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**HEALTH EFFECTS OF MERCURY AMONGST ARTISANAL GOLD MINERS IN LORGORIEN AREA, TRANS-MARA DISTRICT, KENYA**

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## DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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**DEDICATION**

This work is dedicated to my parents; the late Cosmas Aduwo and Mrs. Loice Auma Aduwo. They exemplify commitment, hope, humility and patience even in most difficult circumstance.

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## OPERATIONAL DEFINITIONS

**Amalgamation** is a concentrating process in which metallic gold or silver, or an alloy of the two, is mixed with mercury. This can either be in amalgamation drum, or on an amalgamation table, where the precious metal bonds with the mercury to form the metal laden mercury.

**Artisanal or small-scale gold mining (AGM)** is the use of rudimentary processes to extract gold minerals from primary and secondary ore bodies, and is characterized by the lack of long-term mine planning/control.

**Biodiversity** is the totality of genes, species, and ecosystems in a region. Biodiversity can be divided into three hierarchical categories genes, species, and ecosystems that describe quite different aspects of living systems and that scientist's measure in different ways.

**Land degradation** is a composite term that describes how one or more of the complex aspects of land resources has changed for the worse over time. It includes biological degradation (loss of biodiversity), physical degradation (soil erosion), and chemical degradation (salt accumulation).

**Mutation** a gene mutation is a permanent change in the DNA sequence that makes up a gene. Mutations range in size from a single DNA building block (DNA base) to a large segment of a chromosome.

**Pollution** is the introduction of contaminants into an environment that causes instability, disorder, harm or discomfort to the ecosystem that is, physical systems or living organisms. Pollution can take the form of chemical substances, or energy, such as noise, heat, or light.

**ABBREVIATIONS AND ACRONYMS**

°C	Degrees centigrade
AGM	Artisanal Gold Mining
AIDS	Acquired Immune Deficiency Syndrome
CIP	Carbon-in-pulp
CNS	Central Nervous System
Db (A)	Decibels (Amps)
DNA	Di-Nucleic Acid
GoK	Government of Kenya
Hg	Mercury
HgEX	Expert System for Mercury Discharge
HIV	Human Immune Virus
ITCZ	Inter-Tropical Convergence Zone
KNBS	Kenya National Bureau of Statistics
NCST	National Council of Science and Technology
NEMA	National Environmental Management Authority
NGO	Non-Governmental Organization
NIMD	National Institute for Minamata Disease
SPL	Special Prospecting Licence
SPSS	Statistical Package for Social Sciences
STD	Sexually Transmitted Diseases
UNCRD	United Nations Centre for Regional Development
UNEP	United Nations Environment Management Programme
USA	United States of America
USEPA	United States Environmental Protection Agency

WCC World Chlorine Council

WHO World Health Organization

## ABSTRACT

Gold occurs in a number of places within the gold-bearing greenstone rocks in western Kenya. From 1995, prospecting has been active in Lorgorien by licensed gold mining companies coupled with the influx of artisanal miners. Artisanal gold mining (AGM) using mercury (Hg) is of great environmental health concern. Mercury is one of the priority toxic elements of global consideration and its abusive discharge into ecosystems by miners poses serious health problems. The study was prompted by widespread use of mercury by small-scale gold miners in Lorgorien and lack of information on the effects of mercury to human health. This study examined the associated health problems of mercury (Hg) used by artisanal miners of gold in Lorgorien mine area, Transmara District, Kenya. Small scale gold mining contributes positively to social and economic development of Lorgorien Township. Mercury is used to purify gold and has been characterized by improper handling, unintentional spill and dumping into rivers and waterways. The health effects of mercury remain poorly studied in Kenya, and especially in Lorgorien area. The main objectives of the study were to; determine the community's knowledge on mercury problems, examine health effects associated with artisanal gold mining and to find out other factors that compromise the health of artisanal gold miners in the study area. The study was carried out in Lorgorien gold mining licensed area (Moyoi and Masurura locations). The study utilized a descriptive analytical study design. Data were collected using semi-structured questionnaires administered to 196 systematically sampled households by two clinicians and two research assistants. In-depth interviews with key informants, observation checklist, water and sediments sampling and health records from Lorgorien Sub-District Hospital were also used in the study. Data collected were cleaned, entered and analyzed using Statistical Package for Social Statistics (SPSS) version 16 for both descriptive and inferential statistics. Descriptive statistics that included frequencies, percentages and means were used to analyze data. Binomial test, Correlation and Regression tests were used to assess the null hypothesis at a significance level of 0.05. The study found out that mercury is widely used in the processing of gold. Majority of the miners (64%) indicated low awareness to mercury toxicity and identified some measures to reduce toxicity. Precautionary measures on how to mitigate negative effects of mercury were found out to be use of protective equipments, outdoor blowtorching and use of tailing ponds. Findings of the study revealed a statistically significant P-value (0.001) thus rejecting the null hypothesis. Hence, the study concluded that the health problems associated with mercury released by artisanal gold mining are widespread in the study area. The study recommends scaling up campaign to bolster awareness on what mercury does to human health and on-site training of miners on safe and healthy mining practices.

## CHAPTER ONE: INTRODUCTION

### 1.1: Background information of the study

Kenya is endowed with occurrence of different types of minerals such as gemstones, gold and industrial minerals (titanium ores, gypsum, iron ore, limestone, diatomite, fluorspar, vermiculite, soda ash or trona and carbon dioxide) summarized in Table 1.1 (GoK, 2010).

**Table 1. 1: Kenya's mineral production for the period 2005 to 2009**

Mineral	Unit	2005	2006	2007	2008	2009
Soda Ash	MT	360,161	374,210	286,578	502,846	404,904
Fluorspar	MT	97,608	132,030	85,115	130,100	5,500
Crushed refined soda	MT	640,291	662,939	842,043	865,788	948,076
Salt (Magadi)	MT	26,595	35,024	11,596	24,345	24,125
Carbon dioxide	MT	8,723	9,359	11,028	22,030	15,711
Diatomite	MT	1,221	1,595	1,841	1,775	1,696
Gold	KGS	616	432	3,023	340	1,055
Gemstones	KGS	5,420	5,044	8,927	20,933	39,408

Source: GoK, 2010

In the last 20 years, mining in Kenya has been dominated by the production of a variety of industrial minerals, among which are soda ash, fluorspar, diatomite and limestone. Gold and gemstone production is the main activity of small-scale miners. Gold mining activities have existed in Kenya at least for the last one hundred years (GoK, 2005). These activities have expanded extensively in this century due to new exploratory techniques and application of new mining and metallurgical technologies. These mineral resources hold the promise of exceptional long-term social and economic benefits for the country and their exploitation has accelerated dramatically during the past century (Donkor *et al.*, 2006). Today, gold mining and its associated industries continue to form the cornerstone for the economies of developing countries Kenya included.

The Lorgorien mine area is located in Transmara district of Narok county, Kenya and borders Maasai Mara game reserve to the East. The population of the Lorgorien mine area is estimated by Kenya National Bureau of Statistics (KNBS, 2005) at 10, 574 persons. Gold mining has taken place in Lorgorien for close to 40 years however, active gold prospecting started in 1995 (GoK, 2010). The activities of artisanal gold miners are on the rise including the widespread use of mercury to process gold (Karani *et al.*, 2008). The normal gold recovery process is the stamp mill and amalgam plate and subsequent recovery of the gold from the amalgam using mercury (Israel and Asiro, 2002). Mercury is frequently lost in this process, causing significant environmental health contaminations (Baker, 2004).

Mercury is one of the most toxic heavy metals, and mercury pollution has led to many tragic incidents around the world (Gunson and Veiga, 2004). Small-scale gold mining is a major source of global mercury releases; the health effects of this mercury are of significant concern, both locally and globally (Ogola *et al.*, 2002). The long term effects of mercury include damage to central nervous system and kidney. On the other hand, short term exposure to mercury can cause chest pains, dyspnoea, cough, haemoptysis, impairment of pulmonary function and intestinal pneumonitis. Low level mercury exposure is known to cause fatigue, irritability, loss of memory, vivid dreams and depressions (Donoghue, 2004; Gunson and Veiga, 2004; Horvat, 2009).

## **1.2: Problem statement of the study**

The use of mercury in gold extraction has become a source of concern. The increased use of mercury has led to death of some biological species that include humans, plants

and animals (Horvat, 2009). Although precautionary measures exist on how to mitigate the negative effects of mercury on environment, small-scale gold mining is organized on individual basis making it difficult to determine human mercury concentration levels in short term (Donkor *et al.*, 2006). The artisanal gold mining activities are intensifying resulting into overcrowding and related health and social problems. The supply of occupational hazards protection equipment and sanitation services to small scale miners has been deteriorating. This exacerbates health conditions associated with the use of mercury. Furthermore, there is seasonal, environmental and geographical variation on effects of mercury.

The artisanal gold mining activities have been taking place in Lorgorien, Trans-Mara district for close to 30 years (Karani *et al.*, 2008). The ongoing mining involves the use of mercury to purify gold and has been characterized by improper handling, unintentional spill, and dumping into rivers and waterways. In addition, mercury has been released in the atmosphere in vapour form through blowtorching or gold panning. Unfortunately, majority of the people, especially those involved in mining activities are not adequately aware of the dangers posed by mercury to environment or their own health. Besides, mercury contamination is yet to be documented in Lorgorien compared with other regions around the world. Consequently, the study endeavored to ascertain potential health risks that could be emanating from the use of mercury in the study area.

### **1.3: Research questions**

The study sought to answer the following questions:

- a. What is the knowledge level of miners on effect of mercury used for gold processing in the study area?
- b. What are the health effects of mercury amongst Lorgorien's artisanal gold miners?
- c. What are the other factors that affect the health of artisanal gold miners in the study area?

### **1.4: Objectives of the study**

#### **1.4.1: Main objective**

The main objective of this study was to determine the knowledge of miners on the effects of mercury and the magnitude of mercury health effects in Lorgorien mining area.

#### **1.4.2: Specific objectives**

- a. To determine the miners' knowledge on mercury problems in Lorgorien mine area;
- b. To assess health effects associated with mercury used by artisanal gold miners in the study area; and,
- c. To find out other factors that contributes to the health effects of the artisanal gold miners.

### **1.5: Hypothesis**

This study addressed the following hypothesis;

H<sub>0</sub>- There is no predominant health effects of mercury amongst artisanal gold miners in Lorgorien study area

### **1.6: Justification of the study**

In Kenya, environmental health problems from mercury (Hg) generated by artisanal gold mining (AGM) remain poorly studied. The AGM has resulted in the use of an enormous amount of metallic mercury that is poorly handled and discharged despite its high toxicity. In Lorgorien area, AGM activities are on the increase and this study attempted to determine potential health effects of mercury posed to the artisans and community. The study suggests possible AGM policy requirements or is useful in initiating AGM policy formulation process. The study thus provides data that could be used to assess the extent of mercury contamination in Lorgorien mine area. This is so because the effects of mercury contamination differ based on season, environment, climate and geographical region (Baker, 2004). This study intended to determine the health risks associated with use of mercury in mining gold in the study area.

### **1.7: Significance and anticipated output**

The study examined and documented health effects of mercury in Lorgorien mine area and forms a basis for further studies. Results of the study are bound to be published and disseminated to various institutions. This is to ensure that threshold awareness level of Hg health problems from AGM activities is attained. Relevant government ministries and agencies, NGOs and the general public will be empowered through workshops and seminars. The study also contains information that will

expand knowledge about various adverse environmental health and social side effects of artisanal gold mining in Lorgorien. These findings shall also be used to shed light on the management of artisanal gold mining as well as in suggesting measures to address the problems associated with the use of mercury, designing appropriate sanitary and remedial measures for mercury usage. This will further contribute to the achievement of Vision 2030's social pillar on health that encourages preventive rather than curative measures.

### **1.8: Limitations and scope of the study**

Health effects of mercury exposure do not work in isolation and some health problems that might be cited by the miners can result from a combination of other factors. As cited by Amutabi and Lutta (2001) high HIV/AIDS prevalence in mining areas can be worsened by mercury exposure. The study looked at perceived health problems of mercury used by artisanal gold miners and not long-term effects of bio-accumulation and bio-concentration of mercury.

There are numerous sources of health challenges to miners (Donkor *et al.*, 2006; Israel and Asiro, 2002). These sources could be physical hazards, biological, chemical, psychosocial and overwork. However, the study was limited to health challenges accruing from chemical hazards that involve the use of mercury.

## CHAPTER TWO: LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

### 2.1: Introduction

The study reviewed literature on the health effects of mercury used by artisanal gold miners and emerging issues in mercury handling and disposal that are obtainable in this chapter. The appraisal was done so as to identify research gaps and develop theoretical and conceptual framework for the study. The literature review also enabled researcher to develop research instruments and identify relevant variables for the study. The review placed this research in the emerging discourses on health concerns of mercury releases and measures taken by miners in reducing these effects. The review was based on the following themes:

- a. Global mercury pollution
- b. Gold mining with mercury
- c. Health effects of mercury on miners
- d. Safety and environment concerns in AGM
- e. Gender issues in gold mining

Artisanal gold mining (AGM) with mercury (Hg) has been a subject of keen interest and intense debate by the public, international agencies and many environmental pressure groups lately, because of Hg's toxicity to living organisms in general (UNEP, 2008). The disaster in Minamata, Japan, where several mass poisonings involving Hg which attracted the general attention of the scientific community towards the end of the 1950s, is still fresh in memory (NIMD, 2001). Other incidents of Hg poisoning have been reported in Iraq, Pakistan, and Guatemala, with numerous deaths resulting from the eating of Hg-contaminated fish or consumption of foods

prepared from seed grain treated with mercurial fungicides (Zhrlich, 1990). Presently, this fearful concern of Hg's hazards or toxicity has heightened as observed in the numerous scientific international conferences and publications on Hg as an environmental pollutant (Horvat, 2002). Both empirical and theoretical literature was reviewed based on the themes under the study.

## **2.2: Empirical review**

Horvat (2009) studied mercury levels in air, soil, vegetables and fish in Tuscany Italy. He found out that levels of mercury differed significantly with individuals who had dental mercury fillings recording highest level compared to others without dental amalgam (in urine sample). The study focused only on industrial workers. There was also an examination on the possibilities of mercury dental amalgam traveling from the tooth to other parts of the body (Harris *et al.*, 2008). The study found out that mercury from the tooth had travelled up to several millimeters from where the amalgam filling had been done. This finding illustrates the possibility of mercury migrating from one part to other parts of human body.

