	7.2	216	57.8	27	40	26	65	427	nil	11.3	0.12	6	nil	0.54	nil	0.5	0.21	0.02
78	Debre Zeite well no3	04/08/1979					376		7.6	191	30.5	8	51	16	68	305	nil	14.2	0.05	2.8	nil	nil	nil	0.4	0.1	nil
79	Debre Zeite well no4	05/04/1979					377		7.8	202	31	5.6	52.1	17.5	71	311	nil	15.9	0.03	2.65	nil	nil	nil	0.35	nil	nil
80	Debre Zeite WSSA # 3	11/02/1984		501094	974460	1910	353	418.1	8.1	216	30.6	7.9	57.7	17.5	73	341.6	nil	14.2	nil	3.5	nil	0.19	nil	3.58	0.02	0.11
81	Debre Zeite WSSA # 4	14/11/84		500516	974053	1903	343	444	7.9	216	34	8	58	18	78	342	nil	10.4	0.03	3	nil	0.07			nil	nil
82	Debre Zeite well no5	20/4/79					342		8	205	33.2	9.9	54.5	16.8	70	335.5	nil	10.6	0.03	2.6	nil	nil	nil	0.5	0.1	nil

Annex6b

Chemical anlysis Result ; Mojo area

unit in meq/l , conductivity in ns/cm and T in°C

s/no	Site Name	Date of sampling	Temperature	Longitude	Latitude	Altitude(m)	TDS	CC	pH	Hardness	Na^+	K^+	Ca^{2+}	Mg^{2+}	SiO_2	HCO_3^-	CO_3^{2-}	Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	F	Po4	Cr	Cu	NH4	Mn	Fe^{2+}
1	Mojo Ethio- Japan tex factory well no1	17/2/64		513858	950204	1780	657.1		7.7	180	54	15	48	15	126	372	nil	6			17	1.4						
2	Mojo Ethio- Japan tex factory well no2	15/2/65		513681	950101	1792	659.5		7.8	160	59	13	48	10	131	366	,,	6			22	1.1						
3	Mojo Ethio- Japan tex factory well no3	15/1/66		513737	949929	1774	753.5		7.8	220	68	15	56	19	131	472	,,	20			17	1.1						
4	Mojo Ethio- Japan tex factory well no4					,,	725.8		7.6	180	68	14	48	15	146	397	,,	10			24	0.8						
5	Mojo municipality#1	08/10/1959				,,	653.5		7.8	180	52	15	48	15	131	366		9			14	0.2						
6	Mojo municipality#2	20/7/79					750		7.6	160	76.5	14.9	49	11.4	84	409	nil	12.4	0.006	2.3	nil	0.89	0.23			0.16	0.2	0.02
7	Mojo municipality#3	12/06/1984		512502	948888	1787	542	543.4	8	225	81.6	13.2	38	18.2	35	396	nil	26.6	nil	0.9	,,	1.05	nil			nil	nil	0.4
8	Mojo municipality#4	07/03/1985		512020	948516	1769	488	504.7	8.6	160	88.4	11.6	45	11.7	71	353.8	36	14.2	0.26	0.27	nil	1.44	nil			0.05	nil	0.13
9	Mojo Tannery						1175.9		7.8	440	138	20	120	34	126	409	,,	262			64	1.26						
10	Mojo Aid Bank BH 1			512056	949397	1771	606.41			157	69.7	13.2	17	18	97	341.6	18	14.2		0.89								
11	Mojo Aid Bank BH 2			512064	948877	1778	660.59			183.5	76.5	14.9	47	11	50	409		12.4		2.5								
