ENVIRONMENTAL IMPACT STUDY OF ARTISANAL MINING OF OPAL IN DELANTA WOREDA

By: Mohammed Shikur
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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

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Approval by Board of Examiner

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ABSTRACT

The study area is found in northern Ethiopia in Amhara region in south Wollo zone Delanta woreda. The area is covered by various kinds of volcanic rocks and the places of the study area include mining sites: Echage, Tache Amba, Minychil and Gengena. The main objective of the research is to assess the environmental and socio-economic impact of unorganized/informal opal mining on the local environment. Moreover, the research aims to generate baseline environmental data for the future comparison of environmental changes which will represent from the mining activities. To achieve the research objectives, samples of waste rocks, soil and water were collected from the mining places for heavy metal analysis by using flame AAS test method and water quality, pH and electrical conductivity (EC) were measured on the site. The survey as well as questionnaires and interviews were conducted. The data were treated with the help of statistical techniques of SPSS v15 and Excel. With the help of geographic information systems (GIS) technique, digital elevation model (DEM) and satellite image the land use /land cover maps of the woreda were indicated. Furthermore the soil loss of the study area was estimated using empirical model of USLE model. The following analytical results (ppm) are obtained from waste rock samples. copper(4-8), zinc( 99-140),cobalt(10-17),nickel(2-8),and lead(<1-10);surface waters(mg/l) all tested heavy metals(cobalt, nickel, copper, zinc , lead and iron) have a result of <0.1which is below the detection limit ;soil(mg/l) cobalt(11-20), nickel (11-18), copper (7-20), zinc (85-141) and lead (3-10 ). Zinc has the highest mean concentration in waste rock and soil samples. The values of the physico-chemical parameters of surface waters of the area are: temperature, 12.1-16.2 °C, electrical conductivity (EC) at 25°C, 68.4-74.0 µS/cm, and pH, 6.6-7.6. The surface water samples are neutral. The results with respect to heavy metals in water are within the maximum allowable concentration (MAC) of World Health Organization (WHO) and the 2001 Ethiopian Standards for drinking water. The socio economic study results reveal that 91.3 % of the respondents are aware of the problems of opal mining and its impact on the environment like soil erosion that the problem had increased in recent years. Above 48.9 % of the respondents reported that death and injury are the major problems due to collapse of rock in the mining sites. The overall output from the research showed that appropriate guideline is not in practice so as reduce the causalities. The estimated soil loss in the site area of Tsehay Mewocha and the surrounding kebeles was 1,320,000 tons per year from 22900 hectare. These results will definitely serve as a base line for any decision making on the future large sale planning for the mining activities in the area.

Key Words: Environmental Impact, Opal, Mining, Delanta,
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<tr>
<td>AAS</td>
<td>Atomic Absorption Spectrometry</td>
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<tr>
<td>AAU</td>
<td>Addis Ababa University</td>
</tr>
<tr>
<td>AFI</td>
<td>Acute Fever Infection</td>
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<tr>
<td>ASM</td>
<td>Artisanal and Small-Scale mining</td>
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<tr>
<td>CSA</td>
<td>Central Statistics Agency</td>
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<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
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<tr>
<td>EDS</td>
<td>Energy-Dispersive Spectroscopy</td>
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<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
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<tr>
<td>ENVI</td>
<td>Environment for Visualizing Image</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Authority</td>
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<td>FDRE</td>
<td>Federal Democratic Republic of Ethiopia</td>
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<td>ERDAS</td>
<td>Earth Resources Data Analysis System</td>
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<td>FAO</td>
<td>Food and Agricultural Organization of the United Nations</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>GSE</td>
<td>Geological Survey of Ethiopia</td>
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<tr>
<td>ILO</td>
<td>International origination of labour</td>
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<tr>
<td>LULC</td>
<td>Land Use Land Cover</td>
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<tr>
<td>MAC</td>
<td>Maximum Acceptable Concentration</td>
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<tr>
<td>m.a.s.l.</td>
<td>Meter above sea level</td>
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<tr>
<td>MoWR</td>
<td>Ministry Of Water Resources</td>
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<tr>
<td>NGO</td>
<td>Non Governmental Organizations</td>
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<tr>
<td>NMSA</td>
<td>National Meteorological Service Agency</td>
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<td>RUSLE</td>
<td>Revised Universal Soil Loss Equation</td>
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<tr>
<td>RS</td>
<td>Remote Sensing</td>
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<tr>
<td>SPSS</td>
<td>Software Package for Social Scientists</td>
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<tr>
<td>SRTM</td>
<td>Shuttle Radar Topographic Mission</td>
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<tr>
<td>UNCSO</td>
<td>United Nation Commission on Sustainable Environment</td>
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<tr>
<td>UNEP</td>
<td>United Nations Environment Program</td>
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<tr>
<td>USA</td>
<td>United States of America</td>
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<tr>
<td>USLE</td>
<td>Universal Soil lost Equation</td>
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<td>WHO</td>
<td>World Health Organization</td>
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1. INTRODUCTION

1.1 Background

The word 'opal' comes from the Greek word opallos, meaning "to see changes of colour", although the Romans are said to have based their name opalus on the Sanskrit word for precious stone, upala. Colour is caused by the regular array of silica spheres diffracting white light, and breaking it up into the colours of the spectrum. The diameter and spacing of the spheres controls the colour range. Generally, opal measures 5.5 to 6.5 on moh's hardness scale with diamonds measuring 9 to 10 and pearls 4 to 5 (http://www.costellos.com.au/poals/index2.html). Opal is hydrated amorphous silica (3 to 20 % water) containing aggregates of ordered or disordered microcrystallines of a-cristobalite (is a common product in volcanic rocks). Electron microscopic studies show that opal is made up of closed packed silica spheres (SiO$_2$.nH$_2$O) and interstitial silica (Seid Ali, 2006). Opal was formed many millions of years ago, when a combination of silica and water flowed into cracks and spaces in the ground. This then gradually hardened and solidified to become opal. Opals contain water, which makes them very sensitive to heat (http://www.costellos.com.au/poals/history.html).

Mining activities, by their nature, are one of the main sources of environmental contaminants, which are perceived as the 20th century problem of the world. The Ethiopian mines are not exception to this fact. Irrespective of its economic benefit, mining causes deforestation, loss of biodiversity, water pollution, soil pollution, sediment pollution, air pollution, land use conflicts, socio-economic impacts, and depletion of non-renewable resources, subsidence, aesthetic degradation and noise. These environmental impacts should be evaluated so as to take mitigation and prevention measures. The impacts of mining on the environment depend on the chemical composition of the ore, the depth of the deposit, local hydrologic conditions, climate, rock types, sizes of operation, the nature of the process used to extract the mineral or element from the ore, and topography (Botkin et al., 1998; UNEP, 2000; cited in, Seyoum Zenebe, 2006).

The opal found in Delanta Woreda is found to be a gem-grade opal with sparkling color. This precious stone will be a source of income to the people of the woreda and the country as well. However, the mining activity and trading of the opal must be managed in environmental friendly manner so as to ensure sustainable development in the woreda. Therefore the environmental
impact study of the sporadic mining activity in the woreda is essential and timely to mitigate current and future impacts on the social and natural environment.

1.2 Statement of the problem
In the case of Ethiopia the environmental problem associated with the traditional mining activities is more severe than in the modern mines which have legal entities. The traditional miners have not fulfilled legal requirements; there is no control of trade, mining plan, safety procedure, documentation, good sanitation condition, and proper medical services. All these problems can cause environmental and social problems. Digging, clearing shrubs, and trees contribute to the degradation of arable land. Dust produced by digging, can cause eye troubles, skin diseases, respiratory infections, and security problem, child labour, child prostitution are also problems associated with artisanal mining (EPA, 2003).

The newly discovered Ethiopian opal in Delanta is quickly becoming known for some of the most impressive jewelry grade in the opal world. In the last 3 years, the new Ethiopian opal has proven to be just as strong and in dependable as fine Australian opal (Rondeau et al, 2010). At present there is no proper mining in the study area. The mining method used in the study area is artisanal mining. One of the problems in the case of mining is the nature of mining which affect the environment and its impact on affecting of landscape, collapsing of cliff/gorges, increasing the steepness of the land, increasing soil erosion, conflict among the people and Diseases. There is lack of awareness about planning, controlling, managing and regulating the opal mining and mining business, due to this there is faulty mining and opal is easily cracked so there is limited or absence of economic return from the opal mining to the local community. The mining activity has also effect on the purchasing power of the local community. Child-Labour is employed in artisanal opal mining in the study area. There is a lack of appropriate equipment for the protection, such as boots, gloves, eye glasses, helmets, etc. Also, awareness on these issues is not developed and therefore, miners lack of basic knowledge for their own health and safety. The significant potential of fall of ground in such artisanal mine sites poses a serious threat to miner’s life (Karin, 2007). The heavy metals (lead, copper, cobalt, nickel, zinc and iron) were chosen for this study primarily for their effects on health. Generally these heavy metals tend to have very high enrichment factor and slow clearance rate (Jorgensen and Johnsen, 1981,cited by seyoum zenebe,2006 ). The accumulation of these heavy metals in sediments and water is a major health
concern because of the removal of such metals by plants and the resultant exposure of human and animal life to the elevated metals through the food chain. Nickel is an essential foodstuff for animals in small amounts. It can also be dangerous when the maximum tolerable amounts exceeded causing cancer (Lenntech, 2005). Copper, nickel and zinc are phototoxic with threshold values of 130, 70 and 130 ppm respectively in soils (Harrison, 1992). To address these problems, the environmental geochemistry of above-mentioned heavy metals in this mining area must be studied.

1.3 Research questions
The environmental impact and socio-economic study will be guided by the following research questions:
* What is the impact of opal mining on the landscape and soil?
* What kind of health problem will occur due to artisanal opal mining?
* What are the attitudes and perceptions of local communities towards the social, environmental and economic impacts of artisanal opal mining activities?
* What is the overall feeling of the communities up on artisanal opal mining?

1.4 Objectives of the study
The general and specific objectives of this research are the following.

1.4.1 General objective
The general objective of this research is to assess the impact of artisanal (informal) opal mining on the natural and social environment of the Delanta woreda.

1.4.2 Specific objectives
1. To assess the impact of opal mining on the water, soil and activities at Tsehay Mewcha and Gengena and the surrounding artisanal mining sites.
2. To assess the socio-economic issues of artisanal mining and their influence on resource management.
3. To assess the attitudes and perceptions of local communities towards farmer’s Co-operative opal mining.
4. To identify the major heavy metal pollutants in waste rocks, soils and water.
5. To indicate the current environmental land use / land cover map and estimate the amount of soil loss in study area, and
6. To generate baseline environmental data for the woreda.

1.5 Significance of the Study
From the research it will be possible to understand the awareness of the people about the change of landscape, steepness of land and protection of ecological environment. It will also be possible to evaluate the actual positive and negative socio-economic impacts of opal mining on youth, women and farmers at community levels in the study area and current status and challenges of opal mining in the study area. Furthermore from the data collected by GPS, DEM, and satellite image formulating the land use and land cover of the study area.

Since this study is the first of its kind in the area, it will be a “baseline” for future studies and comparison of actual changes in the future time. Eventually, the output of this study will provide information to policy makers, higher learning institution, Agricultural and mining research institutions, NGOs, Development agents, Agricultural and rural development offices and the local communities. Upon this, first hand information will be made available for further studies for sustainable opal mining resource management so that the people can live in harmony with opal resources utilization.

1.6 Scope of the Study
Since it is impossible to cover the whole aspect of the environmental impact study of the study area with the available time and resources; it is advisable to limit the study size and the scope of the problem to a manageable size. Hence, the study was focused on two major sites in Tsehay Mewocha and Gengena area. It was also focus to identify the impact of opal mining in the areas.

It will also try to investigate the farmers’ perceptions on the mining activity and its importance.

1.7 Limitation of the Study
The lower detection limits of the analytical method (AAS) employed at the GSE laboratory is one of the limitations of the research. For example the WHO (2004) maximum acceptable concentration (MAC) for nickel, lead, chromium and cadmium for drinking water are 0.02, 0.01, 0.05 and 0.003 mg/l respectively while the lower detection limit of the instrument used is 0.1 mg/l for water samples. Therefore, it was not possible to evaluate the quality of the waters of the study area for drinking purposes with respect to the samples which gave results below detection
limits. It was not possible to incorporate some environmentally important elements such as mercury and arsenic in the study, since currently the laboratory is not carrying out analyses for these elements.