Crespo-Lopez *et al.* (2009) analyzed mechanisms through which mercury may radiate in human body. He found out that mercury travels to the rest of the body parts through pulp (nerve tissue) and consequently into pulp blood stream, and to the foetus where it is transferred through the placenta. For individuals with dental amalgam, mercury is physically released during biting and chewing which cause erosion of the surface of amalgam. After the erosion, the amalgam fillings in the mouth can either be inhaled or ingested.

Veiga *et al.* (2004) looked into possibility of substituting mercury in processing of gold. The study found out that 30% of mercury used in amalgamation process is lost to the atmosphere. This creates environmental as well as health challenges. Furthermore, the study found out that amalgamation is inefficient and recovers less than 30% of the gold.

Graydon *et al.* (2009) assessed the absorption and stability of mercury by activated carbon. The study found out that 75% of mercury to be bound in its elemental form that is; it remains pure and does not react with other elements (Graydon *et al.*, 2009). This is important in finding a permanent panacea to circulation of mercury in atmosphere.

Understanding the circulation of mercury is a precursor towards mitigating its effects on environment and living organisms. Pirrone and Mason (2009) assessed transport and circulation of mercury globally. The study found that 2,503 tonnes of mercury that are emitted annually directly come from human activities which represent about 1/3 of all mercury in the atmosphere. The study further indicated that fossil fuel power plant emission stood at 1422 tonnes annually and small scale gold mining became second after registering 400 tonnes per year (Pirrone and Mason, 2009).

It is possible to establish the source of mercury in the atmosphere. This is grounded on the fact that environmental factors such as specific atmospheric and river conditions at pre-historic point in time when coal originally formed influence the concentration of mercury isotopes (Biswas *et al.*, 2008).

Biswas *et al.* (2008) attempted to trace genesis and zero down the source epi-centre of mercury in atmosphere. The study burned 30 coal samples from USA, China, and Russia and found that mercury source or fingerprint for coal from each of the three regions to be different. Hyman (2004) examined the impact of mercury on human health and the environment in USA. The study established high correlation between mercury use and autism. The study reported high cases of autism among women who had dental amalgam fillings during pregnancy. A study of similar feat and in the same realm was done by Nash (2004) in USA. He found fetal brain is more vulnerable to mercury related damage including the division of migration of neuronal cells in nutshell brain compared to adults.

Hyman (2004) and Nash (2004) observed that mercury might be a significant guide in grappling with the challenge of autism as well as toxin-induced oxidative stress caused by the mercury when it gets in touch with a child's unique genetic vulnerability.

Harley *et al.* (2003) linked increase in environmental mercury volume to industrial growth. The study found out increase in mercury volume from 1960 to 2000 to be dramatic and exponential. According to UNEP (2008), there is increase in mercury volume globally with slight decline in Europe and North America. Table 2.1 summarizes the changes in total emissions of mercury worldwide.

**Table 2. 1: Total anthropogenic emissions of mercury worldwide from 1990 to 2000**

	1990	1995	2000
Africa	178	389	407
Asia	705	1121	1204
Australia	48	113	125
Europe	627	338	239
North America	261	215	202
South America	62	84	92
Total	1881	2260	2269

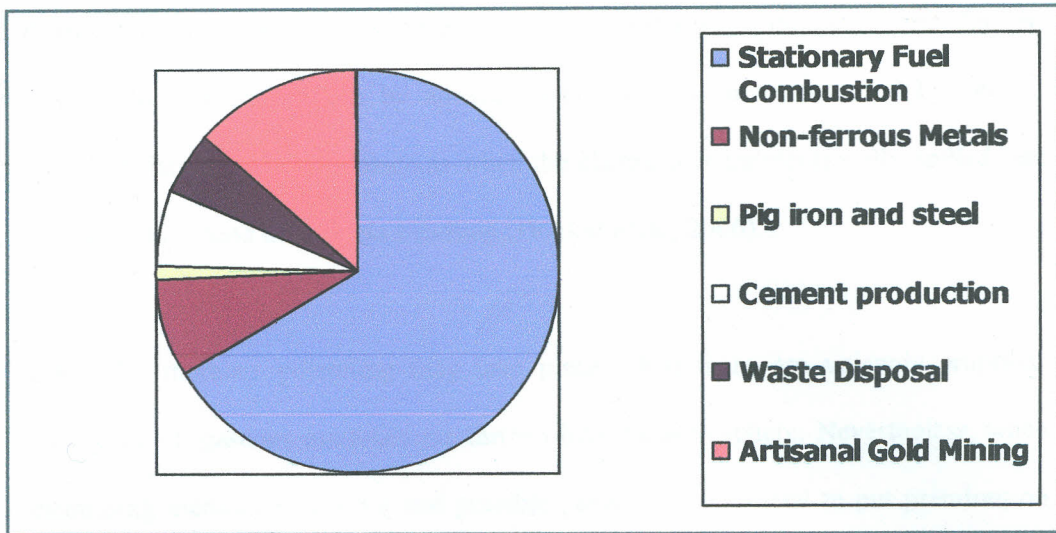
Source: UNEP, 2008

### 2.3: Global mercury pollution

The period between 1960 and 2000 has indicated unprecedented increase in amount of mercury in the atmosphere (UNEP, 2008). Mercury in the atmosphere comes from several sources although the major source is natural existence of mercury. Natural sources of mercury include oceans, rocks, volcanoes and forest fires. They release about 5207 tones of mercury annually in the atmosphere (Biswas *et al.*, 2008). According to Pirrone and Mason (2009), burning of biomass such as forest fires release 675 tones of mercury per year.

There are a number of anthropogenic activities that contribute to atmospheric mercury. The amount of mercury resulting from human activities in Figure 2.1 is approximated at 2503 tonnes, representing 1/3 of mercury in the atmosphere (Pirrone and Mason, 2009). Some of these anthropogenic sources are combustion in coal-fired power stations and chemical plants. Fossil fuel power plants emit about 1422 tonnes annually (Biswas *et al.*, 2008). The second anthropogenic contributor of atmospheric mercury is small scale gold mining. It produces 400 tonnes of mercury in the atmosphere per year (Donkor *et al.*, 2006). Mercury is also released into atmosphere

by the manufacture of chlorine using mercury cell chlor-alkali process. Finally, mercury exists in the atmosphere in form of compounds such as methyl mercury.



Source: Pirrone and Mason, 2009

**Figure 2. 1: Global mercury releases to air by source**

At country level, India and China are the leading source of mercury in the atmosphere. They account for 62% global emission of mercury. The two Far East countries are followed by Europe and America which combined produces 23% of mercury in circulation around the world (Pirrone and Mason, 2009). China's mercury emission from gold processing alone stands at 240 tonnes per annum (Gunson and Veiga, 2004). The existence of mercury naturally in the atmosphere and the additional amount from anthropogenic activities makes mercury poisoning likely. However, pollution from anthropogenic activities are four times likely to occur and harmful than pollution from natural existence (Pirrone and Mason, 2009).

Pollution from mercury first and foremost, happens when vaporized mercury is released into the atmosphere during combustion in coal fired plants and chemical plants. The second way by which mercury poisoning is likely to occur is when

mercury is discharged together with other waste into inadequate tailing ponds or thrown away into rivers and water ways. While in water ways, mercury is transformed into methyl mercury, eaten by aquatic species and in turn consumed by people. Finally poisoning can take place as when the chemical is unintentionally spilled into the ground because of reckless handling (Donkor *et al.*, 2006).

Naturally, mercury poisoning may take place when there are volcanic eruptions during which gaseous materials are thrown into the atmosphere. Nevertheless, when examining mercury poisoning and possible panacea, it is crucial to put premium on human activities that may compromise atmospheric cleanliness. Rapid industrialization that involve the use of fossils fuel and mining activities should be pinpointed for action if progress is to made in mitigating global poisoning from mercury. This is because; mercury pollution comes with adverse price tag involving ecosystem destruction and environmental degradation (Beinhoff and Veiga, 1997).

Poisoning and intake of mercury in human bodies takes place in subtle ways. The major source of mercury in human bodies is through consumption of sea foods contaminated by mercury (Harley *et al.*, 2003). This however has been under raging debate, a scenario that has seen scientists take divergent views on possibilities of poisoning accruing from fish consumption. Some have even negated the possibilities of poisoning from fish consumption. For instance, Harley *et al.* (2003) has been of the view that fish consumption cannot lead to mercury poisoning. This is because; mercury found in fish exists as methyl mercury and this form of mercury compound is generally excreted rapidly from human bodies through urine, faeces, saliva and sweat. This position received credence from a study done by Robinson and Schroff (2004) in

Seychelles Island where there seemed to be little effects from mercury despite massive consumption of fish by the population.

Mercury can also get into human bodies through atmospheric vapour. Chances that mercury will be taken in through ambient air are 80% more likely as compared to 10% oral chances (Donoghue, 2004). This has always remained a risk factor among small scale gold miners because blowtorching of mercury is done in open containers in closed houses making inhalation of vaporized mercury highly possible (Israel and Asiro, 2002). Apart from vapour in ambient air, mercury can be ingested via drinking water, and pharmaceutical vaccines.

There are occupational activities that can lead to mercury uptake by our bodies. These activities are mining and working in coal powered and chemical plants. The study conducted by European Union across Europe found high risks for mercury contamination among workers working in chlor-alkali plants than the population living near processing plant (Horvat, 2009). However, occupational poisoning of mercury is still an issue when the effects are combined with exposure to other toxic substances such as lead, cadmium and cyanide. These substances have wide application and use in industries as well as mining.

Exposure to mercury can equally occur at home. This stems from exposure to fluorescent light bulbs, thermostats, batteries, red tattoo dye, skin lightening creams and over the counter products such as contact lens fluids and neosynephrine and dental amalgams. This source of mercury poisoning is harder to address since it

exposes large population at risk in addition to essential role played by these home appliances.

Mercury poisoning from dental amalgams has elicited intense discourses and studies. The study carried out in Italy found high levels of mercury in urine of individuals who had mercury dental fillings than those who ate fish (Horvat, 2009). During chewing or biting, fillings from amalgam get into the mouth and this makes the prospects of inhaling or ingesting apparent. Lindh (2002) discovered in Sweden that human with amalgam fillings had elevated blood mercury levels (3 to 5 times). For example, individuals with dental amalgams had 3 to 5 times more mercury in their urine and 2 to 12 times more mercury in their tissues than those without amalgam fillings.

Once mercury is ingested or inhaled, it has colossal effects on human bodies. The effect of mercury uptake by humans is compounded by the fact that it is not very clear about its half life in human bodies. Studies have contradicting figure on half-life in human bodies. Some studies have put it at between 52 and 70 days (Lindh, 2002), while others put it at between 33 and 270 days (Robinson and Schroff, 2004).

A report by USEPA to congress indicated that exposure to mercury is influenced by both physiological characteristics as well as individual characteristics of the person. The report further pinpointed that in presence of concurrent disease, concurrent exposure to other toxic agents, altered nutritional status, genetic disparities in the way the agent is metabolized, and differences in biokinetics, or metabolic response that is determined by physiological status such as pregnancy or lactation in women, mercury poisoning and contamination is unprecedented feat and challenge (USEPA, 1997).

#### 2.4: Gold mining with mercury

Artisanal small scale gold mining contributes significantly to mercury emission (Nunes *et al.*, 2009). Gold is often extracted by amalgamating it with mercury. Small scale gold mining produces the second largest amount of direct anthropogenic emissions at 400 tonnes annually. This is because it is the main agent used to separate the gold from the mined ore or employing the amalgamation method of processing (Donkor *et al.*, 2006; Pirrone and Mason, 2009). Apart from the use of mercury, cyanide and carbon-in-pulp method can be used to process gold. Unfortunately, carbon-in-pulp method is unpopular among miners because of high cost required (Israel and Asirof, 2002).

In China, Gunson and Veiga (2004) found that the use of mercury using amalgamation process was always the first option among gold miners. This was even when miners knew of alternatives to the use of mercury. The reason advanced by the miners for their preference of amalgamation using mercury was that it is simple to use as well as requiring low initial capital investment. Similar views were echoed by the World Chlorine Council when it lamented about the slow pace in embracing alternatives to mercury use.