12	Mojo WSSA no 1	24/12/85		512090	949397	1771	390	403	8	212	69.7	14.7	49.7	21.4	90.5	414.8	nil	15.6	0.01	0.4	nil	1.4	0.003					
13	Mojo well no 3	21/12/84					493	501	7.8	164	61.2	13.9	49.7	9.7	92.5	360	,,	14.2	0.01	0.6	nil	1.32	0.02			0.1	nil	nil
14	Mojo Defence cons #1							589			57.8	10.3	65.7	21.4	90.5	414.8	,,	28.4	0.18	2.7	nil	1.5	nil			0.13	nil	
15	Mojo Defence cons #3	12/06/1984					542	543.4	8	225	81.6	13.2	38	18.2	35	396.5	nil	26.6	nil	0.89	nil	1.05	nil			nil	nil	0.4
16	Mojo Defence cons #4										81	14	40	17	37	366												
17	Mojo Defence cons #5	03/11/1985					450	603	7.6	206	57.8	13.9	64.1	18.5	33.8	396.4	nil	22.7	0.02	14.9	17.6	1.2	0.01			0.06	nil	0.05
18	Mojo Defence cons #6	12/06/1985					465		8	252	58.2	13.9	56.1	27.2	70	463.6	nil	13.9	0.03	2.5	nil	0.9	nil			0.03	nil	nil
19	Mojo Defence cons #7	16/12/85					446		7.9	220	74.8	17.2	52.1	21.9	76	427	nil	26.6	0.01	1.6	14	0.9	nil			nil	nil	0.15
20	Mojo Defence cons #8	30/11/85					506		8	224	71.4	13.9	69.3	18.5	73.7	463.6	nil	20.8	0.01	2.5	nil	1.1				0.04	,,	
21	Mojo Defence cons #9	11/07/1985					474		7.6	200	61.2	12.5	74.1	18.2	80	427	nil	35.5	0.03	9.2	nil	0.9	nil			nil	nil	
22	Mojo Defence cons.#10	24/1/86					510		8	200	72	17.2	54.5	15.6	95	414.8	,,	22.7	0.05	4.8	,,	1.19	nil			nil	nil	nil
23	Mojo Defence cons #11	15/3/86					527		8.5	240	106.6	16.8	62.5	20.4	90	366	97.6	21.3	0.07	nil	nil	2.1	nil			nil	nil	
24	Mojo Ethiopian food corp (Dairy dev't Agency)	08/04/1980					344		7.6	80	74.8	8.3	25.7	4	47	298.4	nil	28.4	0.01	6	nil	0.52	0.05			nil	nil	
25	Mojo Ethiopian food corp #1	27/9/83					486	510.6	7.9	200	91.8		57.7	13.6	83.5	439.2	nil	25.5	nil	7.3	,,	0.4	nil			0.06		
26	Mojo Ethiopian food corp #2	30/10/83					463	482.2	7.9	204	75		60.9	12.7	63.5	390.4	nil	26.9	nil	7.3	nil	0.75	0.02			0.05		
27	Ethio- Japan Textile well no 5	01/10/1998		513532	949805	1784	344	502	8.32	160					60			5	nil	nil	10	1.47	0.19	nil		,,	nil	nil
28	Mojo Poultry farm	05/11/1998		512205	949949	1793	284	510	7.67	166					58.9			5	0.016	0.09	0.3	1.45	0.3	0.113		0.09	0.1	0.02
29	Mojo Tannery						1176		7.8		138	20	120	34	126	409		262			64	0.2						
30	Mojo well no 1	06/04/1979					449		8.3	160	69.7	13.2	47	11	90	341.6	18	14.2	0.01	0.89	nil	0.82	nil			nil	nil	nil