Sending samples abroad is recently impossible due to the limited amount of fund available for thesis work by the University. The total fecal coil form and fecal coli form was not included as the study area is far from sites where laboratory serves is available. And a sample taken from a site would be tested in laboratory within six hours.

Because of the constraints of time and budget, the researcher did not take that enough number of samples (soil, waste rock and water) for making comparisons between soil, waste rock and water parameters.
2. LITERATURE REVIEW

2.1 Definitions

Mining, in its broadest sense, is the process of obtaining useful minerals from the earth’s crust. The process includes excavations in underground mines and surface excavations in open-pit or open cut (strip) mines. Mining normally means an operation that involves the physical removal of rock and soil. (Encarta, 2009).

According to Mining Proclamation No.52/1993, Artisanal mining means unless otherwise specified by the Minister, non–mechanized mining operations of gold, platinum, precious minerals, metals, salt, clay, and other similar minerals, an essentially manual nature carried out by Ethiopian individuals or groups of such persons.

Artisanal is generally taken to refer to non-organized small-scale mining. It involves only individuals or families and is mainly manual. A recent definition of artisanal mining describes it as ‘the most primitive type of informal, small-scale mining, characterized by individuals or groups of individuals exploiting deposits with the simplest equipment’ (Barry, 1996).

According to Mining Operations Council of Ministers Regulations No. 182/1994, Small scale mining operations means any mining operation of which the annual run-of-mine is does not exceed 100,000m$^3$ for placer operation; 75,000 tones for primary deposit mining regarding gold, platinum and silver and other precious and semiprecious minerals.

Gemstones are minerals that are treasured for their beauty and durability. A large number of minerals have been used as gems. Their value generally depends on four elements: the beauty of the stone itself; its rarity; its hardness (the resistance of the smooth surface of a mineral to scratching) and toughness; and the skill with which it has been cut and polished. Stones such as diamonds, rubies, and emeralds represent one of the greatest concentrations of money value. During times of war or economic disturbance many people convert their wealth into precious stones, which are transportable and more easily sold (Encarta, 2009). For this research paper, the terms “gem” and “gemstone” are taken to be interchangeable.

Opal is mineral consisting of hydrated silica (SiO$_2$·nH$_2$O) in the gel state. Opal has a hardness of between 5.5 and 6.5 and a specific gravity of 1.9 to 2.3. The fracture of the mineral is conchoidal, and its luster varies from glassy to dull. It also shows variations in color from white to black and in transparency from transparent to opaque (Encarta, 2009).
Numerous types of opal are known, but usually only the transparent or translucent varieties are used as gems. Gem opals include white opals; black opals; fire opals, which are yellow to red in color; girasol, which has a bluish-white opalescence; harlequin opals, which show uniform patches of contrasting colors; and lechosa opals, which have a deep green play of color within the stone. Other types of opal include moss opal, which has inclusions of foreign material resembling moss; hydrophane, a porous, white opal that is cloudy when dry and transparent when the pores contain water; and hyalite, a glasslike, transparent variety. (Encarta, 2009)

2.2 History of opal and its mining
Throughout history, opal has been regarded as a stone of good fortune. In ancient times, precious opal was included among the noble gems; it was believed that the gem possessed magical properties. The Romans established opal as a precious gemstone, obtaining their supplies from traders in the Middle East. They believed the opal was a combination of the beauty of all precious stones. They ranked opal second only to emeralds, and carried opal as a good luck magic because it was believed that like the rainbow, opal brought its owner good fortune. The history of Australian opals started as late as 1849 at a cattle station called Tarrawilla, near Angaston some 80km outside Adelaide however, Australian opal did not appear on the world market until the 1890s. Precious opal occurs in both sedimentary and volcanic rocks. Nearly 100 per cent of Australia's opal production is derived from sedimentary opal deposits. Prior to the emergence of Australian opal on the market, opal was sourced in Hungary and South America. Australia is the world's greatest producer of precious opal. Over 90 per cent of the world's commercial opal comes from the deserted remote area. All of the significant opal deposits in Australia are located within the Great Artesian Basin or close to it. The places where opal has been mined over the past 100 years are located here. The most important deposits are found in New South Wales, South Australia and Queensland. The type, colour, size and soundness of precious opal are factors that determine the price paid for the gemstone. The price is based on the quality of the opal and expressed per carat.

In nearly 2008, a new source of play-of-color opal was discovered by farmers near WegelTena in northern Ethiopia (Fritsch and Rondeau, 2009; Mazzero et al., 2009; Rondeau et al., 2009 cited by Rondeau et al., 2010). The opals are mostly white, which is uncommon for play-of-color volcanic opal, and may resemble material from Australia or Brazil (plate 2.1).

The WegelTena opals differ from those found at Mezezo, in Ethiopia’s Shewa Province, or in neighboring Somalia, which are mostly orange to red to brown (Koivula et al., 1994; Gauthier et al., 2004 cited by Rondeau et al., 2010).

Plate 2.1 Volcanic play-of-color opals mined at Wegel Tena. Source: Rondeau et al., 2010

The opals of Ethiopia are mostly white, translucent to opaque, and show vivid play-of-color. The round orange cabochon in the center weighs 41.70 carat (Rondeau et al., 2010).

In fiscal year 2007-08 (the latest year for which data was available), the manufacturing sector accounted for 4% of the gross domestic product, mining and quarrying (0.4%). Between 300,000 and 500,000 Ethiopians were estimated to be employed in artisanal mining activities (OECDE, 2009, cited by Thomas, 2011).
2.3 Rules and regulation on mining in Ethiopia

Between 1974 and 1991 private investment was not allowed in the mineral sector rather government institutions were given the right to explore and develop the mineral wealth of the country (MoME, 2009). The Mining Proclamation No.52/1993, Mining operation and regulations No.182/1994, Mining Income Tax proclamations No.53/1993, Transaction of precious minerals proclamation No.651/2009 and Environmental impact assessment proclamation No.299/2002, environmental pollution control proclamation No.300/2002, Environmental protection organs establishment proclamation No.295/2002 were issued to attract private investment and preserve the environment. The proclamations were consecutively amended so as to be competitive internationally and in favour of the investors. The major issues addressed in the legislations are:-

- Require adequate health and safety of employees and environmental protection and environmental impact study depending on type and nature of a project;
- Invite private investment in all kinds of mineral operations;
- Provides a prospecting license for one year;
- Provides an exploration license for an initial period of three years and renewed twice for one year each;
- Provides a mining license for 20 years and renewed for 10 years unlimitedly;
- Guarantee the licensee’s right to sell all the minerals locally or abroad giving marketing freedom;
- Provides for exemptions from custom duties and taxes on equipment, machinery, vehicles and spare parts;
- Gives securities of tenure;
- Gives clear provisions on fiscal and other issues;
- Considering taxation on repatriation of profits and capitals, a licensee shall pay a 2-5% royalty at production site, and a 35% income tax on taxable income. Taxable income is computed by subtracting from gross income for any accounting year all allowable revenue expenditure, a four years straight line depreciation, reinvestment deduction and permitted loses;
• The mining proclamation guarantees the opening and operation of a foreign currency account in banks in Ethiopia, retention of portion of foreign currency earning and remittances of profits, dividends, principal and interest on a foreign loan out of Ethiopia.
• The limitation of grams of personal use example 30 gram for precious stones and 100 gram for semi precious stones.
• Types of licenses and certification of competence.
• Validity period of licenses and certification of competence.
• Obligation of holder of certificate of competence and obligation of licenses.
• Prohibition and penalty.

2.4 Environmental impacts of artisanal and small scale mining (ASM)
The existing literature on the impacts of ASM of gems can be divided into two fairly distinct parts. The first, are those that are technical-scientific in nature and describe the chemical and biological character of the impacts caused by ASM and processing operations (Grosser et al. 1994; Malm et al. 1995; Meech et al. 1998 cited by Macfarlane, 2003). The second, are those that are concerned with the socio-political and economic conditions, impacts of ASM and processing activities, and the identification of policy measures to manage these (Barry, 1996).
According to Macfarlane (2003), In relation to environmental impacts of ASM and gemstone ASM in particular, the situation in each country varies according to the type of gemstones being exploited, the social and natural environment of the area, and cultural and organisational aspects of the mining operation itself. The main determining factors, however, will be the stage and the nature of the method of mining and processing. These factors are the following.

**Exploration**
Exploration and development techniques are generally primitive, labour intensive and essentially non-technical, using local traditions, methodologies and practices that have not changed significantly for generations. Instead prospecting and exploration activities usually include pitting and in some cases trenching, to assess the geological setting for possible pockets containing gemstones. These excavations are often made indiscriminately and in the absence of mechanization, are rarely more than five meters deep. In many countries, finding good workable
gem deposits may become increasingly difficult, due to over-working and lack of proper exploration strategies at local, regional and national levels (Macfarlane 2003).

**Underground extraction**

In general, underground gemstone mining and processing includes breaking the rock using low-energy explosives, followed by material sorting by hand after cobbled (rock fragmented). Underground mining takes the form of pits, often excavated by illegal miners either on virgin gemstone field or fields already developed. Excavated materials may be processed on-site, or extraction is being undertaken illegally removed to a more discrete location where the valuable gemstones can be recovered. As many of the pits are dug in relatively fine-grained soils and silts, the extraction of the gems from the matrix involves considerable washing. However once the gems are washed out of the soil, not only is a lot of fine grained material washed into rivers and streams, but much of the material which should used for back filling the pit is lost. As a result many of the large pits are left unfilled, partially collapsed and/or flooded. There are environmental impacts from different types of operations. Pits and other mining excavations are often left in a dangerous and visually unattractive state due to the lack of economic or other imperative to reclaim and rehabilitate workings. Siltation of streams occurs as a result of erosion from waste dump areas. A failure to carry out even basic remediation such as back filling pits or draining flooded workings is recognised as poor practice with significant negative environmental impacts. The raising of the beds of river channels by enhanced sedimentation reduces their capacity to carry flood water and silting up of minor drainage and irrigation channels reduces their effectiveness (Macfarlane 2003).

**2.5 The social impacts of mining and their potential causes**

**2.5.1 Social health**

**Accidents and Injury**

ASM excavations can be deep and hard to identify. They have been known to be the cause of many, even fatal, injuries through internal collapse or fall. Other ASM accidents and injuries result from over exertion, inadequate workspace, inadequate and obsolete equipment, rock fall, subsidence(sinking of land level due to human activity), poor training, and poor pit ventilation (heat, humidity, lack of oxygen). In gem ASM the ventilation issue can be compounded by high
concentrations of methane and hydrogen sulphide present in the bottom of some deeper pits due to the high organic content of the gem bearing sediments. These injuries are symptomatic of ASM’s unregulated or unenforceable nature and fatality and injury rates are difficult to determine due to the secret nature of much ASM (ILO 1999b).

**Physical Exhaustion**
ASM workers are rarely given fixed working hours and are often contracted as share workers. As a result, they do not work specific hours as a daily waged earner. They work at a stretch from morning till evening. At times they have to work through the night in order to complete certain work. Apart from having to work continuously, they do not enjoy leave facilities. Once a mine is excavated, work often has to be continued nonstop. Frequently, a worker absent due to illness or any other reason has to send a replacement on his behalf to be employed on a daily paid basis (Macfarlane, 1999a).

**Eye and Respiratory Infections**
The generation of excessive atmospheric particulates or dust from activities such as soil stripping and dumping, blasting, open pit drilling and all act as particulate generators. Atmospheric dust caused by mining activities like these raise the incidence of respiratory infections such as tuberculosis and silicosis in ASM miners and communities (ILO, 1999b).

**Digestion and Gastric Disorders**
Gastric disorders are particularly pronounced where ASM miners have temporarily converged in camps around new or remote deposits with poor sanitary conditions and no public health facilities. The release of mine oxides following extensive surface ASM can generate acid rain (Franklin, 1998; MMSD, 2002).