There is urgent need to devise alternatives to the use of amalgamation process using mercury in processing gold (USEPA, 1997). This is informed by immense health and environmental implication of using mercury as well as its inefficiency. Nunes *et al.*, (2009) found that 30% of the mercury used in amalgamation process to be lost to the atmosphere. The study also established amalgamation to be inefficient where less than 30% of pure gold is recovered from crude ore. The release of 30% mercury in the

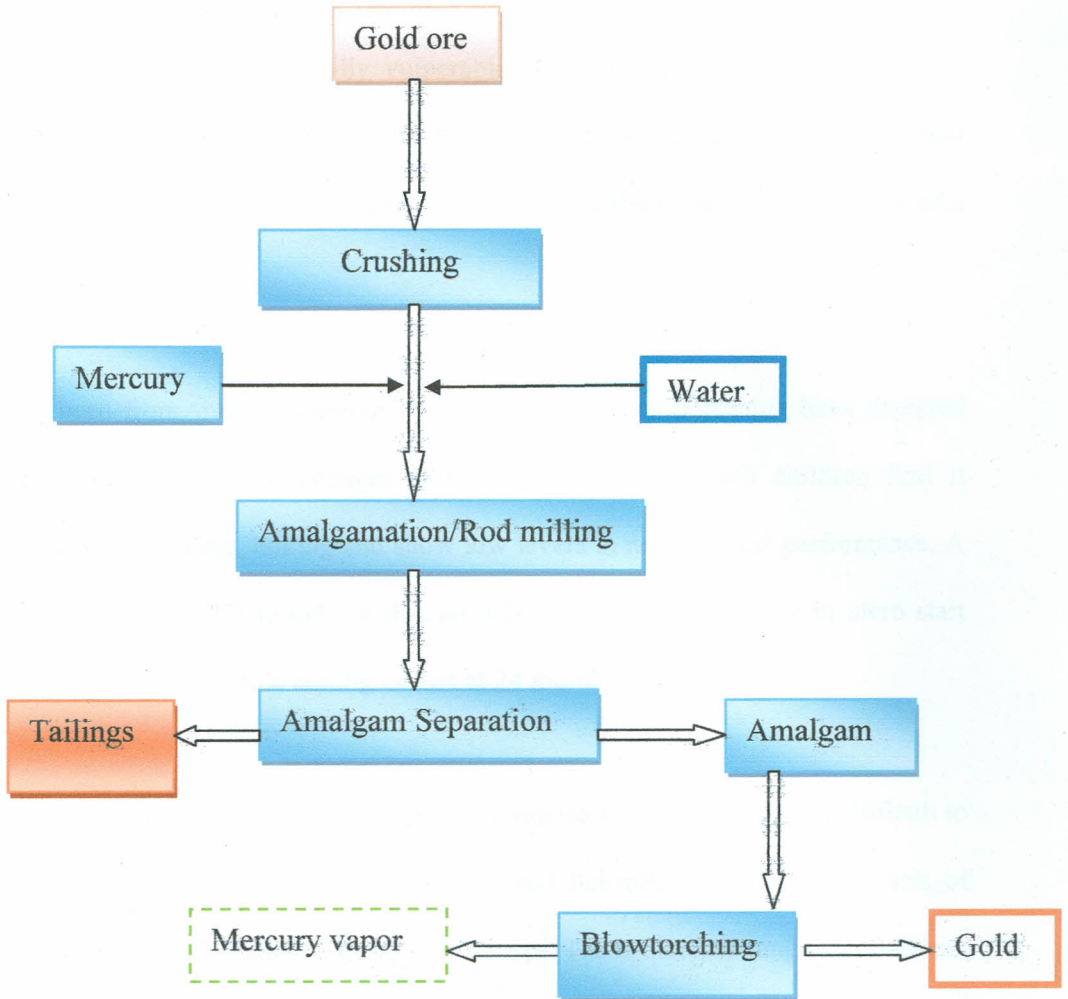
atmosphere is tremendous environmental catastrophe while 30% gold recovery makes the process not worthwhile economically. Horvat (2009) looked at the possibilities of alternatives to mercury in the processing of gold. He observes that the possible alternative to the use of mercury is to embrace mill-leaching with cyanide. He however found staggering cost as the major impediment to the adoption of mill-leaching process using cyanide. Although the use of mercury in gold processing appears inevitable as for now, there is need for sustained efforts to reduce the health effects associated with the use of mercury to gold miners. There is even more agent need to shed more light on potential ways of exposure to mercury.

### **2.5: Health effects of mercury use in mining**

Mining has long been acknowledged as being arduous and prone to injury and diseases (Donoghue, 2004). Mercury is popularly used in the processing of gold and studies have found out that small scale gold miners would opt for processing using mercury amalgamation process as shown in Figure 2.2 (Gunson and Veiga, 2004; Donkor *et al.*, 2006). According to Horvat (2009), artisanal gold mining can be a lifeline for many communities. However, the use of mercury in processing gold ore poses toxic threat. This situation is exacerbated by the fact that scientists have wavering answers to key questions related to long-term low-level mercury exposure, short term exposure or even chronic exposure.

When examining health effects of mercury use, it is imperative to look at longevity of exposure (Gunson and Veiga, 2004). In this realm, one can view effects of mercury use as long term, short term and prolonged exposure. The long term effects of

mercury include damage to central nervous system and kidney (Donoghue, 2004; Gunson and Veiga, 2004; Horvat, 2009).



Source: Modified from Israel and Asirof, 2002

**Figure 2. 2: Processing of gold ore using mercury**

On the other hand, short term exposure to mercury can cause chest pains, dyspnoea, cough, haemoptysis, impairment of pulmonary function and intestinal pneumonitis. Low level mercury exposure is known to cause fatigue, irritability, loss of memory, vivid dreams and depressions. However, this is apparent where there is long and sustained exposure to mercury (Gunson and Veiga, 2004).

The health effects of mercury exposure are first and foremost felt by an individual coming in direct contact with the vapour. However, if this individual is an expectant woman, the unborn life is equally vulnerable to poisoning. According to Crespo-Lopez *et al.* (2009), mercury causes development of defects in unborn embryos. This happens when methyl mercury is directly transferred to the fetus through the placenta affecting the CNS.

Children born from women previously exposed to mercury poisoning have depicted numerous developmental challenges (Roulet *et al.*, 1999). Such children find it difficult to start walking, talking and show low levels in neurological performance. A study by USEPA (1997) found out that an infant affected by mercury in utero start walking by 18 months while talking occurs at 24 months.

The health effects of mercury poisoning are immense and some time very difficult to assess (Lindh, 2002; Nash, 2004; Robinson and Schroff, 2004). Toxic effects of mercury spread across broad spectrum of diseases. These diseases range from autism, Alzheimer's disease, multiple sclerosis, Parkinson's disease, Neuro-developmental diseases, Nephrotoxicity and cancer (Nash, 2004). The effects of mercury toxicity on central nervous system are very pronounced. They include erythrim symptoms of shyness, emotional labiality, nervousness, insomnia, memory impairment and inability to concentrate (Lindh, 2002). Among patients suffering from Parkinson disease, mercury toxicity is manifested through tremor, ataxia, impaired hearing, tunnel vision, headache, fatigue, impaired sexual function and depression (Lindh, 2002). To the above symptoms, nausea, vomiting, diarrhea and colitis are experienced by those with gastrointestinal diseases. For those suffering dermal toxicity the signs

are allergic dermatitis, cheilitis, gingivitis, stomatitis and excessive salivation (Robinson and Schroff, 2004).

According to USEPA (1997), the effects of mercury toxicity are convoluted. This stems from the fact that mercury can exist in multiple valence and numerous chemical compounds. The adverse effects of mercury are felt in the form of methylmercury found in fish mainly on the nervous and reproductive systems. Infants are more vulnerable to toxicity of mercury and the effects will show signs of cerebral palsy, altered muscles tone and deep tendon reflexes (Robinson and Schroff, 2004).

The health effects of mercury poisoning are conspicuous but difficult to delineate. The major reason why it is difficult to delineate is that symptoms of mercury toxicity are also shown by alcoholics (Nash, 2004). The same symptoms can also be found among those affected by malaria (Gunson and Veiga, 2004). Horvat (2009) indicated that the effects of mercury exposure are still not fully understood. The study consequently observed that the development of effective strategies of combating any toxic consequences of mercury is required. This can only occur after precisely grasping comprehensive and in-depth knowledge about what mercury does to human bodies. This study assessed knowledge levels of miners and its relationships with health effects associated with mercury.

## **2.6: Safety and environment in AGM**

The employment, income and production generated from artisanal gold mining often come with significant costs to miners' and nearby communities' health, safety and environment (Gunson and Veiga, 2004). To curb all these, there has been heightened

call to outlaw mercury in the production of gold. This has hitherto remained elusive because the alternative technologies are expensive and require advanced skills to use. Curtailing mining activities will also come with massive economic effects from job losses and this is likely to exacerbate poverty among communities that derive income from gold mining. Income generated from gold mining was found to be Ksh. 5,000 to 10, 000 per month in Kenya (Dreschler, 2001; Hinton *et al.*, 2006). This income surpasses earnings accruing from peasantry farming and some jobs in civil service in Kenya. In China, Gunson and Veiga (2004) found that over 80 to 100, 000 million people to be earning their livelihood from small scale gold mining while the sector was contributing 60 tonnes of gold to national grid.

The realization about the essential role played by small scale mining has led to slight paradigm shift. The former position has been strong opposition with environmentalists and health experts leading the war. Currently, there is strong call to institutionalize safety measures as pertains to use and handling of mercury. According to Horvat (2009), the issue has already received considerable political attention and what remains was to dovetail it with practical measures. Donoghue (2004) noted substantial progress in controlling health hazards associated with mining and mercury use. He however singled out possible avenues that still warrant intervention as noise, trauma and exposure to chemical substances.

Legislation on mercury use has been identified as possible measures in addressing mercury poisoning. The European Union has promulgated law that will absolutely ban the import and export of mercury by the year 2011 (Horvat, 2009). This is aimed at addressing environmental and health effects of mercury use. The World Chlorine

Council (WCC) has also put in place mechanisms supported by legislation. It calls upon stakeholders in the sector to commit not to sell or transfer mercury cells. It is anticipated that this will reduce mercury use and emission by over 90 % (WCC, 2009). However, coming up with legislation and upholding its tenets are two different things. Beinhoff and Veiga (1997) established the existence of laws forbidding mercury use in Brazil. Despite the existence of laws, there was continued use of the chemical causing wanton destruction to the environment and ecosystem. There was little monitoring and enforcement of the legislation by the authorities vested with responsibilities to do so. In 1933, legislation was passed in Ghana to contain the use of mercury (Donkor *et al.*, 2006). This meanwhile failed to curb or deter mercury use among gold mines. This is again made possible by inability of local or national government to enforce or monitor legislation.

Safety measures to address mercury pollution should commence with understanding its movement in atmosphere (Pirrone and Mason, 2009). Knowledge on mercury circulation should however be verified by comprehensive understanding of its longevity in atmosphere (USEPA, 1997). Once this is mapped out, global treaties intended to trace, control and reduce use and emission can be put in place. Once the treaties and concessions on mercury use are in place, it can be followed by development and sharing of technical information that can be used by facilities to reduce mercury use and emissions (WCC, 2009). To buttress international concession on mercury use, legally sound binding instruments on mercury transfer should be enacted complimented by voluntary approaches among stakeholders.

Perhaps the hardest hurdle in ameliorating mercury harm on humans is addressing its uptake through seafood. This is the position taken by Crespo-Lopez *et al.* (2009). This is because of nutritional importance of fish. In areas where mercury is drained or washed into waterways, the possibilities of ending up in human bodies are undisputable. Environmentalist can respond to this by agitating for measures to clean wastes before they are drained in waterways and tight control on landfill waste. Risks springing from home exposure can be addressed by educating people about dangers of mercury use and contamination. The knowledge on health effects of mercury poisoning has been wanting. A survey by UNEP found low awareness of mercury poisoning in many countries (Horvat, 2009). Population's low awareness about mercury harm can cause undue apprehension. This was vividly captured in the study carried out by UNEP (2008) in Mongolia, where it was discovered that the inhabitants residing closer to mines using mercury were living in anxiety. These fear got a boost when the inhabitants of the area dramatically developed dermatologic complications. However, UNEP study found no relationship between skin complex ailments among the people and mercury (UNEP, 2008).

One major impediment to controlling mercury poisoning from small scale mines is that most of them operate illegally or informally (Donkor *et al.*, 2006; Gunson and Veiga, 2004; Nunes *et al.*, 2009). This makes it difficult to enshrine measures to curb poisoning. It also complicates efforts to get data on mercury poisoning (Israel and Asiro, 2002). Mines that operate formally or legally operate have fewer cases of accidents and injuries to workers. Horvat (2009) found low traces of mercury poisoning among workers and attributed this to sound occupational measures in industries to protect individuals against potential contamination.

## 2.7: Gender issues in gold mining

It has been estimated that 30% of the world's artisanal miners are women who play different roles although these roles are almost similar globally (Hinton *et al.*, 2006). Unfortunately, women are often overlooked by initiatives and measures aimed at streamlining and making the sector more lucrative. Donoghue (2004) observed that involvement of women in mining activities have its pros and cons. Positively, income generated from mining is directly used to improve the welfare of the family. On the other hand, women are more likely to work from home or are accompanied by their children to mines and by so doing exposing more people to hazards associated with mining.

Gunson and Veiga (2004) think that the number of women indulging in artisanal mining is higher than 30% projection. This is because apart from actual mining, women also double up as cooks, service providers, transporters and processors of the minerals. Cope (2000) while observing that there is limited data to ascertain actual number of women in sector has highlighted reasons why women are more likely to be employed in artisanal mining. First women are trustworthy and therefore reliable, they accept lower wage and rarely indulge in alcohol.

Although women are preferred as workers in mines, their out-put is low (Beinhoff and Veiga, 1997). A study found out women out-put to be 10 to 15 times less men's out-put (Cope, 2000). The reason for low women out-put is that they are likely to use rudimentary tools and be found working on low value/grade ores or even old mines.

Hinton *et al.* (2006) has identified the role of women in artisanal mining as labour-intensive activities (panning, crushing, grinding, sieving and washing). These activities come with a lot of physical health hazards. Blasting, drilling and cutting generate a lot of physical activities that can exacerbate spinal disorders. Women play crucial role when it comes to meeting family basic needs. Unfortunately, their income from mining is low. This has created fertile ground for prostitution around mines creating amenable environment for HIV/AIDS spread. Donoghue (2004) and Hinton *et al.* (2006) have examined invisible role of women in mining. They have shown high cases of prostitution around mining areas and increased cases of HIV/AIDS infection.