Annex 6c

Chemical anlysis Result : Nazret

unit in mg/l , conductivity in ns/cm and T in°C

s/no	Site Name	Date of sampling	Temperature	Longitude	Latitude	Altitude(m)	TDS	EC	pH	Hardness	Na^+	K^+	Ca^{2+}	Mg^{2+}	Sio_2	Hco_3^-	Co_3^{2-}	Cl^-	No_2^-	No_3	So_4^{2-}	F	NH4	Po4	Cu	Cr	Mn	Fe^{2+}
1	Melka Hida well no 1	09/06/1990					458		7.2	180	54.4	18.5	64	5	75	341.6	nil	14.2	negil	1.8	18.3	2.5	nil	0.04			nil	
2	Melka Hida well no 2	09/06/1990					537		7.1	184	55	25.7	67.3	6.4	80	390.4	,,	28.4	0.02	36.5	12.3	3.4	,,	nil			,,	
3	Melka Hida well no 3	09/06/1990					854		7.3	172	204	21.1	54.5	8.8	110	622.2	,,	40.6	0.05	21.9	24	6.8	,,	,,			,,	
4	Melka Hida well no 4	14/8/90					435		7.2	200	85	26.4	64.1	9.7	85	414.8	,,	21.3	nil	15	23.9	4.85	,,	,,			,,	
5	Melka Hida well no 5	14/6/90					695		7.4	144	210.8	22.4	44.9	7.8	103	646.6	,,	35.5	0.02	15.9	25.4	6.5	,,	negil			,,	
6	Melka Hida well no 6	09/06/1990					758		7.2	124	190.4	21.8	40	5.8	120	501.2	,,	40.6	negil	31.9	13.4	3.85	,,	nil			,,	
7	Melka Hida well no 7	14/8/90					672		7.4	124	197.2	20.5	40	5.8	104.8	512.4	,,	42.5	nil	14.5	71.6	5.5	,,				,,	
8	Melka Hida well no 10	09/06/1990					733		7.6	164	234.6	22.4	32	5.8	92.4	634.4	nil	35.5	negil	41.5	21.8	5.4	nil	0.1			nil	
9	Melka Hida well no 11	14/8/90					592		7.3	224	108.8	13.2	67.3	13.6	94	488	,,	28.4	0.03	13	14.8	5	,,				,,	
10	Raising main at Melka Hida	09/05/1990					670		8.1	156	150.4	23.1	48.1	8.8	100	524.6	,,	35.5	negil	11.7	20	3.75	,,	0.05			negil	
11	Chem.corp BH at Melka Hida	09/06/1990					538		7	236	85	11.6	60.9	20.4	97	439.2	,,	14.2	0.05	16.3	25.9	2.6	,,	,,			,,	
12	Melka Hida well no 12	29/5/90					485		7.7	204	47.6	12.9	65.7	9.7	83.3	341.6	,,	28.4	0.02	3.6	nil	2.4	,,	0.01			,,	
13	Melka Hida well no 13	29/5/88					405		7.8	120	50.5	20.4	40.1	4.9	76.7	292.8	,,	25.5	0.01	2.1	,,	3.02		0.03			,,	
14	Melka Hida well no 14	07/12/1988					487		7.9	192	61.2	11.6	60.9	9.7	85.5	366	,,	19.5	0.01	0.5	,,	1.67	1.17	0.02			,,	
15	Melka Hida well no 15	29/5/88					698		7.6	280	114	16.8	80.2	19.5	98.3	610	,,	31.2	0.01	2.1	,,	1.7	0.25	0.21			,,	
16	Chem corp BH at Melkasa	06/09/1986		530348	930881	1533	543		7.5	252	75	12	51.3	30.2	95	451.4	nil	21.3	3	15.1	30	2	0.3	nil				
17	Etage Hotel well no 1						807.18		6.9	141	125	15	43.69	7.78	109.1	485.56		3.68			16.05	1.32						
18	Nazret well no 2	14/4/79					425		8.2	87	86.7	7.6	27.3	4.5	64	329.4	nil	10.6	0.02	0.1	nil	1.2	nil	0.1			nil	nil
19	Nazret well no 2	09/07/1991					582		7.3	72	156.2	15.2	20.8	4.9	100	439.2	nil		negil	4.4	12.6	5.5	0.6	nil			nil	0.08
20	Nazret rehabilitation Agency for disabled	03/04/1989					497		7.9	88	81.6	26.4	24	6.8	85	317.2	nil	14.2	nil	0.7	nil	2.5	0.3				nil	0.26
21	Awash Melkasa well no1	07/02/1995		535994	930146	1549	520		7	192	113.9	12.5	43.3	20.4	80	439.2	nil	42.5	0.03	0.5	25.1	2.25	0.75	0.12			nil	0.02
22	Nazret ministry of education	26/2/87					105		8.1	160	115.6	19.8	48.1	9.7	87	402.6	nil	31.2	0.1	30.3	24.5	1.45	0.1	0.1			nil	nil
23	Nazret Metal works	15/7/87					565		7.7	80	124	18	24	5	99	390	nil	26	trace	9	nil	4	0.3	nil			nil	0.06
24	Nazret Berta	21/11/93					420		7.5	80	108.8	11.2	20	4.9	71	329.4	nil	21.3	1.15	1.8	17.4	1.6	0.13	nil			0.2	0.1
25	Nazret well no2	09/07/1991					582		7.3	72	156.4	15.2	20.8	4.9	100	439.2	nil	28.4	negil	4.4	12.6	5.5	0.6	nil			nil	0.08
26	Nazret(NFTC well no 11	18/3/89					561		7.7	80	91.8	29.7	22.4	5.8	70	329.4	nil	28.4	0.7	0.9	nil	3	0.26	nil			nil	0.05
27	Awash River intake to Koka lake						84.2	168.1	8.73													1.05					0.08	
28	Awash river at Koka Dam	09/05/1990					206		7.3	80	28.9	5.6	27.3	2.9	23.5	158.6	nil	14.2	nil	nil	nil	1.17	nil	0.05			nil	
29	Awash River at Wonji Bridge	09/05/1990					278		8	80	40.8	6.6	27.3	2.9	30	183	nil	14.2	nil	negil	nil	1.92	nil	0.08			nil	
30	Nazret National metal works						609		7.7		124	18	24	5	99	390		26		9		4						
31	Nazret food corpration						727		7.5		95.2	6.6	44.9	9.7	131.3	414.8		14.2		10.3								
32	Nazret LI LPA						531.5		8.2		86.7	7.6	27.3	4.6	64	329.4		10.6		0.1		1.2						
33	Nazret Etage Hotel						807.18		6.9		125	15	43.7	7.8	109.1	485.6		3.68			16.05	1.32						
34	Nazret town (municipality BH-3)						652.95		7.75		87.5	10	48.5	15.22	11.12	455.84		6.82			5	1.52						
35	Nazret Yilma Dheresa BH-1			527845	942127	1615	714.95				120	1.5	47.28	8.32	35.79	470.31		5.68			37.28	1.32						