**Malaria, cholera and Bilharzia**
Alterations by ASM to the hydrological environment in tropical regions can significantly increase the risk of malaria. The excavations associated with ASM mining create stagnant waters that are in direct proximity to mine workers and the community and are breeding grounds for malaria carrying mosquitoes. This has resulted in the reappearance of malaria in areas considered
disease free and where the local population has little or no immunity to illness. This has a major impact on local health resources (MMSD, 2002; Henney, 1999).

**Reduced wellbeing**

Land is usually destroyed ground cover of place through ASM in the form of waste dumps and excavations, and stripped of its vegetation. Unless these effects are mitigated through back filling, re-vegetation and landscaping, the aesthetic appeal of an area can be dramatically reduced with an extent of psychological effect on the surrounding community (Wilson, 1982).

**2.5.2 Socio-cultural**

*Increased levels of Social Malaise (feeling of discontent)*

Some, particularly migratory, ASM gem projects are characterized by increased crime and violence, drug and alcohol abuse, stress, community instability, drunkenness and suicide. A marked rise in crime, and particularly violent crime, is specifically linked to informal migrant ASM’s due to their lack of regulation, transitory and non-cohesive nature, and defense of land (Amnesty International. 1993; Avotri, 1997; Seyditz et al.,1999).

*Conflict*

In isolated areas ASM can cause tensions and divisions between migrant workers and the indigenous community (Goreux, 2001; McKee and Bell, 1986, Neil et al., 1992).

*Urbanization and Dissolution of Existing Norms*

In remote rural areas, the arrival in large number of migrant ASM workers, can lead to the dissolution of existing traditional cultures and admire of urban cultures among indigenous community members, resulting in rapid rural-urban migration with its attendant social impacts (Renner, 1997; Macfarlane, 1999a).

**2.5.3 Socio- Economic impact**

*Increased National Revenue*

Formal and regulated ASM can provide a small source of national revenue through fixed taxation. Mine developments can also potentially benefit the local economy through the payment of local taxes and government royalties if they are fed back through localised mineral reinvestment funds (Harrison *et al.*, 2003; Waelde, 1992).
Material and Consumption Gains
Given the risky nature of many, especially illegal, ASM activities, gem miners can be comparatively well payed for service or can supplement income from alternate employment. This can extend the range and quantity of items they can purchase and consume. However, research found that male ASM workers often spent disposable income on gambling, prostitution and alcohol. This is shown to be less likely when female partners or community members are also in ASM and can exert cultural or financial control (O’Faircheallaigh, 1991; UNDP, 1999).

Enhanced Social Development
Some formal and regulated gem ASMs have made small financial or ‘in kind’ contributions to local communities by facilitating and supporting the development of community infrastructure, housing, training, and health (Harrison, et al., 2003).

2.5.4 Socio-Livelihood

Loss of Sustainable Livelihoods
Local people attracted by real or imagined ASM opportunities can abandon less profitable but more sustainable livelihoods. When the rush is over and mining activities have subsided, local people may conclude that they have sacrificed their traditional livelihoods for few lasting benefits (MMSD, 2002; Labonne, 1997).

Direct Employment
Where ASM has taken place over an extended period of time in the same location, the livelihood contribution of such employment tends to be limited to supplementing existing incomes. However, in new and remote areas it can provide temporary or full-time work and is often the only real source of income and only means of survival. Overall, because ASM involves low start-up costs it represents an important and accessible source of employment at national level in several countries and a very important level of rural employment in many countries of the world (Redwood, 1997; Labonne, 1997; Labonne and Gilman, 1999).

Indirect and Secondary Employment
The direct employment potential of ASM decreases with more exhausted or inaccessible deposits and higher mechanisation, but its indirect employment potential, through increased demand for
local goods and services remains high. In addition, workers in ASM often make much more than in alternative activities in the area recent surveys in Indonesia and the Philippines suggest that these can be as much as 200% - 500% higher. These higher incomes can lead to higher savings and investments (which ASM are typically made locally) and therefore employment in other activities (Labonne, 1997; Labonne and Gilman, 1999).

2.6 Water quality

Water quality standards are regulations that set specific limitations on the quality of water that may be applied to specific use (Fetter, 2001). International and national guidelines for water are employed by this study for comparing the analyses results of metals in waters of the study area. The WHO guidelines for drinking water quality set MAC for water quality parameters and repeatedly updated (1998, 2002, 2004 2006, 2008,). The primary aim of the guideline is the protection of public health. These guidelines have been set for potentially hazardous water constituents and provide a basis for assessing drinking water quality (WHO, 1998). Some values, for example turbidity, pH, hardness and iron, are set just desirable. The quality of water defined by this guidelines is suitable for human consumption and for all usual domestic purposes, including personal hygiene. The Ethiopian Standards established in 2001 for drinking water has set maximum values for parameters and metals that have health effects (QSAE, 2001). The turbidity of water affects aquatic plants and animals at the lower part of the food chain (Down and Stocks, 1978). The sources of the pollution could be geogenic and anthropogenic. Progressive accumulations of trace elements at each successive level of the food chain ultimately pose health risk to humans which are found at the top of the food chain (Solomon Tale, 2000).

2.7 Soil Erosion

Soil erosion is the removal of soil from a landscape by erosive agents such as water and wind. Water erosion involves the detachment, transport and deposition of soil particles by the erosive forces (Renard et al., 1997).

The Universal Soil Loss Equation (USLE) and its revised version, Revised Universal Soil Loss Equation (RUSLE), are two of the empirical models that have been most widely used and generally accepted by the natural resources community because they are relatively easy to use (Saavedra, 2005, cited by Kiflu Gudeta, 2010). In this study RUSLE was chosen over other
methods because of its ease of implementation, reliance on easily accessible data and its relatively accurate results.

2.7.1 RUSLE Model

2.7.2 Erosion factors in the universal soil loss equation (USLE)

The RUSLE is an empirically based model that has the ability to predict the long term average annual rate of soil erosion on a field slope as a result of rainfall pattern, soil type, topography, crop system and management practices (Renard et al., 1997). It retains the factors of the USLE by including improved means of computing soil erosion factors. The RUSLE model in GIS environment can predict erosion potential on a cell-by-cell basis, which is effective when attempting to identify the spatial pattern of soil loss present within a large watershed area (Shi et al., 2003). GIS can then be used to isolate and query these locations to identify the role of individual variables in contributing to the observed erosion potential value (Saavedra, 2005). RUSLE computes average annual erosion as (Renard et al., 1997):

\[ A = R \times K \times LS \times C \times P \]

Where: \( A \) = computed average annual soil loss in tons/hectare/year; \( R \) = rainfall-runoff erosivity factor; \( K \) = soil erodibility factor; \( L \) = slope length factor; \( S \) = slope steepness factor; \( C \) = cover management factor and \( P \) = conservation practice factor.

The process of soil erosion is determined and influenced by a combination of different factors (Wischmeier and Smith 1978) developed a soil loss equation (USLE) containing six main factors. The equation is one of the best-known and most comprehensive models in terms of data, for predicting soil erosion. The USLE is a long-term model that is it predicts long-term mean values for erosion.

2.7.3 USLE rule in Ethiopia

The USLE was specifically developed for conditions in the USA. The results of measurements on test plots as well as different correlations between individual factors in the equation were designed for natural conditions in the temperate zone. Use of USLE in other areas requires adaptation to local condition. Thus, Hurni (1985) simplified the USLE by adapting the factors to conditions in Ethiopia (Appendix 8).
2.8 Heavy metals
Heavy metals are metallic elements, with high molecular weights (with a density greater than 5 gm/cm$^3$) generally toxic to plant and animal life even in low concentrations (Pierce et al., 1997). To understand the occurrences, distribution and transportation of heavy metals in the drainage water and sediments of the area environmental geochemistry is important. Environmental geochemistry is a branch of geochemistry that explores the complex interactions among the rock, water, soil, air and life systems that determine chemical characteristics of the surface environment (Singh et al., 2003).

2.9 Geology of study sites
The entire region around Wegel Tena consists of a thick (>3,000 m) volcano-sedimentary sequence of alternating layers of basalt and rhyolitic ignimbrite. The layers of basalt or ignimbrite are a few meters to hundreds of meters thick. (Ignimbrite is a volcanic rock of andesitic-to-rhyolitic composition that forms sedimentary-like layers after the volcanic plume collapses and falls to the ground. The particles that form this rock are a heterogeneous mixture of volcanic glass, crystals, ash, and xenoliths.) (Rondeau, 2010). This volcanic sequence was emplaced with the opening of the East African continental rift during the Oligocene epoch (Cenozoic age), about 30 million years ago (Ayalew and Yirgu, 2003; Ayalew and Gibson, 2009 cited by Rondeau, 2010). Over the entire volcanic series, only one very thin seam (<1 m thick), hosted by ignimbrite, is mineralized with opal (see plate 3.1b). Common opal and play-of-color opal most often cement grains of volcanic debris or sometimes fill in fractures or cavities in the rock. As a result, the rough gem material often has an irregular shape. Microscopic examination of our samples revealed that, for the most part, the host rock consists of mixed altered material, including clays, common opal, and some minor iron oxy-hydroxides. Some large crystals of alkali feldspar were unaltered, while others were transformed into clays. By comparison, the ignimbrite sampled only a few meters above the opal-bearing layer was unaltered and contained abundant quartz crystals. The opals are found in a specific layer of a thick volcanic sequence of alternating basalt and ignimbrite of Oligocene age (Rondeau, 2010).
2.10 Characteristics of Wegel Tena/Tsehy Mewocha Opal

Table 2.1 shows the standard gemological properties of Wegel Tena opal observed from 33 samples tested.

<table>
<thead>
<tr>
<th>Characteristics of opal and Optical Phenomena</th>
<th>Properties</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Appearance and Optical Phenomena</td>
<td>White, brown, fire, and colorless</td>
<td></td>
</tr>
<tr>
<td>The behavior of hydrophane</td>
<td>opaque-to-translucent</td>
<td>became more transparent when immersed in water for a few minutes</td>
</tr>
<tr>
<td>Specific Gravity (SG)</td>
<td>ranged from 1.74 to 1.89</td>
<td>After immersion in water for less than one hour, some samples weighed as much as 10.2% more, resulting in higher SG values of 1.90 to 2.00</td>
</tr>
<tr>
<td>Refractive Index</td>
<td>1.42 to 1.44</td>
<td></td>
</tr>
<tr>
<td>Stability and Toughness</td>
<td>Very stable, no change in appearance</td>
<td>a fall from 1.5 m onto a concrete floor with no visible damage, even under the microscope</td>
</tr>
</tbody>
</table>

Source: Rondeau et al., 2010

2.11 Chemical composition of Wegel Tena opal

The chemical composition of several samples were measured by energy-dispersive spectroscopy (EDS) both major and minor elements. Values are expressed in atomic percent. O is calculated for a sum of 100%. (Rondeau et al., 2010). These compositions are typical for opal (Gaillou et al., 2008a, cited by Rondeau et al., 2010).

<table>
<thead>
<tr>
<th>Color</th>
<th>Si</th>
<th>Al</th>
<th>Ca</th>
<th>K</th>
<th>Na</th>
<th>Fe</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorless</td>
<td>31.3-31.7</td>
<td>1.4-1.5</td>
<td>0.5-0.6</td>
<td>0.2</td>
<td>Nd</td>
<td>Nd</td>
<td>66.1-66.1</td>
</tr>
<tr>
<td>Brown</td>
<td>32.5-32.7</td>
<td>0.6</td>
<td>0.05-01</td>
<td>0.2-0.3</td>
<td>nd-0.1</td>
<td>Nd</td>
<td>66.2-66.4</td>
</tr>
<tr>
<td>White</td>
<td>31.1</td>
<td>1.7</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
<td>Nd</td>
<td>65.82</td>
</tr>
<tr>
<td>Yellow</td>
<td>31.9</td>
<td>1.9</td>
<td>0.4</td>
<td>0.3</td>
<td>nd</td>
<td>0.3</td>
<td>65.9</td>
</tr>
<tr>
<td>White</td>
<td>30.9</td>
<td>1.2</td>
<td>0.3</td>
<td>0.2</td>
<td>0.4</td>
<td>Nd</td>
<td>66.2</td>
</tr>
<tr>
<td>Colorless</td>
<td>31.6</td>
<td>1.5</td>
<td>0.3</td>
<td>0.5</td>
<td>nd</td>
<td>Nd</td>
<td>66.1</td>
</tr>
</tbody>
</table>

nd= not detected  Source: Rondeau et al., 2010.
3. THE STUDY AREA

3.1 General description of the study area

3.1.1 Location

The study area, Delanta Woreda, is located in Amhara National Regional sate in South Wollo Zone and its town is Wogel Tena. The area is located about 510 km to the north of Addis Ababa and 110km away from Dessie, the zonal town (400 km asphalt and the remaining all-weather gravel road) (fig 3.1). It is bounded by 500000-550000m E and 1260000- 1310000m N. The elevation of the area is 2100 – 3800 meter above sea level. The Woreda is located east and south of Wadila Woreda, North of Dawont and Worehimeno Woredas, West of Gubalafto and Ambassel Woredas. The study area are Tach Amba (Mehal Ways/Tabot Maderia/Woyis Mariam), Echega, Minyichil and Gengena.