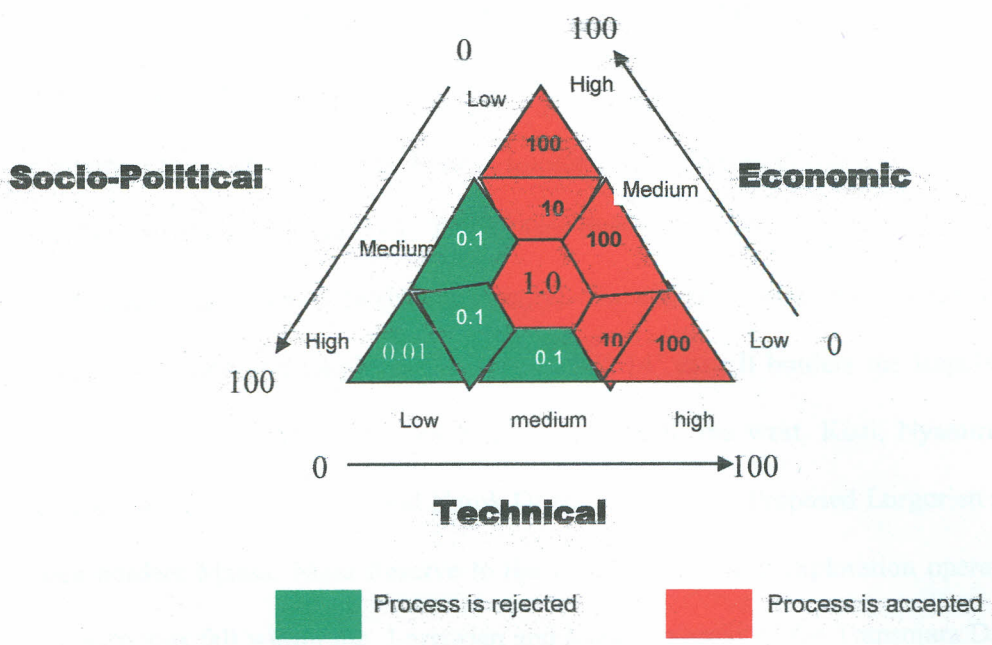
Women participate in mining for various reasons. Donkor *et al.* (2006) linked women participation to long historical tradition in West Africa, where in some countries like Burkina Faso, 90% of mineral processing activities are undertaken by women. Prolonged droughts that impact negatively on agriculture drives many people in mining activities. And because women are tied to their households through family obligations, they are left with limited options but venture into mining. Nevertheless, one looking at large scale mining sector will get high number of men as compared to women. This partly explains high representation of women in small scale mining sector. Large scale formal mining industry calls for advanced skills and training which many women may be lacking (Donoghue, 2004). Because of this, most troop to small scale mining sector as it does not require advanced skills.

The skewed nature of mining industry has seen women play second fiddle in most things. Less often, women are concession owners, mine operators, dealers and buying

agents or even equipment owners. This scenario can only be reversed when gender-sensitive technology assistance is put in place and equipping women with advanced skills including managerial and accounting (Hinton *et al.*, 2006). This can only take place if and when substantial information concerning individual women, age, status, wealth and health of both men and women are documented. This study looked at the health effects of mercury to both men and women involved in artisanal gold mining in the study area.

## **2.8: Conceptual framework**

The study employed Veiga and Meech's "Expert System for Risk Assessment for Mercury Discharge from Gold Mining Operations", or HgEX (1996). Conventional approaches that attempted to correlate natural variables with mercury biota levels relied on empirical regression models that often yielded poor bioaccumulation predictions (Håkanson *et al.*, 1988). The system can handle uncertain or vague data using fuzzy logic and neural network techniques. These procedures were intended to reduce the need for extensive monitoring programs and provide a preliminary diagnosis about bioaccumulation risk (Veiga and Meech, 1992). Despite sparse data and uncertainty, a diagnosis can still be made about the likelihood of a critical situation. As demonstrated in Figure 2.3, HgEX was developed to make risk assessments of mercury discharge from small-scale gold mining operations, primarily in the Amazon region by integrating information on biology, chemistry, geochemistry, and medical, social and political issues in order to evaluate mercury contamination for a single site or region (Veiga and Gunson, 2004).



Source: modified from Veiga and Gunson, 2004

Figure 2. 3: Expert system for risk assessment for mercury discharge

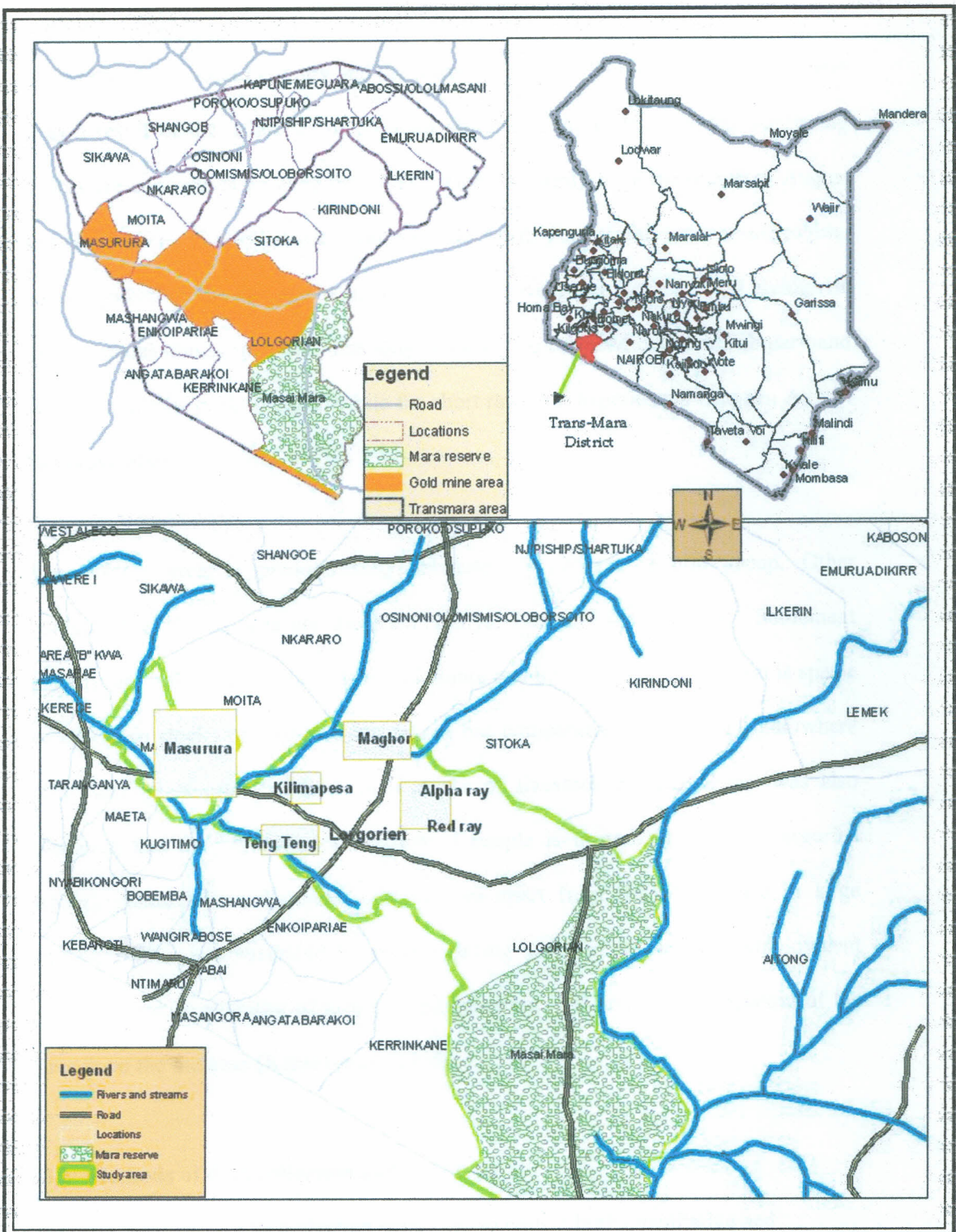
As the behaviour of workers depends on societal incentives and reactions, the definition of the level of acceptable mercury releases will differ with the values of the society. To map these differences, an alpha factor ( $\alpha$ ) is calculated based on socio-political, technical and economic aspects of a society which relate to the acceptance or rejection of mercury use in gold mining operations. A high alpha factor indicates acceptance of amalgamation practice and low control of mercury releases enforced by a society, which may be a country, a region or a city. For many regions in Africa, Latin America and Asia,  $\alpha = 1$ ; however, for Canada, where mercury is practically banned and well monitored by authorities, the alpha factor is much lower that, is 0.1 or 0.01 (Gunson and Veiga, 2004).

## CHAPTER THREE: METHODOLOGY

### 3.1: Location of the study

Lorgorien study area is located both in Lorgorien and Keiyan divisions of Transmara district as shown in Figure 3.1. Trans Mara district is situated in the south-western part of Rift Valley province (Narok County). The district lies between latitude  $0^{\circ} 50'$  and  $1^{\circ} 50'$  south and longitude  $34^{\circ} 35'$  and  $35^{\circ} 14'$  east. It borders the Republic of Tanzania to the south, Kuria and Migori Districts to the west, Kisii, Nyamira and Bomet Districts to the north and Narok District to the east. Proposed Lorgorien study area borders Maasai Mara Reserve to the East. For the gold exploration operations, the activities fall within the Lorgorien and Masarura areas of the Transmara District within the Special Prospecting Licence (SPL) area which covers  $325.4 \text{ km}^2$  (Karani *et al.*, 2008).

The topography of Trans Mara district comprises two major categories: the highlands which lie between 2,200 and 2,500m above the sea level and the plateau which rises from 1,500 to 2,200 m above the sea level. The highland areas are the main source of permanent and seasonal rivers in the district. The major rivers which originate from these areas are the Mara River and its tributaries Moor, Enkare, Entituak, Shartuka, Orerai and Siteti draining into Lake Victoria. The plateau covers the eastern part in Kirindoni Division and the southern part in Lorgorien Division. Parts of Maasai Mara, Murgan, Soit in Kirindoni Division, Masurura in Keiyan Division, Kerinkan, Olopikidogoe and Angata Barikoi in Lorgorien Division are also part of the plateau. The terrain both on the highlands and plateau permits agricultural and livestock activities. Crop production is concentrated on the highlands while livestock development takes place on the lower grounds on the plateau (GoK, 2003).



Source: Modified from Karani *et al.*, 2008

Figure 3. 1: Location of the study area

The district enjoys medium temperatures ranging from 14.8°C to 20.3°C. The highest temperatures occurs in February and the lowest June/July. This range of temperatures is as a result of the influence of the high altitude in the district. Other modifying factors are cool winds blowing from Lake Victoria mainly from the month of August and November and also between February and April. The rainfall amount and regime are influenced by the passage of Inter-Tropical Convergence Zone (ITCZ) giving rise to a bi-modal rainfall pattern. The long rains are experienced between February and June reaching its peak in April, while the short rains are experienced between August and November (GoK, 2003).

The project area is predominantly inhabited by Maasai ethnic group. Other communities in this area are the Kisii, Luhya, Luo and the Kipsigis. Settlement patterns are influenced by land use, land tenure and urbanization. Settlement is sparse where large stocks of livestock are reared but comparatively dense in areas where crop farming is practiced and small stocks of livestock are reared. It was also observed that the highest concentration of people is in and around the Lorgorien trading centre where the other communities apart from the Maasai are in large numbers. This is contributed by people getting attracted to business, employment opportunities, availability of services and economic welfare. The population of the area is on the increase (Karani *et al.*, 2008).

### **3.2: Methods of data collection and data type**

Several methods of data collection were used to collect both quantitative and qualitative data as follows;

### **3.2.1: Methods of data collection**

The study relied on both primary and secondary sources of data to obtain information on the health effects of mercury used by artisanal gold miners in Lorgorien, Trans-Mara district, Kenya. The sources of primary data included the key informants and the small-scale gold miners and processors in the study area. The secondary sources of data were; department of mines and geology, Lorgorien sub-district hospital, Transmara county council, district public health office, water services board, National Environment Management Authority (NEMA), Kenya National Bureau of Statistics (KNBS) and the existing research literature on small-scale mining.

### **3.2.2: Primary data**

The primary methods of data collection used in this study were; interviews, observation and photography. In particular, interviews involved use of questionnaires and interview guides whereas observation and photography consisted observation checklist and digital photography respectively. The questionnaires contained both open and closed ended questions and were administered to systematically sampled households. The questionnaire explored the household characteristics, miners' awareness on mercury health impacts, socio-economics, gender issues and concerns about mercury use in small-scale mining in the area.

Interview guides that constituted lead questions were given out to key informants, namely government officials including division officers, Moyoi and Masurura locations chiefs and assistant chiefs, mines and geology department, county council of Transmara, public health officers, water officer, NEMA officer, Lorgorien sub-district hospital administrator, chamber of mines and representatives from the licensed gold

mining company in the area. The researcher explored the opinions and concerns in regard to artisanal gold mining activities in the area.

### **3.2.3: Secondary data**

Secondary data was collected by means of literature review through which objective and systematic inferences from books, articles, journals, and internet search. Literature on the artisanal mining of gold using mercury and its associated health effects in various study areas was sought. Health records were also obtained from Lorgorien sub-district hospital to provide more inferences on the mercury exposure in the study area.

### **3.3: Research design**

The study employed descriptive/diagnostic study design which is a scientific method that involves observing and describing the subject to obtain an overview of the subject (Kothari, 2004). This study looked at the association between the use of mercury in artisanal gold mining and the health effects in Lorgorien area.

This resulted in both qualitative and quantitative data. Qualitative data were gathered using key informants guide, observation checklist (Environmental Health Inspection sheet) and photography while quantitative data were obtained from the administered questionnaires and clinical examination of exposure to mercury from miners.

### **3.4: Variables**

The study endeavored to determine different factors associated with AGM including both dependent and independent variables in the Lorgorien licensed mine area,

Transmara district. Dependent variable in this study was the associated health problems of mercury exposure to artisanal miners. This was analyzed further with knowledge, social, environmental, economic and legislative framework. Independent variables included sex and roles in artisanal gold mining.

### **3.5: Data collection techniques and sample size**

The study used the following techniques to determine the respondents;

#### **3.5.1: Target population**

The study was undertaken within Moyoi and Masurura locations in Lorgorien and Keiyan divisions of population totaling to 10,574 persons (KNBS, 2005). Inclusion criteria were restricted to persons involved in artisanal gold mining activities as a source of livelihood in the study area. An exclusion criterion taken into account non-gold miners found in Lorgorien mine area.

#### **3.5.2: Sample size**

$$\begin{aligned} \text{Sample Size} &= Z^2 * (p) * (1-p) / SE^2 \\ &= 1.96^2 * 0.15 * 0.85 / 0.05^2 = 195.92 \text{ that is, } 196 \text{ respondents} \end{aligned}$$

Where:

Z = Z value (that is 1.96 for 95% confidence level)

p = percentage picking a choice (15% of study population are engaged in AGM)

SE= Standard Error

#### **3.5.3: Sampling techniques**

Systematic sampling technique was utilized in this study. A list of 1,506 small-scale gold miners and processors was obtained from the miners' welfare. Since the study

sample was 196, a sample frame of 8 miners was used to identify the respondent. That is, an interview was conducted to every eighth miner or processor in the study area (Mugenda and Mugenda, 1999, 2003; UNCRD, 2004).