Figure 3.1: Location of the study area
3.1.2 Climate

The rainfall and temperature data were collected from the Ethiopian Meteorological Service Agency (NMSA) from Kombolcha Station (1999 - 2008) (Appendices 1, 2 and 3) were used to describe the climate of the study area. The sites are located in the highland area of the Woreda which is found the northern part of the woreda.

Table 3.1 Climate of the Woreda

<table>
<thead>
<tr>
<th>Climate</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highland (degama)</td>
<td>26.4</td>
</tr>
<tr>
<td>Mid plateaus (woyin adegga)</td>
<td>41.3</td>
</tr>
<tr>
<td>Low land (kola)</td>
<td>28.5</td>
</tr>
<tr>
<td>Chilly (worchama)</td>
<td>3.8</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Delanta Woreda information bureau, 2010

3.1.2.1 Rainfall

The rainfall data between 1999 and 2008 shown in Figure 3.2 is based on data from the NMSA from Kombolcha Station. The annual rainfall varies from 614.80 - 968.7 mm and the average annual rainfall is 803.14mm. The area receives a bimodal rainfall where the small rains are between March to April while the main rains are from July to September.

Figure 3.2 Average rainfall of Delanta woreda (1999-2008), Source: NMSA, 2010
3.1.2.2 Temperature

The average annual temperature of Delanta Woreda area is 5.9 – 19.11 °C. Records obtained show that the maxima temperatures are between 21.2 °C - 28.0 °C from January to June and minima of 1.6 °C - 7.1 °C from October to December.

Figure 3.3: Average temperature of Detanta woreda (1999-2008), Source: NMSA, 2010

3.1.3 Topography

Delanta’s topography can be categorized as highland. The altitude of the woreda ranges from 2100 - 3800 meter above seas level (m.a.s.l.). And most of the study sites are found at an elevation about 3100 m.a.s.l.

Table 3.2 Topography of the Delanta Woreda

<table>
<thead>
<tr>
<th>Type of relief</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rugged terrain (wota geba)</td>
<td>36.5</td>
</tr>
<tr>
<td>Craggy (gedelama)</td>
<td>30.5</td>
</tr>
<tr>
<td>Plain (medama)</td>
<td>30</td>
</tr>
<tr>
<td>Mountainous (terarama)</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Delanta Wereda information bureau, 2010
The mining sites have the craggy/cliff type of relief of the study area. Hence it is very difficult to reach the sites because there are not even clear roads. From these sites the mining holes (50 - 80 cm height and 1 – 1.5 m width) have a horizontal distance into a cliff from 2 – 34 m and the area covers along the cliff from 30 - 270 m length. Especially the Minychil site having one hole 34 m distance horizontally in to cliff and 270 m along a cliff (Plate 3.1). According to Rodeau et al., (2010) the cliff of Minychil above a canyon is located approximately 350 m below the top of the plateau. The cliffs consist of alternating layers of basalt and rhyolitic ignimbrite.

Plates 3.1 The mining sites of the study area a) Top left: Echagen site b) top right: Minychil site c) bottom left: Tachi Amba site d) bottom right: Gengena site
3.1.4 Soils of Delanta Woreda

Soil is a complex mixture of weathered mineral materials from rocks, partially decomposed organic molecules, and a host of living organisms (Cunningham and Saigo, 1997). The soil types of the Delanta Woreda are categorized in three classes according to FAO class1 (1997) these are Cambisols, Leptosols and Vertisols. Cambisols are combine soils with at least an incipient subsurface soil formation. Transformation of parent material is evident from structure formation and mostly brownish discoloration, increasing clay percentage, and/or carbonate removal (IUSS, 2007). Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions (IUSS, 2007). Vertisols which are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years (IUSS, 2007). The definitions of the formative elements for the second-level units of the World Reference Base for Soil Resources (WRB) are the following. a) Eutric: having a base saturation (by 1 M NH₄OAc) of 50 percent or more in the major part between 20 and 100 cm from the soil surface or between 20 cm and continuous rock or a cemented or indurated layer, or in a layer, 5 cm or more thick, directly above continuous rock, if the continuous rock starts within 25 cm of the soil surface and b) Lithic : having continuous rock starting within 10 cm of the soil surface (in Leptosols only) (IUSS, 2007). From these classes the soil units are Eutric Cambisols (CMe), Eutric Leptosols (LPe), Lithic Leptosols (LPq), Eutric Vertisols (VRe). The opal mining sites area are covered by the soil units of Eutric Leptosols (LPe) and Lithic Leptosols (LPq).

Table 3.3 Type of Soil Coverage in Delanta Woreda

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Area(Km²)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPe</td>
<td>200.2</td>
<td>19</td>
</tr>
<tr>
<td>LPq</td>
<td>627.4</td>
<td>59</td>
</tr>
<tr>
<td>CMe</td>
<td>64.0</td>
<td>6</td>
</tr>
<tr>
<td>VRe</td>
<td>165.4</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>1057.0</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: FAO (1997)
3.1.5 Land use and natural vegetation

3.1.5.1 Land use/Land cover mapping

Land cover is defined as the physical materials on the earth’s surface of a given parcel (portion) of land (for example grass, vegetation, bare soil, rock, sand and water) and land use can consists of varied land covers (examples a mosaic of biophysical materials found on the land surface) (Treitz and Rogan, 2003). Land use is an abstract concept, consisting a mix of social, cultural, economic and policy factors, which have little physical importance with respect to reflectance properties, and hence has the limited relationship to remote sensing. Remote sensing data record the spectral properties of surface materials, and hence are more closely related to land cover (Treitz and Rogan, 2003).

3.1.5.2 Natural vegetation

The spatial distribution of natural vegetation depends on many factors. Among these factors, climate, drainage pattern, and soil types are the most ones. In Ethiopia, temperature and rainfall, which largely are altitude dependent, determine the type and density of vegetation (Tewolde
Birhan Gebre Egziabehere, 1991 cited by Anteneh Getachew, 2009). The commonly observed remained tree species in the area are *Acacia* species (*Cordia Africana*) and *Eucalyptus* species. These tree species are observed throughout the woreda mostly scattered in the cultivated landscape. Because of long history of agriculture and high population in the area, vegetation cover is very low. Consequently, erosion hazards on the steep slope areas are enormous. Gullies are observed towards the northern part of the woreda (the miming sites area), where soils are totally removed beyond recovery. This is believed to have been aggravated due to the easily detachable nature of the soil.

3.1.6 Demographic features

According to CSA (2010), the total population of the woreda is 135,246, out of which 67,581 (50.24%) are male and 67,946 (49.76%) are females. Economically active population of the woreda (15-55 years of age) is 102,176 people; out of which, 55,668 (54.48%) are male and 46,508 (45.51%) are female. The region is densely populated due to increasing number of human population pressure. As a result food deficiencies and meaningful resource degradation are continuously occurring furthermore aggravating land degradation, soil erosion, and shortage of water supply are common problems. In general loss of forest resources, land degradation from agriculture and loss of habitat and biodiversity are the result of high population density in the region. The marketing of fire wood and forest products example eucalyptus trees, very small number of cottage industry example weavers, carpenters, potters, blacksmiths, charcoal makers and tanners, supply the indigenous people with very small amount of extra cash incomes. Some of the local people are engaged as daily labourers in opal mining (TIGDW, 2009).

3.1.7 Agriculture

In the study area agriculture is the dominant economic activity, which includes crop farming and livestock production. Cropping patterns in the area follow rainfall. Summer is the main rain season. Both crops and livestock production have employed traditional tools and techniques. Obviously, this way of farming affects productivity (TIGDW, 2009).
3.1.7.1 Crop production
Major growing crops are barely, wheat, beans, teff, and sorghum. Most of the product is used for consumption and only some is used for sale. The cultivation method is still traditional and animals are the main source of labour (TIGDW, 2009).

3.1.7.2 Livestock production
The most important livestock breeds of the region include cattle, sheep, goats, equine (horses, mules and donkeys), chickens, and honey bees. The livestock resource of the woreda is mainly indigenous. Livestock are bred for the sources of power for ploughing, transportation, milk and meat production, hided and skins production, fuel manure production and prestige (TIGDW, 2009).

3.1.7.3 Farming system
A subsistent mixed agriculture, involving cropping and livestock rearing, forms the basis of the economy of the region. Shortage of arable land is increasingly forcing farmers to cultivate steep slopes and shallow soils, which in turn are aggravating, soil erosion (TIGDW, 2009).
4. MATERIALS AND METHODS

4.1 Reconnaissance survey

Preliminary field survey has been conducted just before the actual sampling survey. And observation was also made on the geology, distribution of mining activities, and topographic features of the mining site.

4.2 Data collection

Data Collection focused on the waste rock, soil, water, mining and environmental situation of the area. Topographic map at 1:50,000 scale was used to illustrating the location map of the study area. Photographs of some sampling sites and areas affected by opal mining activities were taken. Information was documented about each activity of opal mining. The samples were collected beginning from November 2010 to January 2011. The description includes geographic locations, altitude, topography, vegetation, soil and human activities around the sites. The letters R, S, W were pre-fixed to the sample location sites for waste rock, surface water, and soil samples respectively. In conjunction with sampling, close field observations were made on the types of physical land degradation (supported by plates.)

4.2.1 Sampling

4.2.1.1 Waste rock sampling

Four samples of waste rocks were collected (rock of Minychil (Rm), rock of Echagan (Re), rock of Tachi Amba (Rt), rock of Gengena (Rg)) for heavy metal analysis from opal mining sites. The samples (about 500 gram each) were freshly deposited as remains in the mining sites. The samples were taken in composite form in which for single station an average of five subparts were taken in a radius of approximately 5-10 meters for each site. The waste rocks were collected from each mining site and kept in plastic bags. The samples were then air dried in the field.

4.2.1.2 Soil sampling

Four soil samples were collected (soil of Minychil (Rm), soil of Echagan (Re), soil of Tachi Amba (Rt), soil of Gengena (Rg)) from the mining sites and analysed for heavy metal (Pb, Zn, Cu, Ni and Co). At each sampling site about 500g of soil was taken from B-horizon (from
average depth ranging from 40-70 cm) by digging with crowbar then the samples were put into plastic bags. Soil sampling was conducted for the purpose of checking the presence or absences of natural sources of pollution of heavy metals in the soils of the study area.

4.2.1.3 Water sampling

The water samples from the surface were taken from (upper stream of Digut river at site of Echagan (Weu1), down stream of Digut river at site of Echagan (Wed2), upper stream of Digut river at site of Minychil and Tachi Amba (Wmu1), down stream of Digut river at site of Minychil and Tachi Amba (Wmu1) ) and it kept in zero head space one-liter polyethylene bottles with caps. The plastic bottles were rinsed repeatedly with distilled water first and then with the water to be sampled. The latter is done to prevent the mixing of rinse water with the final sample. After sampling, the bottles were tightly covered with caps and sealed with tape to minimize oxygen contamination and the escape of dissolved gases. The presence of air may chemically or biologically alter the sample (Fiefield and Haines, 1996).

The water samples collected for heavy metal analysis were first filtered at mining site by putting filter paper (Round filter type) on funnels followed by the use of a 0.45 µm pore-size filter mounted on a syringe from which water is injected past the filter into a sample bottle. The filtering was done to leave out any suspended solids that can possibly dissolve and change concentrations of the dissolved metals. One filter was used only once per sample so as to minimize the contamination of the sample. Preservation after filtration was carried out using concentrated nitric acid (concentrated HNO₃ - with a technical grade of 61% w/w) per one-litre sample. Acidification of the samples is performed to keep metal ions from precipitating and to minimize adsorption of dissolved species on to sample container walls. The combination of a low pH (<2) and nitrate ions by acidification keeps most metal ions in solution (Keith, 1990).

The water samples were stored in cool and dark place during the fieldwork and transported to the laboratory in Addis Ababa for subsequent analyses. The samples are kept in cool place so as to minimize chances of chemical reactions, which can result in precipitation of dissolved elements. Some parameters of water samples such as pH, electrical conductivity (EC) and temperature were measured at each sampling site during sampling because of their unstable nature. A conductivity meter (Wagtech internation N377 tM207/03IM, USA sensor) was used to measure
the pH and EC of the water samples. Indicator paper was also used to measure pH to check the performance of the pH-meter. The pH was measured before the water was filtered and acidified.

4.3 Socio-economic survey
To identify the major environmental impact in the study area, socioeconomic data were obtained from the administrator, sampled households and sampled miners through a structured questionnaire (Appendix 11). A total of 92 persons were sampled for the questioner. Based on the research questions observation, survey, and interviews were made. The informal survey was used to gather information on the management and state of the community. The outcomes from the informal survey were used as a basis for the preparation of questionnaires for the formal survey. The formal survey, using semi-structured questionnaire, were conducted on 10, 21 and 61 respondents which were selected from administrators, community and miners of the study area respectively. The questionnaire was prepared in the local language (Amharic) and so was the interview. Local experts from the District Office of Agriculture and Rural Development was hired and trained to administer the interview. An interview was held with different sections of the society such as elder people, youth, farmers, administrators from different economic status.

4.4 Estimation of soil loss using RUSLE
The RUSLE model developed by Renard et al., (1997) was used in this study for estimation of soil loss. Digital Elevation Model (DEM) from the SRTM data has been used to obtain slope. Land-use/land-cover map has been produced from satellite land sat image of 2006 data using Maximum likelihood classification. Input parameters for RUSLE model derived through GIS analysis and digital image processing. GIS analysis included: a) generation of R, K, LS, C layers b) integration of layers c) generation output of soil loss and d) reclassification of derived datasets, and weighted overlay analysis. The GIS analyses were performed using ArcGIS9.3. Digital image processing included a) preprocessing of satellite image data b) masking the image with the Administration boundary c) enhancement and visual interpretation d) fraction image production. For digital image processing ERDAS Imagine 9.1 was used. All derived maps were projected into WGS1984 Zone 37N and held in grids of 30-m cell size.
4.5 Data analyses

4.5.1 Sample data analyses
The chemical analyses of waste rocks, soil and surface water samples were carried out in the laboratory of the Geological Survey of Ethiopia (GSE) for heavy metals (lead, copper, zinc, nickel, cobalt and iron). The sample preparation for waste rocks and soil samples involves drying in an oven, crushing, grinding, sieving, and digestion with perchloric acid (HClO$_4$) and hydrochloric acid (HCl). Atomic Absorption Spectrophotometer (AAS) was used to analyses heavy metals. The instrument will be calibrated with standard solutions. The analytical detection limit of AAS is 0.1 ppm for heavy metals (for water samples) and 1ppm for heavy metals (for waste rock and soil samples). There are three commonly used approaches for the substitution of concentrations that are below detection limits: assuming all non-detectable points as zero, half the detection limit and the detection limit itself (Travis and Land, 1990, cited by Seyoum Zenebe, 2006).

4.5.2 Socio economic data analysis.
Qualitative data from the formal and informal socio-economic survey was interpreted, analyzed and synthesized by using Microsoft Excel, SPSS v15 in which frequencies, tables, histograms and pie charts were used to summarize the results.

4.5.3 The USLE factors determination
The RUSLE was applied in GIS based on the flow chart as shown in figure 4.1
Figure 4.1 Flow chart showing analysis of soil loss based on GIS application.
1. The Erosivity (R) factor

The erosivity factor R that was adopted by Hurni (1985) for the Ethiopian conditions based on the available mean annual rainfall $Pr$ was used in this study. It is given by a regression equation:

$$ R = -8.12 + 0.562 \times Pr $$

Where, $Pr$ is the mean annual rainfall in mm.

The mean annual rainfall data of 10 years (1999-2008) (Appendix 3-6) recorded by the NMSA at Wegel Tena, Woldia, Mersa, and Wurgessa stations were 803.14 mm, 949.9 mm, 942.5 mm, 1109.8 mm respectively. The R factor value for the Tsehy Mewocha and its boundary kebels were determined by using spatial analyst extension in ArcGIS 9.3.

2. K-factor

In this study soil erodibility or the k-factor was estimated based on the characteristics of the soil color. Hurni (1985) and Hellden (1987) developed USLE for Ethiopian condition by adapting different sources and proposed the K values of the soil based on their color. After assigning values for each soil types the soil map was reclassified with a grid map of 30 m-cell size using adopted K values (Kaltenrieder, 2007).

3. Slope length and Slope steepness (LS)

The slope length and slope steepness can be used in a single index, which expresses the ratio of soil loss as defined by (Wischmeier and Smith 1978).

$$ LS = \left( \frac{X}{22.1} \right)^m (0.065 + 0.045 S + 0.0065 S^2) $$

Where $X$ = slope length (m) and $S$ = slope gradient (%)

The values of $X$ and $S$ were derived from DEM. To calculate the $X$ value, Flow Accumulation was derived from the DEM after conducting FILL and Flow Direction processes in ArcGIS 9.

$$ X = (\text{Flow accumulation} \times \text{Cell value}) $$

By substituting $X$ value, LS equation will be:

$$ LS = (\text{Flow accumulation} \times \text{Cell value} /22.1)^m (0.065 + 0.045 s + 0.0065 s^2) $$

Moreover slope (%) also directly derived from the DEM using the same software. The value of $m$ varies from 0.2 – 0.5 depending of the slope as shown in appendix 9 (Wischmeier and Smith, 1978).
4. Crop Management factor (C-value)

The crop management factor represents the ratio of soil loss under a given crop to that of the base soil (Morgan, 1994). The land use map (figure 5.6) was used for analyzing the C-value. After changing the coverage to grid, a corresponding C-value was assigned to each land use classes using re class method in ArcINFO 9 (as given by Wischmeier and Smith 1978).

5. Erosion Management Practice Factor (P-value)

The erosion management practice, P value, is also one factor that governs the soil erosion rate. The P-value ranges from 0-1 depending on the soil management activities employed in the specific plot of land. These management activities are highly depends on the slope of the area. Wischmeier and Smith (1978) calculated the P-value by delineating the land in to two major land uses, agricultural land and other land. The agricultural land is sub-divided in to six classes based on the slope percent to assign different P-value. In this study, the researcher employed this same technique to assign the P-value of the basin.
5. RESULTS AND DISCUSSION

In this section of the paper the results obtained from research survey question analysis, field observations, laboratory analyses of waste rock, soil and surface water samples, in situ measurements of water quality parameters, current LULC and soil erosion condition of the mining site kebeles are presented.

5.1 Environmental impacts

5.1.1 socio-economic impacts

5.1.1.1 Health

Mining affects people’s health directly when people work in dangerous conditions. The nature of mining is to exploit every last piece of earth and every available worker, sacrificing the health. And there is death due to collapse of cliff on mining site.

![Cause of Causalities due to opal mining in study site, field survey, 2011](image)

The main cause of death near the mining sites is collapse of rock which has killed 44 persons in three years time (2008-2010). This is because the miners do not leave blocks of rock that serve as pillars. Flood and disease are the least causes of death which has killed 2 persons each. Mining damages health in many ways: Heavy lifting and working with the body in awkward positions can lead to injuries to the arms, legs, and back. Long hours of working underground with little light can harm vision. Working in very hot conditions without drinking enough water
can cause heat stress. Signs of heat stress include: dizziness, weakness, rapid heartbeat, extreme thirst, and fainting.

Table 5.1 Common diseases in the study area

<table>
<thead>
<tr>
<th>Type of disease</th>
<th>Age</th>
<th>Sex</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤15</td>
<td>16-30</td>
<td>31-45</td>
<td>&gt;45</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>0</td>
<td>11</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>2</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>AFI</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Typhoid</td>
<td>15</td>
<td>7</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Injured persons</td>
<td>4</td>
<td>29</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>58</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

Source: Tsehy Mewocha clinic center, field survey, 2011

The data collected from the Tsehy Mewocha clinic indicated that typhoid is the main disease affecting the mining site (29.66%) followed by pneumonia (12.71%) and injury is the most severe problem in the mining site (45.76%). This is because the miners work for long hours in the holes of underground mining sites. The will lead to suffocation of air. Furthermore miners remove their wastes (faces) near the mining sites. There may be bacteria that cause of pneumonia and typhoid. The number of injured persons by far exceeds the number of persons caught pneumonia and AFI. Injury is a big problem of the mining sites. It is because the miners do not use safety tools while mining. Mining conditions are very different depending on the location, type, and size of the mining operation.

Table 5.2 Number of persons infected by HIV/AIDS

<table>
<thead>
<tr>
<th>Age</th>
<th>≤14</th>
<th>&gt;14</th>
<th>Total</th>
<th>M&gt;14</th>
<th>F&gt;14</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008(June-Aug)</td>
<td>2</td>
<td>53</td>
<td>55</td>
<td>20</td>
<td>33</td>
<td>53</td>
</tr>
<tr>
<td>2008/9</td>
<td>9</td>
<td>121</td>
<td>130</td>
<td>42</td>
<td>79</td>
<td>121</td>
</tr>
<tr>
<td>2009/10</td>
<td>28</td>
<td>144</td>
<td>172</td>
<td>48</td>
<td>96</td>
<td>144</td>
</tr>
<tr>
<td>2010(Sep-Oct)</td>
<td>11</td>
<td>58</td>
<td>69</td>
<td>18</td>
<td>40</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>376</td>
<td>426</td>
<td>128</td>
<td>248</td>
<td>376</td>
</tr>
</tbody>
</table>

Source: Wegel Tena health center field survey, 2011

According to the result obtained from Wegel Tena health center women and men who are more than 14 years old are highly infected with HIV/AIDS. The figure has reached to 376 persons.
This may be related to fast growth of mining towns, with little planning or care. And as the people interviewed many people migrate looking for jobs in the mines, women who need income become sex workers, and this combination can lead to the rapid transmission of HIV/AIDS and other sexual diseases (Table 5.2). Furthermore; they have indicated that the sudden wealth and sudden poverty that mining brings is often accompanied by increased violence against women and children, abuse of workers by mine owners, and fights for control over resources.

5.1.1.2 Economy

The illicit dealing (mining and trading) in gemstones (diamonds and emeralds mainly) is a fast growing activity in African countries which produce these minerals. This is not unexpected, as these gemstones have huge unit values and low volume, as well as low transport costs (Vaxi, 2003). ASM mining productions of gemstones are traded illegally, causing significant direct and potential economic losses to affected countries (Kambani and Stephens, 1995).

Figure 5.2 Main beneficiaries of opal mining, field survey, 2011

Opal mining activities can benefit different sections of the society. In this regard, a field survey is conducted which group of the society are the main beneficiaries. Accordingly 38% and 27% of the respondents indicated that brokers and local people are more beneficiaries respectively.
The result shows that the woreda did not get benefit from opal mining operation as tax revenue. And also the miners themselves do not directly benefit by selling the opal because if they leave the mining site other person/miner may take their mining hole.