#### **3.5.4: Construction of research instruments**

Research instruments were developed with intention of addressing particular objective, research question and consequently hypothesis. Doing so was significant since it created consistency and reduced biasness that were likely to enhance study reliability. The questionnaire contained both structured and unstructured questions under the guidance of principal researchers in meeting the study objectives. The corrections and comments were incorporated into the final data collection instruments based on validity, reliability and pilot study.

##### **3.5.4.1: Pilot study**

The constructed questionnaires were pre-tested in the pilot study. This kind of test run revealed unanticipated problems with question wording and instructions to skip questions. It also helped to see if the interviewees understood the questions and gave useful answers. Comments and any issue raised were incorporated before the final administration of the questionnaire.

##### **3.5.4.2: Validity**

The study instruments were validated through the application of content validity procedures. Content validity is usually established by content experts who establish evidence by looking for agreement by judges (Mugenda and Mugenda, 1999). In

connection to this, the researcher established content validity by seeking expertise from the supervisors while developing and revising the research instrument.

#### **3.5.4.3: Reliability**

Reliability of the instruments is the level of internal consistency or stability of a measuring device. An instrument is reliable when it can produce the expected results (Mulusa, 1998). In this study, the instrument reliability was attained through pilot study and content validity.

#### **3.5.5: Data collection**

Collection of data involved the use of the following tools;

##### **3.5.5.1: Environmental health inspection**

The mine processing area was visited for two weeks. Consent was sought from the respondents while permission was obtained from the relevant government agencies as directed by national council for science and technology (NCST). Lorgorien mining area inspection was done using the observation checklist of possible hazards in the amalgamation process. This covered; condition of the working area, housekeeping sanitation/welfare, hazards and safety regulations for protection of workers from hazards or accidents.

##### **3.5.5.2: Health records**

Health records for the past financial year (July 2009-June 2010) were provided by the Lorgorien sub-district hospital administration. With the assistance of a clinical officer, the study identified cases related to small-scale gold mining in the area including

carbon and mercury poisoning, skin infections, respiratory diseases, typhoid, rheumatism, mine accidents and mercury exposure.

### **3.5.5.3: Miners health assessment**

All the 196 systematically sampled miners and processors were subjected to an interview administered questionnaire however, 163 (83%) satisfactorily responded to the instrument. The questionnaire gathered general information; demographic data; occupational history; history of occupational accidents; knowledge, attitude and practice on use of protective clothing; and, clinical history and examination of exposure to mercury.

Sub-clinical exposure: the miners were asked for the presence or absence of symptoms of sub-clinical exposure to mercury as outlined in various literature by two trained health workers. The symptoms were grouped into four categories viz; Central Nervous System (CNS), renal toxicity, gastrointestinal symptoms, and dermal toxicity. Clinical exposure; health record for the past financial year was obtained from Lorgorien sub-district hospital and analyzed for specific exposure to mercury.

## **3.6: Data management, analysis and presentation**

In the study, the following were done;

### **3.6.1: Data coding, editing and cleaning**

After collecting data using both primary and secondary sources, it was coded, edited and verified before entry into the statistical package for social science (SPSS) version 16 software for analysis. Coding is the process by which responses are classified into

meaningful categories. In this study, numbers were assigned to observations in order to develop a coding scheme. The scheme was compiled for each of the variable in a codebook. Each variable was identified by its name (for example A1), brief question content, coding scheme employed (values) and which values stand for a missing value. Data editing occurred before and after coding phase. The researcher checked for errors and omissions making sure that all questionnaires had been completed as required. The researcher further proofread the data on computer to catch and correct errors and inconsistent codes.

### **3.6.2: Data analysis**

The data collected were analyzed both qualitatively and quantitatively. This was significant in examining the effects of artisanal gold mining using mercury. The data accruing from questionnaires filled by the sampled households was subjected to calculation of simple descriptive statistics such as frequencies, means and percentages. Any significant difference observed after descriptive analysis was subjected to further tests using Correlation, Regression and Binomial tests. The SPSS (version 16) programme was used to carry out statistical analysis. More information resulting from interviews with officials and key informants (officials of agencies concerned with gold mining) was transcribed into written texts by merging the notes taken during the interviews into coherent descriptions and analyzed qualitatively.

#### **3.6.2.1: Descriptive analysis**

Data on the knowledge of miners about health effects of mercury, extent of mercury health problems and socio-economics of Lorgorien residents was analyzed using descriptive statistics. Descriptive statistics involve interpretation of data in words,

graphs/charts or tables that further summarize variables in an order or sequence that answers available questions.

### **3.6.2.2: Inferential statistics**

Statistical inference is the process of drawing conclusions from data that are subject to random variation, for example, observational errors or sampling variation. In the study, the following inferential statistics were employed;

Correlation analysis was used to test for the relationship between health problems of mercury of the miners and morbidity data obtained from the Lorgorien sub-district hospital.

Regression analysis is a statistical tool for the investigation of relationships between variables. Usually, the investigator seeks to ascertain the causal effect of one variable upon another (Payne and Payne, 2002). The study used regression analysis to determine the relationships between mercury health problems and other variables such as the duration as small scale miners, age and gender of the study population.

The binomial test of significance is an exact probability test, based on the rules of probability, and it is used to examine the distribution of a single dichotomy when the researcher has a small sample. Binomial was used to compare the observed frequency in each category of the dichotomous variable with expected frequencies from the binomial distribution of health effects associated with AGM.

## CHAPTER FOUR: RESULTS AND DISCUSSIONS

### 4.1: Introduction

In this chapter, findings, results and discussions are presented and interpretation done guided by the study objectives. It is important to take note that the results and discussions are based on 163 responsive questionnaires and not the sampled 196. During data cleaning and verification, 33 respondents were found out to be non-responsive due to incompleteness and inconsistencies.

### 4.2: Demographic characteristics of the miners

The study shows that 91 of the 163 respondents representing 56% were male while the rest (44%) were female as summarized in Table 4.1.

**Table 4. 1: Demographic characteristic of the respondents**

Demographic characteristic (n=163)	Category	Frequency	Percentage
Sex	Male	91	56
	Female	72	44
Level of education	None	17	10
	Primary	120	74
	Secondary	24	15
	Post secondary	2	1
Age	Below 18	3	2
	18 to 35	104	64
	36 to 55	48	29
	Above 55	8	5

Table 4.1 shows that more male than female were involved in small scale gold mining. In this study, education was categorized under formal education into pre-primary, primary, secondary, youth polytechnics, middle level colleges and university. As found out in the pilot study; pre-primary was not recognized by the respondents, some had never attended any educational institution and limited response was obtained after secondary education. Hence, the study categorized education into; none (persons never attended school), primary, secondary, and tertiary (persons with qualification above secondary). At least 73% of respondents attended primary level of education, 14% enrolled in secondary schools and merely 1% had post-secondary training.

Most of the miners were below 35 years, representing 64% of the study population. Only 2% were considered underage that is, below 18 years of age while 62% were between 18-35 years. Those reported to be between 36 to 55 years were 29% and a mere 5% were found to be above 55 years of age. Age is a crucial resilience factor, especially as regards to some terminal diseases. Age also determines intervention measures as observed in some infection. Individuals below 35 years represent sexually active group vulnerable to HIV/AIDS and other sexual related illnesses.

Those undertaking gold processing were 49%, but 21% reported processing as well as actual on-site mining of gold. The results summarized in Table 4.2 indicate processing to be a dominant activity. The processing of gold is done using mercury through amalgamation method. In this process, 30% of the mercury is lost in the atmosphere. While in the atmosphere, mercury can be inhaled by both miners and people of up to one kilometer away. Individuals involved in gold processing are inevitably exposing

themselves to mercury poisoning, with its associated effects. Those engaged in exploration and digging sites to get gold handle drilling, blasting and cutting equipments. They produce noise caused by crushing. In addition, mines collapse burying people alive and cause injuries.

The study further revealed that 47% of the males were engaged as gold processors, 14% as miners and, 39% as both processors and miners. The study also established that almost all females interviewed (99%) worked as processors. Women are at great risk in mining as almost all deal directly with mercury in the processing of gold. This scenario can be explained by the physical and distant nature of mining fields as compared to processing which women can do while attending to other domestic duties.

Houses are generally categorized into three categories as follows; permanent, semi-permanent and traditional houses. The grouping in the study was done using construction material of the wall. Permanent considered brick, block, or stone-walled houses; semi-permanent involved cemented-mud walls; and, traditional houses were houses with mud walls only. The type of a house occupied is a good indicator of the standard of living or poverty levels. As regard to the type of house occupied by the miners, 15% resided in traditional houses, 80% in semi-permanent houses and 5% occupied permanent houses. With mining presenting majority residing in semi-permanent houses, it signifies that mining has moderate social and economic benefits.

House can be occupied by the owner or rented by the household for habitation. In the study area, ownership symbolizes locals while tenancy reflects to immigrants brought

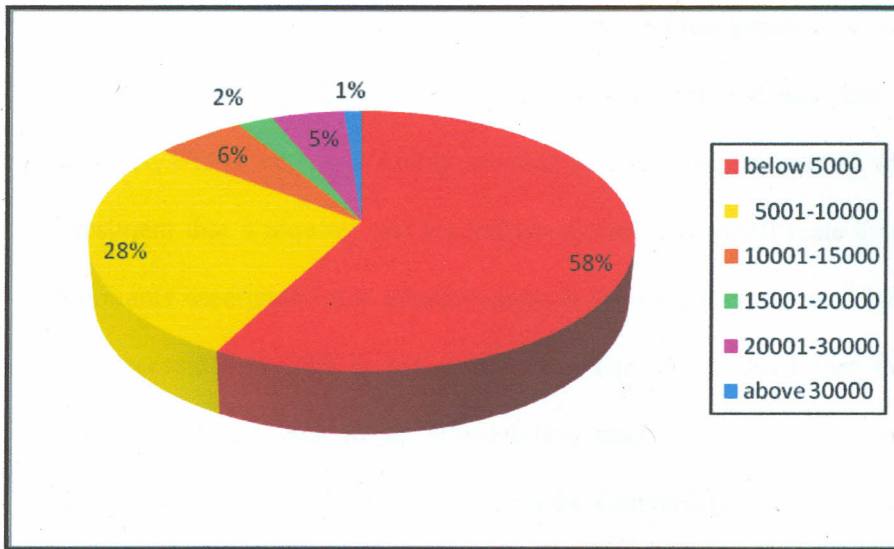
about by the widespread small scale gold mining activities. Up to 88% of sampled population was tenants and only 9% said they owned the house in which they were residing. High tenancy percentage means that most of the people interviewed were immigrants in the area a fact confirmed by both miners and several stakeholders. Mining attracts people from various backgrounds because of its economic value. The ability of the miners to rent a house also signifies good economic return.

**Table 4. 2: Main activity in the mining, housing and age of miners**

Demographic characteristic (n=163)		Category	Frequency	Percentage
Main occupation	Male	Miner	13	14
		Processor	43	47
		Both	35	39
	Female	Miner	1	1
		Processor	71	99
		Both	0	0
House type		Traditional	24	15
		Semi permanent	131	80
		Permanent	8	5
Ownership status of the house		Owned	15	9
		Rented	144	88
		Others	4	3

Kenya aims to create a socially just and equitable society without extreme poverty as spelt out in her National Development Vision 2030. The ultimate objective is to improve the livelihoods of the poor. Kenya's average annual income per person is estimated at KShs. 45,447.00 (US\$ 600) that corresponds to KShs. 3,787.25 (US\$ 50) monthly (GoK, 2007). Average monthly income of the small scale miners of

Lorgorien is KShs. 6,426.50 (US\$ 85). Small scale mining is paying fairly well- almost double the average monthly income per person. Key informants indicated figures of between KShs. 10,000-20,000 (US\$ 135-270) monthly to be on the lower side of miners' monthly income. Figure 4.1 summarizes the approximate income of the miners by category.



**Figure 4. 1: Approximate income earned by miners**

#### **4.3: Knowledge of mercury problems in Lorgorien mine area**

To achieve this objective; data on mercury use in gold processing, knowledge about mercury toxicity, precautionary measures against mercury effects, and knowledge about reduction of mercury effects were pursued.

##### **4.3.1: Mercury use in gold processing**

Approximately 85% of the respondents indicated to use mercury in their operations while the remaining 15% were solely involved in gold ore digging. About 30% of mercury used for processing gold is lost to the atmosphere. Key informants explained that amalgamation is less efficient and less than 30% of pure gold can be recovered.

No substitute method exists in the area for small-scale miners. However, the licensed gold mining companies that have operated in the area have used Carbon-in-pulp method. The companies even bought tailings from small scale miners for further processing thus reaffirming the ineffectiveness of amalgamation. According to Israel and Asirot (2002), an alternative to amalgamation is Carbon-in-pulp (CIP) method of processing gold that involves cyanide. This method can process the slurry produced by amalgamation or the milled ore coming from the rod and ball mills directly. However, CIP is not used widely in small-scale mining because of the high cost of investment that it requires and the individual nature of small scale gold mining. Key informants ascertained that amalgamation is the only method used by the miners in the processing of gold in the study area. The study noted that the respondents preferred mercury due to its affordability, easy to use and lack of alternatives. Mercury is not readily available in the area. Conversely, most of the miners (92%) embraced need for an alternative to mercury. Noteworthy is the desire for change, alluded to miners' past experiences with licensed mine companies.

#### **4.3.2: Knowledge about toxicity of mercury**

Knowledge about toxic effects of mercury is a precursor in ensuring cautious and vigilant handling. About 64% had little knowledge on the toxic effects mercury. The remaining 36% had no knowledge threshold on toxicity effects of mercury. None of the respondents indicated to have adequate knowledge on the toxic effects of mercury. At the processing area, use of unprotected hand to stir ore mixture with mercury was widely observed as shown in Plate 4.1. Children were allowed to play on heaped tailings. Mercury spills were witnessed in the measuring of mercury for processing. 78% of the households indicated to carryout indoor blowtorching. The houses are not

adequately ventilated coupled with limited use of protective respiratory equipments. Key informants highlighted a case in which a whole family was poisoned by mercury vapour as a result of indoor blowtorching.