From the criminal code of the FDRE articles 346 and 347 under illicit traffic in precious minerals: whoever violates provisions or regulation of forbidden or unlawful traffic in precious minerals such as gold, platinum, uranium or any other similar, as well as in precious stones is punished under article 356. It says “--- is punishable with rigorous imprisonment not exceeding ten years and fine not exceeding fifty thousand Birr, without prejudice to the confiscation of the subject matter of the crime”. And article 521 under acts contrary to environmental impact assessment: whoever, without obtaining authorization from the competent authority, implements a project on which an EIA is required by law, or makes false statement concerning such assessment, is punishable with simple imprisonment not exceeding one year. Table 5.3 shows the number of people sentenced by court of Delanta woreda due to illegal trafficking of opal mine

Table 5.3 Decision of the Delanta Woreda court on illegal opal traders

<table>
<thead>
<tr>
<th>Type of punishment</th>
<th>Imprisonment (in months)</th>
<th>Financial punishment</th>
<th>Confiscated rough opal in (kg)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>No person</td>
<td>14</td>
<td>7</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>500</td>
<td>1000</td>
<td>2000</td>
</tr>
</tbody>
</table>

Source: Delanta Woreda court, (2011)

Most of the illegal trades were sentenced by court for only three months due to the illegal trafficking of opal mining. The lowest and the highest periods of imprisonment range from 3 - 60 months. 300 Birr is the lowest and the commonest financial punishment. The total amount of rough opal (not lapidary/processing) confiscated is 257.7 kg which worth a total of about 25,880 Birr (TIGDW, 2011). The number of persons whose opal was confiscated is 54 while those who are punished by money and imprisonment are 51. This may be a good lesson to brokers and illegal traders.
Plates 5.1 Women get benefited by selling food and drinks.

Opal mining has opened new jobs for women. They get indirect benefit by selling food items, soft and alcoholic drinks to miners and brokers (plate 5.1).

Plate 5.2 The Expansion of Tsehy Mewocha town due to opal mining activity
Even though artisanal mining is an illegal activity in the Woreda it has been changing the live of many youth people in the sites. For example based on the field observation people have started to build their houses by using concretes and cements rather than the traditional ways. And small towns are expanding following the road of opal mining sites especially in Tsehy Mewoccha (plate 5.2).
Table 5.4 Benefit of the respondents from opal mining

<table>
<thead>
<tr>
<th>Have you gained any benefits from the opal mining?</th>
<th>Respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
</tr>
<tr>
<td>Yes</td>
<td>73</td>
</tr>
<tr>
<td>No</td>
<td>9</td>
</tr>
<tr>
<td>If yes, what type of benefits you received from the opal mine?</td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>67</td>
</tr>
<tr>
<td>Indirect</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: field survey, 2011

Most of the respondents (89%) have gained benefit from opal mining directly or indirectly. Direct benefits are obtained by selling the opal to brokers and sometimes to foreigners and indirect benefits (selling food items, soft and alcoholic drinks) are obtained especially by women (plate 5.1). Other beneficiaries are farmers who sell wood especially for (house building) and tools for mining.

5.1.1.3 Child Labour

Children often work in mining to help their families. Working long hours under difficult conditions is dangerous for them, creates serious problems for their growing bodies and soft bones, and gives them no time to go to school. Child labor is illegal under international labour origination (ILO) Convention No. 138 (Edmonds, 2008). The constitution of federal republic democratic of Ethiopia article 36 (d) states that children are not to be subject to exploitative practices, neither to be required nor permitted to perform work which may be hazardous or harmful to his or her education, health or wellbeing.

Table 5.5 Annual dropout of students at Tsehy Mewocha 1st cycle school

<table>
<thead>
<tr>
<th>Academic year</th>
<th>Grade level</th>
<th>No of enrollment in each year</th>
<th>No of dropout in each year</th>
<th>No of dropout due to opal mining in each year</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>Sum</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>2008/09</td>
<td>1-8</td>
<td>672</td>
<td>729</td>
<td>1401</td>
<td>16</td>
</tr>
<tr>
<td>2009/10</td>
<td>1-8</td>
<td>694</td>
<td>761</td>
<td>1455</td>
<td>64</td>
</tr>
<tr>
<td>2010/11</td>
<td>1-8</td>
<td>666</td>
<td>747</td>
<td>1413</td>
<td>68</td>
</tr>
<tr>
<td>2011</td>
<td>1-8</td>
<td>544</td>
<td>685</td>
<td>1229</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>1-8</td>
<td>1924</td>
<td>2193</td>
<td>4117</td>
<td>201</td>
</tr>
</tbody>
</table>

Source: Tsehy Mewocha 1st cycle school, field survey, 2011

39
The table shows summary report of the number of student dropouts of Tsehy Mewocha 1st cycle school that is associated with opal mining directly or indirectly. After the beginning of opal mining in 2009/10 the percentage of dropout has increased from to 2.6% in 2008/09 to 7.7% and 8.6 in 2009/10 and 2010/11 respectively. This indicated that the total percent of student dropout due to opal mining has great contribution for students dropout that is 70.5 % in 2009/10 and 73.8% in 2010/11. Furthermore, even though the number of females enrollment exceeded that of males in all of the three years surveyed, the number of male dropout is greater than that of females. Probably this is because mostly men are engaged in the mining sites (Table 5.5).

Plates 5.3 School age children in the mining site

Based on the data obtained from the school most of the students dropout from the school are in the range of age 12-15 years old. The main reason for students dropout is the need to engage in the mining activity so as to make money (Plate 5.3).

5.2 Perceptions of the Community and Miners

In this section the perception of the respondents on environmental and social impact, management of opal mining, rule and regulation and farmers’ co-operative of mining sites will be discussed.
5.2.1 Environmental impact of opal mining

One of the impacts of mining is that it increases erodibility, the steepness of the land and the removal of the vegetation cover of the soil. 67.4% of the respondents agreed that mining has impact on the environment out of which 27.2% agreed that the major impact is erosion. Next to this 18.5% of the respondents indicated that erosion and land slide together are the main environmental impacts and furthermore wastes (especially the wastes like faces, plastics, broken glasses, and waste of chewed sugar cane) are seen on the mining sites. It is also seen in the town of Tsehy Mewocha (Table 5.6).

Table 5.6 Environmental impact of opal mining

<table>
<thead>
<tr>
<th>Do you think that artisanal mining of opal has an environmental impact?</th>
<th>Respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
</tr>
<tr>
<td>Yes</td>
<td>62</td>
</tr>
<tr>
<td>No</td>
<td>30</td>
</tr>
</tbody>
</table>

If yes, What impact/changes have you observed after opal mining?

<table>
<thead>
<tr>
<th>Change</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in Soil erosion</td>
<td>25</td>
<td>27.2</td>
</tr>
<tr>
<td>Increase in land slide</td>
<td>5</td>
<td>5.4</td>
</tr>
<tr>
<td>Increase in Slope steepness</td>
<td>2</td>
<td>2.2</td>
</tr>
<tr>
<td>Increase in soil erosion and land slide</td>
<td>17</td>
<td>18.5</td>
</tr>
<tr>
<td>Accumulation of waste</td>
<td>13</td>
<td>14.1</td>
</tr>
</tbody>
</table>

Source: field survey, (2011)
5.2.2 Opal mining and its social impact
Some of the social impacts of mining are the death of people, conflicts, crimes and disease.

Table 5.7 Social impacts of opal mining

<table>
<thead>
<tr>
<th>Have you observed any undesirable effect due to opal mining?</th>
<th>Respondent Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>84</td>
<td>91.3</td>
</tr>
<tr>
<td>No</td>
<td>8</td>
<td>8.7</td>
</tr>
</tbody>
</table>

If yes, What problems have you observed after opal mining?

<table>
<thead>
<tr>
<th>Problem</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>death of people</td>
<td>24</td>
<td>26.1</td>
</tr>
<tr>
<td>conflicts or other crime</td>
<td>9</td>
<td>9.8</td>
</tr>
<tr>
<td>Sexually transmitted diseases (STDs) or respiratory diseases</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>death and injury</td>
<td>45</td>
<td>48.9</td>
</tr>
</tbody>
</table>

Source: field survey, 2011

Most of the respondents (91.3%) have replied that opal mining has some undesirable effects out of which 48.9% of the respondents have indicated that both death and injury are the common undesirable effects and next to this 26.1% of them have pointed out that the death of persons as undesirable effects (table 5.7).

5.2.3 Responsibility of managing opal mining sites
In order to manage the opal mining site there should be a responsible body that controls the mining activities on the mining site. As the people interviewed, indicated that at present there is no strong government body that genuinely manages the mining activities in the sites. However, the recently established mining and energy department under Agricultural and Rural Development Bureau has started to organize farmers engaged in mining under farmers’ cooperatives.
According to the constitution of FRDE to article 40(3) the right to ownership of rural and urban land, as well as of all natural resources, is exclusively vested in State and in the people of Ethiopia. And according to article 52(d) power and functions of States: To administer land and other natural resources in accordance with federal laws. In relation to this a questionnaire is prepared to assess which form of managing of opal mining is preferable. So they are provided to make choices among the given alternatives. 29.3% and 23.9% of respondents have implied that miners at kebele and immediate users at local level respectively should manage the mine. However, very few 5.4% and 6.5% of the respondents have indicated that (woreda and kebele) and the federal government should manage the mine respectively (Figure 5.3). The reason for this may be when the woreda, regional and federal government manage or control the mining sites the people of the community may not get access to dig these sites at any time without having licenses or joining farmers’ co-operatives

**5.2.4 Rules and regulations**

Based on the result of the field survey, only 23% of the respondents know the existence of mining rules and proclamations. And the majority of the respondents (77%) do not know the existence of mining rule and proclamation. This indicates that the concerned government bodies should facilitate conditions to create awareness about the mining rules of the country and the region (Figure 5.4).
5.2.5 Farmers’ co-operatives

Joining or forming farmers’ co-operative (FC) has proven to be the most effective strategy for miners to earn a decent living, and to defend their human and environmental rights. However, most of the respondents prefer to work individually than to work in FC. This is because some miners believe that if they mine in group they can’t easily find the opal as the devil hides the opal. 59.8% of the respondents indicated that they are not interested to join in farmers’ co-operatives (Figure 5.5). This is because according to their perception the mine cannot easily be found when they are mine together.

Figure 5.5 Perception of the respondents on FC, field survey, 2011
5.3 Chemical analysis

5.3.1. Heavy Metals in waste rock

The waste rock analyses result of heavy metals (lead, nickel, copper, zinc and cobalt) is shown in (table 5.8). Now it is impossible to determine whether or not the physical and hydrological nature of the waste-rock had an impact on the geochemical and mineralogical characteristics of the mining sites and on Digute river because the mining is starting before three years. But it may also useful as baseline for further research.

Table 5.8 Heavy metals analysis of in waste rocks (ppm).

<table>
<thead>
<tr>
<th>Field site</th>
<th>Cu</th>
<th>Zn</th>
<th>Co</th>
<th>Ni</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minychil (Rm)</td>
<td>8</td>
<td>113</td>
<td>15</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Echagan (Re)</td>
<td>8</td>
<td>99</td>
<td>17</td>
<td>6</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Tachi Amba (Rt)</td>
<td>9</td>
<td>140</td>
<td>17</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Gengena (Rg)</td>
<td>4</td>
<td>101</td>
<td>10</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Minimum</td>
<td>4</td>
<td>99</td>
<td>10</td>
<td>2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Maximum</td>
<td>9</td>
<td>140</td>
<td>17</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Range</td>
<td>5</td>
<td>41</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Max/min</td>
<td>2.25</td>
<td>1.41</td>
<td>1.7</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Mean</td>
<td>7.25±2.22</td>
<td>113.25±18.87</td>
<td>14.75±3.30</td>
<td>5±2.56</td>
<td>8.33±2.89</td>
</tr>
<tr>
<td>Median</td>
<td>8</td>
<td>107</td>
<td>16</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>SD a</td>
<td>2.22</td>
<td>18.87</td>
<td>3.30</td>
<td>2.58</td>
<td>2.89</td>
</tr>
</tbody>
</table>

SD = standard deviation

5.3.1.1 Lead

The range of lead concentration is from less than 1 ppm (detection limit) up to 10ppm with mean value of 8.33 ppm (Table 5.8). Re (site of Echagen) Sample showed results below the detection limit. The highest lead concentration (10 ppm) was obtained in waste rock sample (Rt and Rg) collected from the site of Tache Amba and Gengena.

5.3.1.2. Nickel

The waste rock analyses results for nickel varies from 2 up to 8ppm with mean value of 5ppm. The highest value is obtained from sample Rt (taken from the site of Tach Amba). A low nickel value (2ppm) is obtained from the site of Gengena (Rg).
5.3.1.3. Copper
Copper values in the study area vary from 4 to 8 ppm with a mean concentration of 7.25 ppm. The highest value (8 ppm in Rm and Re) of copper is obtained from the site of Minchil and Echagen.

5.3.1.4. Zinc
Zinc concentration varies from 99 to 140 ppm (with a mean value of 113.25 ppm). The highest value of zinc concentration (140 ppm) is obtained in sample (Rt) (taken from the site of Tachi Amba). A low value of zinc 99 ppm is obtained from samples taken from Echagen.

6.3.1.5. Cobalt
Cobalt values range from 10 up to 17 ppm (with a mean value of 14.75 ppm). The highest value is obtained from sample (Re and Rt) (taken from the site of Tach Amba and Gegenena). And a low nickel value (10 ppm) is obtained from the site of Gegenena.

5.3.2. Heavy Metals in Soils
Soil is a very specific component of the biosphere because it is not only a geochemical sink for contaminants, but also acts as a natural buffer controlling the transport of trace element contaminant to the atmosphere, hydrosphere and biota (Fiefield and Haines, 1996; Adeyeye, 2005). The highest copper, cobalt and nickel values were obtained from sample of Gegenena(Sg) while the highest values for zinc were obtained from sample soil of Tachi Amba. This suggests that possible common sources of the pairs of Cu and Ni metals. These of all samples are collected from sites supposed to be not affected by opal mining. The results of all the samples tested for heavy metals indicate below the Dutch standards and European Norms standards for soil contamination assessment in total concentration of heavy metals in soils (Table 5.9).
Table 5.9 Heavy metals analyses results in Soils (ppm)

<table>
<thead>
<tr>
<th>Field site</th>
<th>Cu</th>
<th>Zn</th>
<th>Co</th>
<th>Ni</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tach Amba (St)</td>
<td>12</td>
<td>141</td>
<td>11</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>Gengena (Sg)</td>
<td>20</td>
<td>115</td>
<td>20</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Minychil (Sm)</td>
<td>7</td>
<td>123</td>
<td>13</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Echagan (Se)</td>
<td>7</td>
<td>85</td>
<td>11</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Minimum</td>
<td>7</td>
<td>85</td>
<td>11</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Maximum</td>
<td>20</td>
<td>141</td>
<td>20</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>Range</td>
<td>13</td>
<td>56</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Max/min</td>
<td>2.9</td>
<td>1.7</td>
<td>1.8</td>
<td>1.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Mean</td>
<td>12 ± 6.1</td>
<td>116 ± 23</td>
<td>14 ± 4.3</td>
<td>15 ± 3.5</td>
<td>5.5 ± 3.3</td>
</tr>
<tr>
<td>Median</td>
<td>9.5</td>
<td>119</td>
<td>12</td>
<td>15</td>
<td>4.5</td>
</tr>
<tr>
<td>SD(^a)</td>
<td>6.1</td>
<td>23</td>
<td>4.3</td>
<td>3.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Dutch Standards(^b)</td>
<td>36</td>
<td>140</td>
<td>20</td>
<td>35</td>
<td>85</td>
</tr>
<tr>
<td>European Standard(^c)</td>
<td>30-60</td>
<td>100-200</td>
<td>-</td>
<td>-</td>
<td>50-100</td>
</tr>
</tbody>
</table>

\(^a\) SD = standard deviation, \(^b\) source: Chen (1999). \(^c\) source: Rademacher (2003)

5.3.3 Water Quality

Water quality is determined by the solutes and gases dissolved in it, the matter suspended in and floating on it. Hydrogeochemistry deals with understanding of the complex factors that influence both chemical and physical properties of water like element concentrations, hardness, pH, EC and many others (Rukezo, 2003 cited in Seyoum Zenebe, 2006). The geochemical behaviour and the chemical and isotopic properties of natural waters are related to their location in the hydrosphere as precipitation, stream flow, soil water, groundwater, ocean water etc (Langmuir, 1997). With this background, this study has tried to evaluate the distribution of five heavy metals (copper, iron, nickel, cobalt and zinc), and also has attempted to establish the conditions of the water medium by in situ measurements of pH, temperature and EC.

5.3.3.1. In Situ Physico-Chemical Water Quality Parameters

Some physico-chemical parameters (pH, EC, temperature and TDS) of the waters of the study area are measured at the time of sampling and the results are indicated in the table 5.10.
Table 5.10 Insitu Water Quality Results of Surface Waters.

<table>
<thead>
<tr>
<th>Field site</th>
<th>T in °C</th>
<th>PH</th>
<th>EC µs/cm at local T</th>
<th>EC µs/cm at 25°C</th>
<th>TDS in mg/l At 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weu1</td>
<td>12.1</td>
<td>7.15</td>
<td>68.4</td>
<td>47.70</td>
<td>31.00</td>
</tr>
<tr>
<td>Wed2</td>
<td>12.2</td>
<td>7.55</td>
<td>73.6</td>
<td>51.15</td>
<td>33.25</td>
</tr>
<tr>
<td>Wmu1</td>
<td>15.3</td>
<td>6.83</td>
<td>74.0</td>
<td>45.70</td>
<td>29.71</td>
</tr>
<tr>
<td>Wmd2</td>
<td>16.2</td>
<td>6.60</td>
<td>70.5</td>
<td>41.95</td>
<td>27.27</td>
</tr>
<tr>
<td>Average</td>
<td>13.95</td>
<td>7.03</td>
<td>71.62</td>
<td>46.62</td>
<td>30.31</td>
</tr>
<tr>
<td>FAO b</td>
<td>-</td>
<td>6.5 – 8.4</td>
<td>-</td>
<td>70 – 300</td>
<td>400 – 2000</td>
</tr>
</tbody>
</table>

*Field sites full name found on page 28,  b Source : FAO,1985

5.3.3.1.1 Temperature

Temperature affects parameters of water (pH, EC, rate of chemical reactions) and solubility of gases in various ways. The temperature values obtained from insitu measurement of surface water samples (Table 5.10) vary from 12.1 °C (Weup1) up to 16.2 °C (Wmd2) and the average temperature value for surface samples is 13.95 °C.

5.3.3.1.2 pH

The pH of the sampled surface waters ranges from 6.60 (weakly acidic) to 7.55 (very weak base) with mean value of 7.03. The surface water sample is in the range of the Drinking Water Standards of Ethiopia (2001) and the standard stated by WHO (1984) for drinking water (6.5 to 8.5) and it is also within and also the normal range (6.5-8.4) for irrigation water set by FAO(1985).

5.3.3.1.3 Electrical Conductivity (EC)

The electrical conductivity of water samples is the ability to conduct an electric current which is influenced by the presence of ions dissolved in the water particularly HCO₃⁻, SO₄²⁻, Cl⁻, Ca²⁺, Na⁺, Mg²⁺ and K⁺ (Swennen, 2004). The insitu electrical conductivity measurements are
corrected to 25°C (C25) by using the formula: C25 = Ct (1-0.025Δt); where Δt = sample temperature minus 25°C (Kegley and Andrews, 1998, cited by, Siyoum Zenebe, 2006).

The surface water samples Table 5.10 show a range of EC values from as low as 41.95 microsiemens per centimeter (µS/cm) in a sample collected from Digut River (Wmd2) up to 51.15µS/cm (Wed2.). The mean conductivity value is 46.63µS/cm. All samples are found to be in the range of the WHO (1993) drinking water guideline (250µS/cm) and FAO (1985) for irrigation.

5.3.3.1.4 Total Dissolved Solids (TDS)

Total dissolved solids are the weight of solids obtained on evaporation of a liter of water sample to dryness at temperature of 103-105 °C (Fetter, 2001). For this study, the TDS values (mg/l) were computed by multiplying the insitu EC in µS/cm by a factor of 0.65 that is TDS= 0.65*EC (Subba, 2003 cited by Seyume Zenebe, 2006). The TDS values of this study range from 27.27 up to 33.25mg/l. All surface water samples gave TDS values which are found to be fresh water (<1,000mg/l) (Fetter, 2001).

5.3.3.2 Heavy metals Analyses of Surface Water

The collected Surface Water samples were analysed for heavy metals. The results of all water samples of all heavy metals (lead, chromium, cadmium, iron, zinc, and nickel) were found below the analytical detection limit (0.1mg/l) and are not considered further in this discussion. The results of water samples tested from Digut river (Appendix 10) are all above the WHO (2008) Guideline for Drinking Water values, Ethiopian Standard (2001) Guideline Value for drinking Water and FAO (1985) Water quality for agriculture values.

5.4 Environmental management of waste rocks, soils and other wastes

Miners dig horizontally in to cliffs and they remove the waste rock and soil near the mining sites. Later these waste rock and soil enter in to the Digut river and causes salinity. Salinity is salts in soil or water reduce water availability to the crop to such an extent that yield is affected (FAO, 1985). The mining hole may not be filled/recover after mining and this also affects the stability (equilibrium) of the mining site of the cliff. This implies that the waste of rock and soil has to be used as a landfill. After the mining of one hole has finished, the debris can be used as back fill. The other things that need to be managed are the wastes which are not easily degradable
materials (like plastics, broken glasses, and plastic bottles) and faces. They should be put on the specific separate places of landfill because the human wastes causes diseases like typhoid.

5.5 land-use/land-cover and Soil lost estimation

5.5.1. Land use/Land cover

From visual and digital interpretations of the satellite imagery, seven major LULC categories were distinguished. Both supervised and unsupervised land use classification method was used for land use/land cover classification (Figure 5.6). Based on this method the land of the woreda has the following categories. The total land area of the study area Delanta woreda is 105,936.7 ha, of which 36,842.7 ha (34.7%) is considered suitable for agriculture. The Plantation lands accounts for 3,188.9 ha (3.1%) and cliff/ridge where the opal found is 3, 448.6ha (3.2%). The mining sites are found within the cliff/ridge where there is no vegetation cover. And the miners removed the waste rocks and also the soil on the surface of the cliff to get the opal. It may increases the soil erosion by the water in the rain season.

Figure 5.6 land use/land cover

5.5.2. Estimation of soil loss

The RUSLE model was run within the ArcGIS by multiplying the six factors (RKLSCP) in the raster calculator. The quantitative output of predicted soil loss rates for the Tshey Mewocha and its surrounding kebeles resulting from current farming practices were computed and grouped into
five ordinal classes and displayed on the map. Based on the analysis, the total amount of soil loss in Tsehy Mewocha and its surrounding kebeles is about 1,320,000 tons per year from 22,900 hectares. The amount of soil loss of each parcel of land is from 250 to 205,000 t/ha/year. The mean annual soil loss of the area is 13,200 t/ha/year. According to the estimate of FAO (1984), the annual soil loss of the highlands of Ethiopia ranges from 1248 – 23400 million ton per year from 78 million of hectare of pasture, ranges and cultivated fields throughout Ethiopia.

Removal of vegetation cover through deforestation and overgrazing, repeated tilling of the soil to prepare fine seedbed and lack of adequate soil and water conservation resulting in such loss and in addition, erosion causes a decline in crop yields primarily by reducing rooting depth, water holding capacity and loss of nutrients and organic matter through selective removal of the most fertile soil particles. National (for Ethiopia) level estimates reveal 2% average annual reduction of the agricultural GDP due to erosion (FAO, 1986; Pescod, 1992)
Figure 5.7 R-Factors

Figure 5.8 k-Factor

Figure 5.9 LS- Value
Figure 5.10 C-Factor

Figure 5.11 P-Factor

Figure 5.12 Amount of Soil Loss in Tsehy Mewocha and surrounding Kebeles
Figure 5.10 C-Factor

Figure 5.11 P-Factor

Figure 5.12 Amount of Soil Loss in Tsehy Mewocha and surrounding Kebeles
6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Based on results obtained the following conclusions can be made

The collapse of the rocks was the major socio-economic problem for miners as it may take their lives and interrupts their daily activities. In addition to this soil erosion which is increased by lack of soil conservation practices, farming system of the community, the slopy nature of the land and after mining started there is accumulation of debris in the mining sites is a problem of the study area. It is also found that pneumonia and typhoid are one of health problems. This is because the miners were stay for a long period of time in the mining holes and they remove their waste matter near to the mining sites. Brokers of opal transaction are the major beneficiaries; as the woreda and kebele administration do not apply the rules and regulations of mining operation. Although opal mining is becoming a new job opportunity for the study sites; it has been increasing the number of deaths of miners and student dropouts. The farmers are not interested to work together rather they need to work individually. And it is the related to the perception of the community. The chemical pollutants concentration of heavy metals from waste rock, soil and Digut river comply with the WHO (2008), FAO (1985) and Ethiopia standard (2001). This shows the surface water may be used for irrigation and livestock dirking water. All the results obtained from this research provide a baseline environmental data for the woreda.
6.2 Recommendations

Based on the data and information obtained; the following recommendations can be made.