**Plate 4. 1: Gold processing with mercury without using protective clothing**

The study affirms assertion by Telmer (2008) that low awareness on mercury toxicity is responsible for its wide usage (Telmer, 2008). Several studies have also identified the greatest challenge facing mercury use as low awareness (Crespo-López *et al.*, 2009; Horvat, 2009; Pirrone and Mason, 2009).

#### **4.3.3: Precautionary measures taken by the miners against mercury exposure**

Precautionary measures protect miners and the community from mercury exposure, is a core factor in preventive health care. As emphasized in Kenya's vision 2030, preventive health care reduces disease burden while stimulating economic and social development. Only 48 (29%) of the households indicated existence of measures against mercury poisoning in their working sites. Large proportions (71%) of the respondents remain at risk to the toxic effects of mercury used for processing gold. Notable among precautionary measures in Lorgorien mine area are protective gears (40%), outdoor gold blowtorching (22%) and use of tailing ponds (38%) in the disposal of wastes. Protective gears involved wearing of masks, respirators, boots, goggles and gloves. Key informants validated the results by affirming that few of the

miners use protective wears during their mining operations. Some of the protective equipment are worn out and not regularly replaced as stipulated in occupational health and safety regulations. Use of protective gears was further classified into complete or partial utilization. None of the respondents cited complete utilization of the equipment. They indicated either owning gumboots, masks, respirators, gloves or goggles. This supports Gunson and Veiga (2004) caution that it is not just wearing protective gears that can mitigate mercury exposure. The protective gears are not calibrated in a manner that does not allow seepage of mercury.

Outdoor blowtorching reduces high exposure to mercury vapor to the processor and their families. Ironically, merely 22% of the respondents acknowledged to be carrying out their blowtorching activities outdoor. Incidences of mercury poisoning have been witnessed in the study area as highlighted by key informants. Notable is a case in 2007 where a whole family of 6 was poisoned and died. This was recognized to have accelerated the adoption of outdoor blowtorching or indoor blowtorching in uninhabitable stores. The exposure to mercury vapour is further complicated by not using respirators. There is need to carry out blowtorching in open or highly ventilated rooms, a fact that was also asserted by Nunes *et al.* (2009) and Horvat (2009). Nevertheless, gold panning as displayed in Plate 4.2 continue to be done indoor or outdoor by miners as witnessed during the fieldwork. In addition, use of raised chimneys is important in ensuring mercury vapour is emitted higher thus minimizing health effects due to reduced intake by human beings at high levels.

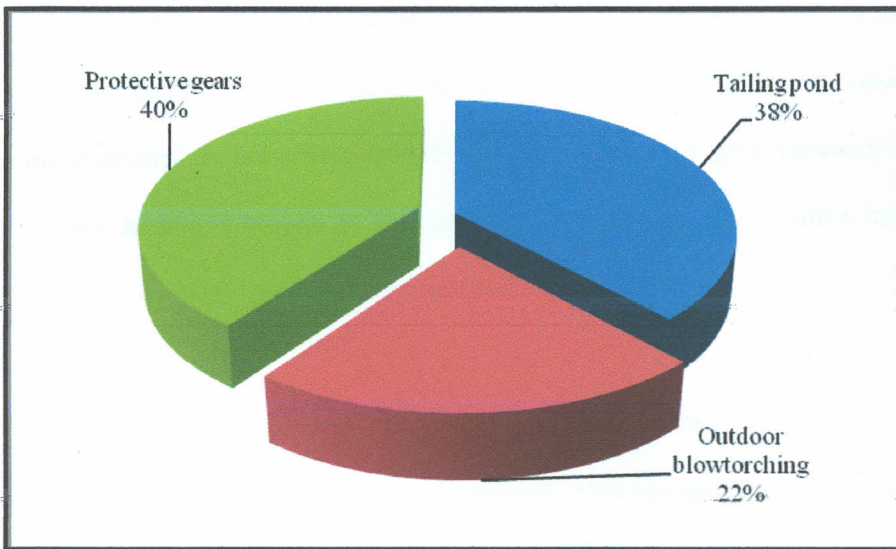


Release of mercury vapour thus putting miners at risk of mercury poisoning

**Plate 4. 2: Panning of gold with charcoal**

Gold processing by artisanal miners in Lorgorien reminiscent of other processing releases both solid and liquid wastes. Tailing ponds are important in disposal and management of wastes from artisanal mining as emphasized by 38% of the respondents. However, major problem exists in their planning and management. Tailings contain up to 20% of mercury. In the study area, the rock sludge is heaped in an open ground. These are often washed by surface runoffs or storm water causing mercury pollution in the ecosystem. Tailing ponds in the mine area are haphazardly dug by individuals. Most of them are health hazards as are left open, unfenced or untreated. Tailing ponds in Lorgorien processing area are nuisance. Miners have several ponds located close to each other without due consideration to human and animal safety. The tailing ponds are considered breeding ground for mosquitoes and other organisms that may spread diseases. The tailing ponds are sometimes flooded by runoffs thus polluting water sources. Key informants stressed that high malaria prevalence in the study area is associated with the existence of several tailing ponds.

Most of the miners operate individually or as a family unit. This makes it very difficult to put in place corporate mechanisms to alleviate health or environmental ramification. In this realm individual measures like wearing protective gears and outdoor working are most vital approaches, as shown in Figure 4.2. Nevertheless, there exist other measures not only to circumvent mercury poisoning but absolutely replace the use of mercury and amalgamation processing in refining gold.



**Figure 4. 2: Percentage of precautionary measures taken by miners against mercury**

#### **4.3.4: Knowledge about reduction of mercury pollution**

Use of appropriate technology is important in minimizing emissions of mercury into the environment thus reducing toxic effects. There are other methods that can be used to process gold with limited environmental or health effects when compared to amalgamation process. Ironically, 96% of miners still observed that amalgamation would be their first option given alternatives. High approval of amalgamation is not attributed to the environmental or health effects of amalgamation process. Alternatives to mercury especially amalgamation process exist. However, the major deterrent factors are the high cost and inadequate technical skills to adopt new

technologies in the area. Mercury is not easily accessible in the area as expressed by 71% of the study. Only 9% of the respondents agreed to have obtained skills in gold mining. The skills were obtained while working for large mining companies in the area. The available technologies are feasible in large scale as demonstrated by Kilimapesa Gold (Pty), a licensed gold mining company in the area. About 40% of small scale miners indicated to rely on abandoned low grade pits, colluviums and laterite deposits. Abandoned mines are health hazard and weak making many people to avoid them. Above 82% of the respondents acknowledge to make frequent improvements in the amalgamation process to increase gold recovery and reduce mercury emission. However, key informants doubted if any tangible improvements have been adopted by the mining populace.

Acquisition of adequate and up to date skills in gold processing can play a great part in reducing mercury emissions. In Lorgorien, 51% recognized having acquired skills from close relatives and 46% got it from friends. About 3%, who are pointed out to have been trained by the mining companies who mined in Migori gold belt. The skills are obsolete and unsustainable. Key informants explained that most of the miners are younger generation who were born or came along with mining parents. Similar findings were unearthed by Donkor *et al.* (2006) in Ghana where it was established that mining is a family heritage. Gold processing as well as actual mining is a generational pre-occupation, passed from parents to children. This means we are going to have generations that have been exposed to mercury for many years. It also trenches challenges associated with exposure to mercury, as the effects may be handed down generation. This raleigh may culminate in genetic mutation and deformation.

#### **4.4: Health effects associated with artisanal gold mining**

The study on this objective demanded vivisection into accessibility to public facilities, perceived sickness accruing from gold panning, physical injuries, infections of parts of body and incidences of death.

##### **4.4.1: Accessibility to health facilities by miners**

Access in this study refers to proximity to health facilities and does not include quality health care and availability of specialized medical personnel. Most of respondents (93%) were able to seek treatment in the available health facilities and only 6% seemingly could not easily get to health facility for treatment. Even though the health facility is less than 2km from the gold processing area, gold ore digging take place up to 15km away. Most mines are situated in remote and less accessible areas with no public health amenities. Reporting of injuries and subsequent treatment become grave challenge. Key informants affirmed that at times, the injured arrive in health facilities even three days later and the prognosis of the injuries might have changed. Amutabi and Lutta (2001) noted that access to health facility is significant watershed in rolling back the health effects of mining. Ideally, it allows monitoring of health effects of mining on people and also avails empirical data about health challenges.

##### **4.4.2: Health effects perceived to be emanating from mercury use**

Dose-response to mercury exposure on human health is associated with several diseases. The symptoms were grouped into the following four categories; central nervous system (CNS), renal toxicity, gastrointestinal symptoms, and dermal toxicity. Those who were identified to exhibit symptoms of central nervous system were 56%,

renal toxicity presented 21%, dermal infections recorded 17% and gastrointestinal complications recorded 7% as presented later in table 4.8. The duration of exposure and concentration levels provide the difference in ailments. These are complications popular among patients suffering from mercury poisoning. Seemingly central nervous system ailments ranked highest. These ailments differ based on duration to mercury exposure. Binomial test specified in Table 4.3 on the four groups of symptoms revealed interesting results.

**Table 4. 3: Symptoms of mercury exposure**

Symptoms	Category	Counts	%	Binomial test		Conclusion
				Observed Proportion	P-value (2-tailed)	
Central Nervous System (n=163)	Yes	91	56	0.560	0.158	accept $H_0$
	No	72	44	0.440		
Renal toxicity (n=163)	Yes	34	21	0.210	0.000	reject $H_0$
	No	129	79	0.790		
Gastrointestinal (n=162)	Yes	12	7	0.070	0.000	reject $H_0$
	No	150	93	0.930		
Dermal toxicity (n=163)	yes	28	17	0.170	0.000	reject $H_0$
	No	135	83	0.830		

Symptoms of the central nervous system were not significant with a P-value of 0.158 thus accepting the null hypothesis on the diseases of CNS. Contrary, differences exists on the renal toxicity, gastrointestinal infections and dermal toxicity symptoms with a p-value of 0.000 hence null hypothesis rejected. Therefore, numerous health effects are associated with mercury in the study area. The results provide enough evidence to reject the null hypothesis ( $H_0$ ) and conclude that there are widespread health effects of mercury in the study area.

#### 4.4.2.1 Relationship of the duration taken as AGM with health effects

The study further looked at the association existing between the duration of respondents in mining activities and the corresponding health effects as summarized in Table 4.4.

**Table 4. 4: Relationship of health effects with duration in small scale miners**

Model		Sum of Squares	df	Mean Square	F	Sig.
CNS	Regression	2.169	1	2.169	9.181	0.003
	Residual	38.028	161	0.236		
Renal toxicity	Regression	0.651	1	0.651	3.993	0.047
	Residual	26.257	161	0.163		
Gastro-intestinal	Regression	0.006	1	0.006	0.091	0.763
	Residual	11.105	160	0.069		
Dermal toxicity	Regression	0.212	1	0.212	1.487	0.225
	Residual	22.978	161	0.143		

It was found out that significant difference exists on the health effects of CNS (0.003) and symptoms of renal toxicity (0.047). The study concludes that the symptoms of CNS and renal toxicity are influenced by the time taken as small scale miner in the study area. However, symptoms of gastro-intestinal infections (0.763) and dermal toxicity (0.225) were insignificant and portray no influence by the duration of involvement as small scale miner.

#### 4.4.2.2 Relationship of gender and health effects amongst AGM

Gender roles in artisanal mining activities results into different health challenges amongst men and women. Table 4.5 presents significant relationship among the symptoms of health effects with gender apart from the issues of CNS (0.313).

**Table 4. 5: Relationship of health effects with gender**

Model		Sum of Squares	df	Mean Square	F	Sig.
CNS	Regression	0.254	1	0.254	1.024	0.313
	Residual	39.942	161	0.248		
Renal toxicity	Regression	2.023	1	2.023	13.091	0.000
	Residual	24.885	161	0.155		
Gastrointestinal	Regression	0.469	1	0.469	7.058	0.009
	Residual	10.642	160	0.067		
Dermal toxicity	Regression	1.009	1	1.009	7.323	0.008
	Residual	22.181	161	0.138		

Indicators of renal toxicity, gastro-intestinal infections and dermal toxicity produced significant values of 0.000, 0.009 and 0.008 respectively. The results attest to the fact that gold diggers and processors are faced by different health cases.

#### **4.4.2.3 Relationship of age with health effects amongst AGM**

In the study, relationship of health effects with age was keenly looked as presented in Table 4.6. As can be seen in Table 4.6, only symptoms of CNS were found to be significant with age at p-value of 0.007. Cases of renal toxicity, gastro-intestinal infections and dermal toxicity resulted to p-values of 0.382, 0.198 and 0.877 respectively. CNS is associated with long-term effects of mercury as opposed to other signs that can be attributed to short and medium term health effects.

**Table 4. 6: Relationship of health effects with age of AGM**

Model		Sum of Squares	df	Mean Square	F	Sig.
CNS	Regression	1.765	1	1.765	7.395	0.007
	Residual	38.431	161	0.239		
Renal toxicity	Regression	0.128	1	0.128	0.77	0.382
	Residual	26.78	161	0.166		
Gastrointestinal	Regression	0.115	1	0.115	1.672	0.198
	Residual	10.996	160	0.069		
Dermal toxicity	Regression	0.003	1	0.003	0.024	0.877
	Residual	23.187	161	0.144		

Age in artisanal gold mining also leads to compounded health effects of the miners. For instance, people who are sexually active are faced with the danger of contracting STDs that can further complicate their health.

#### **4.4.2.4 Health effects associated with AGM by respondents**

In addition, close to 56% of miners acknowledged to have become sick due to their involvement in mining. Persons to have incurred body injuries were 95% while wounds and loss of leg or hand were collectively 94%. Miners who reported to have suffered suffocation stood at 87% and chest congestion reached 39%. Finally, head injuries and hearing problems scored 51% collectively as summarized in Table 4.7.