- In order to minimize (avoid) the collapse of rock in the mining sites; miners should leave some rocks in the middle and sides of mine holes that serve as pillars so as to support the roof of the holes.
- In order to reduce the problem of soil erosion in farming area and the mining sites studied; soil conservation mechanisms (like afforestation and building of terraces) should be practiced.
- Miners should take safety measures (like wearing spectacles, helmets, air suck machines, cloths to cover their mouths and ears). So as to save their lives and stay healthy.
- Health centers should be established near the mining sites in order to provide first aid and other health services. Furthermore, good roads taking to and away from these mining sites should be constructed.
- In order to receive more benefit more from opal mining activities; all the concerned bodies should respect the rules and regulations of the country. Efforts should be taken to raise the awareness of the people about mining rules and the regulations.
- Schools and families of students around the mining sites should work close together so as to reduce or stop student dropouts.
- Government bodies at all levels should give all the necessary support so as to enhance and encourage both miners and opal mining activities.
- The chemical pollutants tested from the surface water of Digut river are less than 0.1mg/l; hence it needs further research by using laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) and / or Graphite furnace atomic absorption spectrometry (GFAAS) (Electrothermal Atomic Absorption Spectrometry(ETAAS)).
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APPENDICES

Appendix- 1 Wogel Tena monthly average maximum temperature (°C)

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Min</th>
<th>Max</th>
<th>Total</th>
<th>Aver</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>19.6</td>
<td>21.1</td>
<td>21.2</td>
<td>21.2</td>
<td>21.4</td>
<td>22.1</td>
<td>16.1</td>
<td>16.5</td>
<td>17.4</td>
<td>16.6</td>
<td>17.1</td>
<td>17.8</td>
<td>16.1</td>
<td>22.1</td>
<td>227.9</td>
<td>19.0</td>
</tr>
<tr>
<td>2000</td>
<td>19.1</td>
<td>20.0</td>
<td>28.0</td>
<td>19.3</td>
<td>24.1</td>
<td>21.9</td>
<td>xx</td>
<td>16.4</td>
<td>17.7</td>
<td>17.5</td>
<td>17.9</td>
<td>18.0</td>
<td>16.4</td>
<td>28.0</td>
<td>219.9</td>
<td>18.3</td>
</tr>
<tr>
<td>2001</td>
<td>19.1</td>
<td>20.6</td>
<td>18.6</td>
<td>20.4</td>
<td>20.5</td>
<td>20.0</td>
<td>16.9</td>
<td>16.4</td>
<td>18.0</td>
<td>18.2</td>
<td>17.9</td>
<td>18.7</td>
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SOURCE: NMSA at Konbolcha Station, (2010)

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SOURCE: NMSA at Konbolcha Station, (2010)
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SOURCE: NMSA at Konbolcha Station, (2010)

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SOURCE: NMSA at Konbolcha Station, (2010)
### Appendix-5 Mersa monthly total rainfall (mm)

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SOURCE: NMSA at Konbolcha Station, (2010)

### Appendix - 6 Wurgessa monthly total rainfall (mm)

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SOURCE: NMSA at Konbolcha Station, (2010)
## Appendix - 7 General background of respondents

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### Distance of home from mining site

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Appendix -8: the Universal Soil Loss Equation (USLE) adapted for Ethiopia (Hurni 1985)

1. Rainfall Erosivity

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2. Soil Erodibility

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(adapted from Hellden, 1987)

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</table>

4. Slope gradient

<table>
<thead>
<tr>
<th>Slope (%)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>40</th>
<th>80</th>
<th>160</th>
<th>240</th>
<th>320</th>
</tr>
</thead>
<tbody>
<tr>
<td>S factor</td>
<td>0.1</td>
<td>0.4</td>
<td>1</td>
<td>1.6</td>
<td>2.2</td>
<td>3</td>
<td>3.8</td>
<td>4.3</td>
</tr>
</tbody>
</table>

5. C: land cover

- Dense forest: 0.001
- Dense grass: 0.01
- Badlands hard: 0.05
- Fallow hard: 0.05
- Sorghum, maize: 0.01
- Ethiopian tef: 0.25
- Other forest: see grass
- Degraded grass: 0.05
- badland soft: 0.40
- fallow ploughed: 0.06
- Cereal, pulses: 0.15
- continuous fallow: 1.00

6. P: management Factor

- Ploughing up and down: 1.00
- Ploughing on contour: 0.90
- Strip cropping: 0.80
- Intercropping: 0.08
- Applying Mulch: 0.60
- Dense intercropping: 0.70
- stone cover 80%: 0.50
- Stone Cover 40%: 0.80
Appendix- 9  P-factor and m-value (Wischmeier and Smith, 1978)

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Slope (%)</th>
<th>P-factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural land</td>
<td>0-5</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>5-10</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>10-20</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>20-30</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>30-50</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>50-100</td>
<td>0.33</td>
</tr>
<tr>
<td>Other Land All</td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>m-value</th>
<th>Slope (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>&gt; 5</td>
</tr>
<tr>
<td>0.4</td>
<td>3-5</td>
</tr>
<tr>
<td>0.3</td>
<td>1-3</td>
</tr>
<tr>
<td>0.2</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Appendix- 10 Result of heavy Metals Analysis in (mg/l) from Surface Waters

<table>
<thead>
<tr>
<th>Field sites</th>
<th>Co</th>
<th>Pb</th>
<th>Cu</th>
<th>Zn</th>
<th>Ni</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weu1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Wed2</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Wmu1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Wmd2</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Appendix 11: Questionnaire to assess socioeconomic dimension of the impacts, problems and causes, perception, consequences of opal mining

Part I. Socio-economic characteristics

1. General
   Survey area: Region-- Zone-- Woreda---- Village------
   Respondent code ---------------------- Name of Enumerator-------
   Date of interview ------------------- Beginning time -------- Ending time ----

2. Code of interviewee --------------

3. Age -------------------
4. Sex 1. Male 2. Female

5. Level of Education
1. Can’t read and write 2. Can read and write 3. First cycle (1-4)


7. Farm size ----------------------

8. What are the types and number of livestock you own?

<table>
<thead>
<tr>
<th>Livestock type</th>
<th>Quantity</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cattle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Sheep and/or goat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Equines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Cattle, sheep and goat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Cattle and sheep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Have not any</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. What is your family’s main source of income?
5. Crop and livestock production 6. Opal selling

10. How far is your home from the nearby opal mining?
1. 1-4 km 2. 5-8 km 3. 9-12 km 4. 13-16 km 5. 17-20 km

Part II. Questions to Administrators, community and miners

A. Awareness of people to rules and regulation about mining and environment

1. Do you know the environmental protection organs establishment proclamation? 1. Yes 2. No
2. If yes, do you get training about it? 1. Yes 2. No
3. Do you know about the environmental protection authority rules and regulation? 1. Yes 2. No
4. If yes, do you get training about it? 1. Yes 2. No
5. Do you know the environmental pollution control proclamation? 1. Yes 2.No
6. If yes, do you get training about it? 1. Yes 2.No
7. Do you know the proclamation of mining operation? 1. Yes 2.No
8. If yes, do you get training about it? 1. Yes 2.No
9. Do you know about the transaction of precious minerals proclamation? 1. Yes 2.No
10. If yes, do you get training about it? 1. Yes 2.No
11. Do you think artisanal mining of opal has environmental impact? 1. Yes 2.No
12. If yes, do you get training about it? 1. Yes 2.No
13. How do you gain permission to mine the opal?
   1. License from agricultural office 2. Permission from local leader 3. No permission
   4. Other specify

B. Opal mining management
1. Do you think that artisanal mining of opal has an environmental impact? 1. Yes 2.No
2. If yes, what impact /changes have you observed after opal mining?
   1. Soil erosion increases 2. Land slide increase
   3. Slope steepness increases 3.2 and 3 4. Sold waste deposition
2. Have you observed any undesirable effect due to opal mining? 1. Yes 2. No
3. If yes, what type of problems have you observed after the opal mining?
   1. Death of peoples 2. conflicts or other crime 3. STD or respiratory disease
   4. Death and injury
4. If there is death of peoples
   1. How many ------ 2. When ------- 3. Where ------
5. If there is injury of people
   1. How many ------ 2. When ------- 3. Where ------
6. If there is conflicts between people
   1. How many ------ 2. When ------- 3. Where ------
7. If there is (STD) or respiratory disease
   1. What kind of STD or respiratory disease ------ 2. When ------- 3. Where ------
8. If there is migration of animals
9. If there is Collapse of mining site
10. Is there any displacement of peoples due to opal mining? 1. Yes 2.No
11. Is there any forest removal due to mining? 1. Yes 2.No
12. If yes what kind of forest------
13. Is there any loss of property due to mining? 1. Yes 2.No
15. Are there people who abandoned the farming or other job and come to opal mining? 1. Yes 2.No
16. If yes, 1. How many 2. When
17. Do children participate in opal mining? 1. Yes 2.No
18. Do you need a change in the existing opal management system? 1. Yes 2. No
19. If yes, what management approach / ownership do you suggest for proper utilization of the opal resources?
20. In your opinion, who should take the responsibility manage/protection the opal?
   4. Kebel 5. Immediate users at local level 6. woreda and kebel
22. Is there any guard for the opal? 1. Yes 2. No
23. Where does the waste material of opal mines go?
   1. in faraway places 2. near the mining place 3. other specify
24. After mining of opal what will happen to the mining place?
   1. Left as it is 2. planting of vegetation 3. other specify
25. Are you a member of the farmer’s co-operative opal mining? 1. Yes 2. No
26. What is your feeling up on the farmer’s co-operative mining management?

C. Benefits gained and their sharing
1. Have you gained any benefits from the opal mining? 1. Yes 2. No
2. If yes what type of benefits have you received from the opal mined?
   1. Direct 2. Indirect
3. To whom the out puts of artisanal opal mining are useful?

4. List the benefits that you have received from the opal mining in your locality?
   (Please list according to their importance)

<table>
<thead>
<tr>
<th>Types of benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income generation as miner</td>
</tr>
<tr>
<td>Mining material supplier</td>
</tr>
<tr>
<td>Food seller</td>
</tr>
<tr>
<td>Money from sale of opal as broker</td>
</tr>
<tr>
<td>Other business opportunities</td>
</tr>
</tbody>
</table>

5. What is the use of opal? ---------------------

PART III Semi–structured questions for interview

1. What are the major and most frequent environmental impacts that affect the society in your area related to opal mining?
2. How the miners mine the opal?
3. What kind of materials they use to mine?
4. What changes do you observe in relation to mining from environment, socio-economic and health points of view?
5. Mention the impacts of opal mining on the community and the environment?
6. Is there any migration or resettlement due to mining in your area?
7. Do you get governmental and or non-governmental aid when death occurs?
8. Discuss the major causes of natural resource degradation? (If there is any)
9. What resource conservation activities are carried out to minimize land degradation?
10. What should be done in the future?
DECLARATION
I the undersigned declare that this thesis is my original work and has not been presented for any
degree in any university, and all the sources of materials used for the thesis have been duly
acknowledged.

Name: Mohammed Shikur
Signature: ______________________

This Thesis has been submitted for examination with my approval as university advisor and co-
advisor

Name                                                                                     Signature
Dr. Worash Getaneh (Advisor)                                                            ________________
Dr. Hameed Suleiman (Co-Advisor)                                                        ________________

Date and place of submission: Environmental Science Program

July 2011
Addis Ababa University