**Table 4. 7: Health effects associated with artisanal gold mining**

Health problems (n=163)	Response	Frequency	Percentage	Binomial test	
				Observed population	P-values (2-tailed)
Sickness due mercury	Yes	92	56	0.56	0.117
	No	71	44	0.44	
Injuries and accidents	Yes	154	94	0.94	0.000
	No	9	6	0.06	
Wounds and loss of hands and legs	Yes	153	94	0.94	0.000
	No	10	6	0.06	
Suffocation and gas poisoning	Yes	142	87	0.87	0.000
	No	21	13	0.13	
Lung and chest infection	Yes	64	39	0.39	0.008
	No	99	61	0.61	
Head injuries and hearing loss	Yes	84	52	0.52	0.754
	No	79	48	0.48	
Death cases from landslides	Yes	15	9	0.09	0.000
	No	148	91	0.91	

Regrettably, 9% of the miners reported to have witnessed cases of deaths in the study area. Health complications caused by mining activities are broad. The mentioned cases may not necessarily be elaborate and comprehensive. Nevertheless in the area, the major challenge is data availability. Injuries are not reported and ailments are merely corroborated. Challenges come to fore only in event of fatal accidents and death. Key informants pointed out that most of the miners come from the neighboring districts. As a result, some get transported back to their home districts for medical attention making it difficult to have a conclusive health data.

The foregoing debate gives insight, both in magnitude and in spectrum on possible dangers besetting miners. In assessment of health challenges accruing from mining, Donoghue (2004) prefer categorizing them as physical, chemical, ergonomics and social hazards. Key informants reported seven cases of direct deaths in the last year and several injuries. Four were due to burying of miners in pits when the supportive poles could not prevent the rock from caving in. The three deaths were due to carbon monoxide poisoning while pumping out water from the mining holes. Death incidence amongst the miners is common. Some correlate deaths with mercury poisoning, a concern confirmed by key informants. Cases of disability are familiar in the area. This happens following broken limbs or injury on spinal column. In some cases, blowtorching releases hot particles of mercury which cause burn of the body. The burns become septic and are likely to cause death within 2-3 years.

The Table 4.7 shows a run of binomial test and the consequent proportions and the P-value associated with the various counts. The question which sought to investigate whether sickness has been witnessed was insignificant with a P-value of 0.117. This is attributed to many reasons; first, due to inability of miners to identify health effects of mercury in short, medium and long term. Secondly, as a result of failure to remember all cases associated with mercury. Thirdly, some of the miners are purely gold ore diggers who have little information on mercury exposure. And finally, frequent threats by government to close down small scale mining in the area led to miners concealing some information. The other results indicated P-values (0.000 and 0.008) that are statistically significant at 95% confidence level and conclude that there are potential health effects of artisanal gold mining.

#### 4.4.3: Lorgorien sub-district hospital records for 2009/2010

The study obtained morbidity data from Lorgorien sub-district hospital as indicated in Table 4.8 to validate health challenges arising from small scale mining in the area.

**Table 4. 8: Morbidity summary for year 2009/2010**

<b>Diseases</b>	<b>Morbidity cases</b>	<b>Percentage</b>
Malaria	1,910	38.6
Typhoid	149	3.0
Sexually Transmitted Infections	150	3.0
Skin infections	605	12.2
Respiratory diseases	1,725	34.9
Accidents	210	4.2
Rheumatism and joint paints	190	3.8
Poisoning	5	0.1
<b>Total</b>	<b>4,944</b>	<b>100</b>

Malaria is the world's leading killer disease. High cases of malaria (39%) were identified. Key informants attributed high cases of malaria in the area to increasing breeding sites created by miners. Mining ore pits and tailing ponds are mosquito and other vectors breeding sites. Respiratory diseases are widespread (35%) as a consequent of crushing gold ore emitting dust, mercury vapor during blowtorching and digging of gold ores. Accidents and poisoning are linked to activities of small scale miners. Particular cases include collapse of mines, cuts, wounds, and mercury and carbon monoxide poisoning. Skin diseases are common and observation confirmed different skin complications amongst the miners. Key informants also revealed shaking of fingers to be familiar with the miners.

The clinical manifestations are varied and mimic many other conditions (Hyman, 2004). Central Nervous System (CNS) toxicity includes erethism with symptoms of

shyness, emotional lability, nervousness, insomnia, memory impairment, and inability to concentrate. Other CNS symptoms may include encephalopathy, peripheral neuropathy, Parkinsonian symptoms, tremor, ataxia, impaired hearing, tunnel vision, dysarthria, headache, fatigue, impaired sexual function, and depression. Renal toxicity includes proteinuria, renal syndrome, and acute renal failure. Gastrointestinal symptoms include nausea, vomiting, diarrhea, and colitis. Dermal toxicity includes allergic dermatitis, cheilitis, gingivitis, stomatitis, and excessive salivation (Hyman, 2004).

The study used the clinical data as control to determine whether the health cases portrayed by artisanal miners were as a result of mercury use. Table 4.9 indicates the correlation results of the case-control analysis. The findings were statistically significant with a p-value of 0.01 and thus concluding that there are numerous differences in health symptoms presented by the miners and the community in general.

**Table 4. 9: Correlation results of health effects**

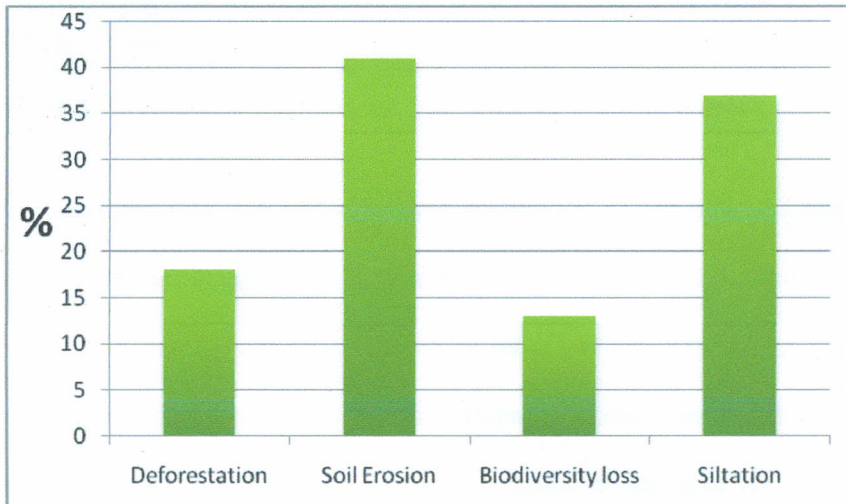
	Case	Control	Sig. (2-tailed)
Exposed	91	2735	0.01
Non exposed	72	2209	

#### **4.5: Other factors that affect the health of artisanal gold miners**

In the study, other factors that affect the health of artisanal miners' were found out to be environmental, social, economic and institutional framework.

### 4.5.1: Environmental impacts of AGM

Environmental degradation is the deterioration of the environment through depletion of resources such as air, water and soil; the destruction of ecosystems and the extinction of wildlife. Artisanal gold mining contributes to the deterioration of the three facet of the environment that is soil, water and air. Figure 4.3 summarizes environmental issues of small scale mining as found out by the study.

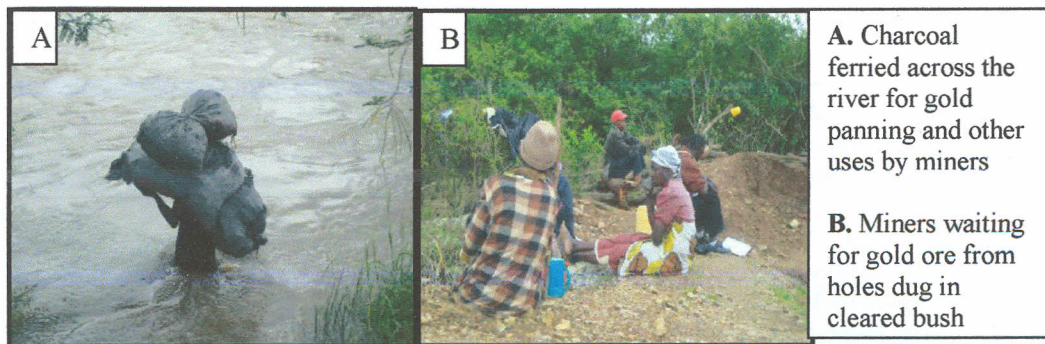


**Figure 4. 3: Environmental issues of small scale gold mining**

#### 4.5.1.1: Deforestation

Deforestation is a natural consequence of small-scale mining since many sites are located in forested uplands. The influx of miners and their families into mining areas results to the clearing of forests for habitation space and other human activities that causes deforestation. The study found out 18% of the miners associating deforestation with their mining activities while the remaining 82% did not. It was well noted that the contribution of small scale mining to deforestation is small compared to those used for farming, charcoal burning and logging. There is substantial cutting down of vegetation by miners to; clear mining area, obtain poles sustaining mining pits, construction of temporary structures and sheds and cooking. Transmara is known to

be a major supplier of quality charcoal (Plate 4.3) to neighboring towns of Migori, Awendo, Rongo and Kisii towns.



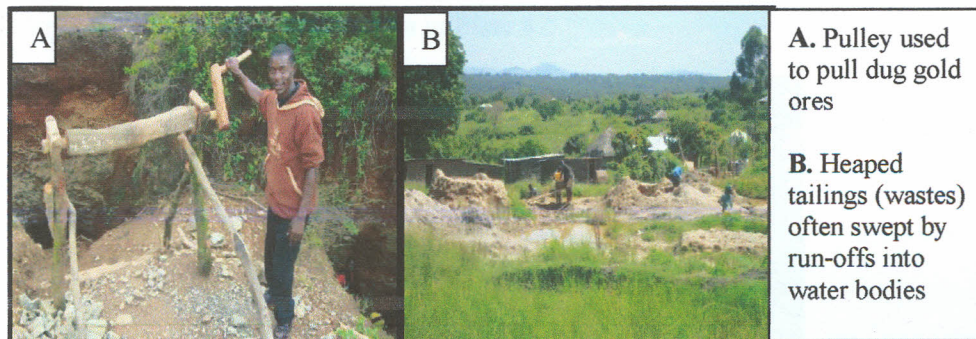
**Plate 4. 3: Charcoal burning and clearing of bush by miners**

This has resulted into indiscriminate destruction of vegetation. Clearing of land for agriculture is being done haphazardly resulting to contemptible destruction of vegetation cover. Finally, Lorgorien as other parts of Transmara district remain the main provider of indigenous timber to populous Kisii, Migori, Nyamira and Homabay counties. The situation has promoted logging in the area leading to depletion of natural trees. Kenya's forest cover has declined to current situation of 1.7% since independence that she had 15% forest cover. This is alarming with the cover 5 times lesser than recommended threshold of 10%. Key informants described forest cover in Lorgorien to be on the decline. The study agrees to assertion by Gunson and Veiga (2004) that the contribution of small scale mining to deforestation is smaller than those used for other economic activities like farming, charcoal burning and logging.

#### **4.5.1.2: Soil Erosion**

At least, 41% of miners were aware that mining can cause soil erosion. This is not necessarily loss of fertility, but systematic removal of soil on earth crust. It happens when soil is loosen to get gold or vegetations are cleared to create room for mining. Miners level sloping land and scrape topsoil to make surface foundations stable for

houses and other structures. They develop pathways and roads across highly sloping and erosive areas and cover fertile soil with waste materials dug out of underground tunnels as shown in Plate 4.4.



**Plate 4. 4: Small scale gold mining activities that leads to soil erosion**

Key informants complained of open dugouts neighbored with heaps of soil and overburden rock particles. Miners take no or limited action to return top soil resulting to erosion, loss of scenic beauty and loss of grazing land. Soil erosion from small scale mining to a lesser extent has contributed to siltation of water bodies compared to agricultural practices. Land clearing, cultivation by either the land owners and or leasers has destroyed massive tracks of vegetation hence exposing the soils to water, wind and animal erosion. The field visits revealed that most farmers do not provide for terracing, wind breakers or even contour farming on the land.

#### **4.5.1.3: Effects on biodiversity**

Biodiversity loss is a complex issue affecting mining industries. It directly occurs when trees and plant growth is cleared to pave way for mineral prospecting and subsequent mining. Only 12% of sampled miners were aware that their activities had effects on living organisms. Small scale mining in Lorgorien area contributes to some extent reduction in local biodiversity. The study area borders Masai Mara Reserve to the East. The Reserve is about 1510 sq km having been reduced from 1672 sq km in

1984. However, the wildlife is far from being confined within the Reserve boundaries and an even larger area, generally referred to as the 'dispersal area' extends north and east of the Reserve. Lorgorien is a dispersal area and witnessed Zebras grazing together with livestock as shown in Plate 4.5.



Lorgorien mine area is wildlife dispersal area as displayed

**Plate 4. 5: Wildlife in the mine area**

Key informants raises concern on the effects of gold mining to tourism. In addition, aquatic organisms and riverine vegetation are at risk from widespread use of mercury in the area. Mercury finds its way to water bodies due to poor waste disposal and careless handling in the area. This vicious mercury chain ends up in human bodies through food chain resulting to bioaccumulation and bio-concentration. Israel and Asiro (2002) pointed that it may be over-stretching miners to understand intricate issues of biodiversity loss, but suffice are that biodiversity loss is not only cutting down trees and vegetation.

**4.5.1.4: Effects of mining on water ways**

Whilst vegetation is cleared, topsoil removed and mining ores are dug; the loose soil and plant sediments are deposited into water bodies causing siltation or sedimentation.

The open and unplanned tailing ponds receive runoffs from the neighboring Lorgorien hill and the overflow ends up into rivers in the area. Mercury ends up in water bodies as confirmed by high concentration of mercury in tested samples. The water bodies serve as source of water for domestic and livestock rearing. 37% of miners linked siltation of water ways with their mining activities in the area. This is not strange because river siltation is a lengthy process and involve different activities a long river profile. Abandoned mine ores also contribute to underground water contamination. Tailing ponds also contribute to underground water pollution.

#### 4.5.1.5: Air pollution

Artisanal gold mining releases significant amounts of dust and gas emissions. Silicosis and other lung infections appear to be widespread (39%) as revealed by the health effects associated with AGM in Table 4.8. This is also illustrated by Plate 4.6 of exposure to dust particles, exacerbated by working in confined areas such as underground tunnels. Generators are used to pump water out of the mining pits resulting to emission of carbon and nitrogen oxides. These are ozone depleting substances that contributes to global warming.



The dust is a risk factor for respiratory diseases described in section 4.5.1.5

The grinding machine also causes noise and vibration explained in section 4.5.1.6

**Plate 4. 6: Gold ore crushing machine emitting dust and noise**

Prevalence of diseases of the respiratory systems in Lorgorien was 1,725, that is about 35% of health cases reported in the area and only second to malaria as shown by the morbidity data in Table 4.9. The findings can be associated with the results of Robinson and Schroff (2004) who found silicosis to have led to the death of 100 miners, a quarter of the mine's workforce in Seychelles.

#### **4.5.1.6: Noise and vibration**

Grinding and crushing of the gold ore results to high noise levels and in some cases, blasting is carried out to break underground ores. Many of the respondents (52% in Table 4.7) cited hearing problems that are actually associated with noise pollution. Environmental management and coordination noise and excessive vibration pollution control regulations of 2009 specifies maximum recommended noise emissions of 85db (A). However crushing as demonstrated in plate 4.6 generate high noise levels of 91.1 db (A). Noise is only problematic if it is sustained at high levels for over one hour (Sunguti, 2007). Crushing of ore in Lorgorien exposes miners and operators to high noise levels for over 3 hours daily creating significant hearing problems, 52% as found out by the study.

#### **4.5.2: Social issues in AGM**

Artisanal gold mining bring people from different backgrounds. The gold activities in Lorgorien have contributed to various challenges. The study has summarized social issues into social instability, accessibility to human activities and the exploitation of women and children.

#### 4.5.2.1: Social instability

The study noted increasing episodes of social instability with 77% responding positively. This is bound to happen in such cosmopolitan areas with high tenancy case. Most of the miners are males who have left their families in their rural homes. Some have opted to come-we-stay with other women. The scenario has led to many contracting sexually transmitted diseases including HIV/AIDS thus transmitting the same to their spouses. The study identified 150 cases of sexually transmitted infections, representing 3% of disease burden in the study area. There are many young persons (over 80%) under 40 years who have settled around Lorigorian. Key informants described the social situation in Lorigorien to be worsening. Alcoholism is pronounced and the associated vice like drunkenness is epicenter for reckless behaviour like cheap and unprotected sex.

Social instability can also take trajectory of land use conflict. There are fears that ongoing small scale gold mining is a threat to tourism. However, some consider gold mining as an alternative to majority of the locals who do not benefit from tourism. Conflicts have also arisen with those rearing livestock. Most memorable incidence by key respondents is the situation where livestock drunk mercury contaminated water and died. This resulted to tension and tribal flare-up. Livestock owners also have problems with abandoned mine dugouts. The holes have caused human and livestock accidents. Even though only 4% reported land use conflicts, Lorigorien experiences fragile security and require activities that promote cohesion rather than issues that cause friction amongst the residents. Most of the mining in the area is carried out in grazing land or hills with limited disturbance to cultivation of crops.

#### **4.5.2.2: Accessibility to public amenities**

On accessibility to basic public services, 59% said they lacked the services. Public basic services refer to water supply, toilets, litter/waste handling facilities and shelter, recreational grounds. Significantly, some 39% of the miners said they were not accessible to toilets. Since miners quarry gold in isolation and mines sites are fragmented. It is not easy to avail public basic amenities in such circumstance. However, supply of public basic amenities can contribute positively in mitigating challenges resulting from mining. Around mines, the study witnessed cooking of food. Without clean water supply, garbage handling and toilets, cases of diarrhea and are pronounced. Over 270 diarrhea and 149 typhoid cases were found on medical records by the study, representing more than 9% of disease burden in Lorgorien. Key informants associated the influx of miners with inadequate housing in the township. Some miners have opted for sheds for shelter. In addition to water and sanitary health challenges, miners are also exposed to cold resulting to pneumonia due to poor housing conditions.

#### **4.5.2.3: Exploitation of women and children**

Women and children are engaged in the gathering of ores inside tunnels and even in processing. Although small-scale miners deny this by only 11% acknowledging exploitation of women and children, key informants and site inspection in the study area confirmed this problem. Children are typically the responsibility of their mothers. At many mine sites, women work with young babies tied to their backs and toddlers at their side as can be clearly seen in Plate 4.7.



Exposure of children to AGM's health risks of dust and mercury

**Plate 4. 7: Women and children in Lorgorien mine area**

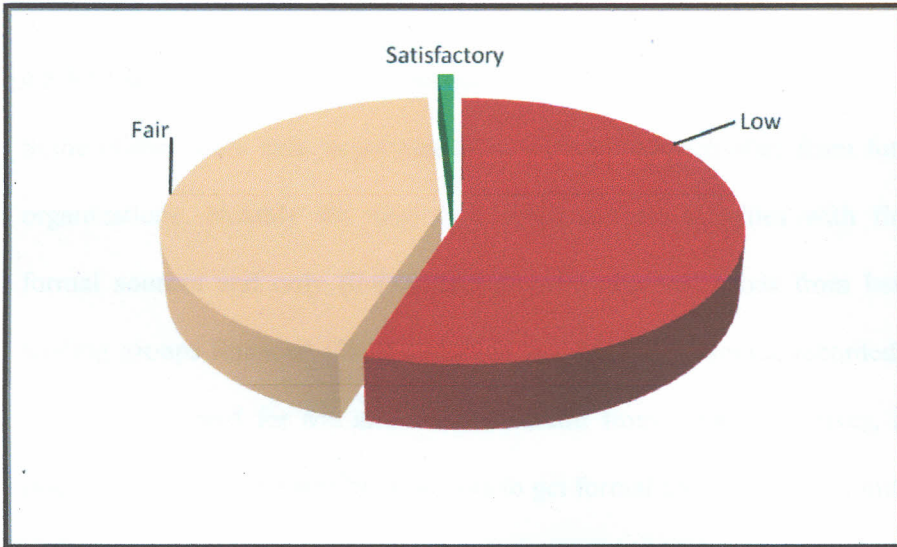
The study established about 2% of the mine workers to be under 18 years of age. Boys engage in digging, grinding, crushing and transportation of ore materials. They have no personal protective equipments. Girls are also involved in processing and transportation of materials. Girls are involved in sexual exploitation. Key informants attributed high drop out in schools to early exposure to sexual activities by mining families. Women of sexually active age have engaged in prostitution for a living especially the poor to sustain their life. Women have difficulties accessing gold ores since they do not go into mining holes. Consequently, some women processors provide sex favors to ore digging men in order to obtain gold ore. The study ascertained the findings of other researchers that exploitation of women and children is a major issue of concern in small scale mining (Amutabi and Lutta, 2001; Hinton *et al.*, 2006; Ogola *et al.*, 2002).

#### **4.5.3: Economic aspects of small-scale mining**

Returns from gold mining are believed to be lucrative. Nonetheless low gold prices, lack of formal financing and gold losses due to AGM illegality are major hindrances to safe and healthy mining.

#### 4.5.3.1: Price of gold

Price of gold is an important factor in the social and economic development in the area. On gold prices, 55% reported receiving low prices. About 44% noted the price to be fair and only 1% acknowledged it was satisfactory as displayed in Figure 4.4.



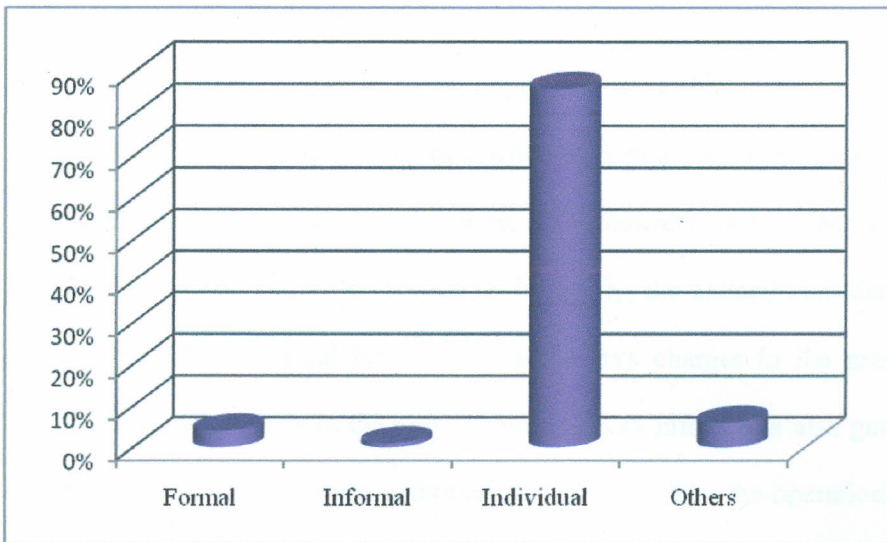
**Figure 4. 4: Satisfaction with the prices of gold by miners**

An ounce is the unit of measuring gold with one ounce equalling 28.340 grammes (0.028kg). The current price of gold in the international market reveals one ounce is trading at \$1,246 (KSh100, 926 under current exchange rates). Key informants consider small scale gold miners in various parts of Western Kenya according to industry estimates, produce a mere Sh15 million annually, although much of it is sold to middlemen at prices well below those in the international market. An ounce is sold between KSh 20,000 to 30,000 in the study area to brokers and cartels, less than 30% of the official price of gold on stock exchange. This concurs with Amutabi and Lutta (2001) who reported that middle men pay about a quarter of the amount offered in the stock exchange. Miners face a myriad of challenges when it comes to selling of gold.

First, the official price on the stock exchange involves a lengthy process while miners are in quick need of cash thus selling to dealers. Secondly, dealers arrive at the most opportune time when miners are vulnerable especially during schools' opening and there is need for fees. Lastly, some buyers provide poor quality or contaminated mercury in exchange of gold.

#### **4.5.3.2: Sources of financing gold mining activities**

Some miners were able to get capital to initiate their activities from formal lending organizations. Notably 4% said they initiated their activities with finances from formal sources and only (0.6%) said to have obtained funds from bank, informal lending groups financed 1% of activities, and individual source recorded 86%. Other sources accounted for 6% and involved credit from friends, relatives, donations or sale of property. The inability of miners to get formal credit is due to limited collateral securities and legality surrounding their operation. Miners are left with individual savings as most feasible alternative. This fickle financial base makes it difficult to embrace new technologies that are environmentally friendly and safe in regard to human health as well as the entire ecosystem. Miners' sources of finance are shown in Figure 4.5.



**Figure 4. 5: Miners' source of finances**

#### **4.5.3.3: Gold loss due to illegal panning and trading**

Sizeable number of miners (33%) reported to have lost gold due to illegal nature of their work. The absence of formal organization or government body to control the sector creates a lacuna. The trade is filled by local cartels and brokers with egocentric interest. They play on innocent local miners leading to loss of refined gold. The situation is denoted by harassment, arbitrary arrest, confiscation of gold and threats of mining closure. In some cases, gold is under weighed and dealers provide fake currencies.

#### **4.5.4: Institutional framework governing artisanal gold mining**

The study found out the following in regard to legislative and institutional framework under which artisanal gold miners operate;

#### **4.5.4.1: Legality of mining activities**

On legality issues, 92% of study population said they were operating legally. However, this verdict became suspect when 82% said they lack licenses from mines and geological department. Furthermore, 66% indicated lacking permits from local authorities to carry out gold processing. Ironically, the council considers small scale gold mining to be illegal but goes ahead to levy charges in the processing area. Legality of such AGMs in the area is complex. Key informants also gave conflicting views on the legality of these activities. Majority consider the operation illegal while some suggested otherwise. The government is dormant in the operation of the miners and only surfaces when accidents and emergencies are reported. In Kenya, local authorities are mandated to regulate activities within their jurisdiction. They ensure adherence to safety, public health as well as environmental standards. Involvement of local authority with small scale miners is low in the study area. Gunson and Veiga (2004) roots for legalization of mining activities. He notes that legalization serve as impetus for miners to report injuries and accidents in mines. In a nutshell, illegal or semi-legal status is first and most deep rooted public health concern. This position also received empirical vindication from Donoghue (2004) and Israel and Asirof (2002) who found out that accident are 3 to 5 times likely to occur in illegal mines compared to legal ones.

#### **4.5.4.2: Government monitoring**

It was observed by 79% of respondents that the government monitors their activities. NEMA was identified by miners to be regulating their activities. NEMA is enforcing provisions of Environmental Management and Coordination Act (1999), Occupational Health and Safety Act (2007) and Environmental Management and Coordination Act

excessive noise and vibration control regulations, 2009. This is done together with the department of mines and geology and the public health office. However, the prevailing attitude change to proper environmental guidelines is a challenge due to ignorance and retrogressive beliefs. Key informants noted that regulating small scale miners is viewed as a punishment and harassment to miners by government agencies. The most conspicuous monitoring by the government is licensing and sometimes random raid and arrest by security agents. In some cases, mining has been temporarily stopped posing social and economic catastrophe to the miners.

#### **4.5.4.3: Involvement of non-governmental actors**

Non-governmental organizations (NGO's) involvement recorded 31% while welfare groups had 14%. The activities of most NGO's in the area revolve around HIV/AIDS advocacy, training and awareness. Small scale miners' welfare mobilizes resources for prospecting license and responds to members needs during emergencies, accidents and death. Currently, they coordinate with NEMA, public health and, department of mines and geology to address environmental impacts as well as potential health outcomes of gold panning. The welfare is an entry point in addressing the benefits and consequences of mining in the area.

#### **4.5.4.4: Mining rights and mineral prospecting**

In Kenya, minerals prospecting rights exclusively fall with the government department of mines and geology. About 13% and 17% of respondents observed that they had mining rights and minerals prospecting rights respectively. The result contradicts the information provided by the welfare group. The miners have in their position small scale prospecting license obtained from the department of mines and

geology. However, the miners make personal agreements with individual landowners in cash or mutual benefit arrangement. For instance, the owner of the land takes one bucket of gold ore for every five dug. In maximizing economic returns, mining is done without due regard to safety issues and environmental conservation norms.

## CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMENDATIONS

### 5.1: Introduction

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This study examined the magnitude of health effects associated with mercury use in gold processing in Lorgorien licensed mine area. To achieve the objective, interview schedules and questionnaires were used to collect data. Questionnaires were administered to miners while interview with key informants, health officials was also conducted. Questionnaires were administered to 196 miners but only 163 (83%) were satisfactorily answered and analyzed. Data processing was done and it involved checking for completeness of questionnaires, and consistency of information from respondents. In addition data coding, entry, computation and consequently presentation of descriptive statistics were done. Inferential analysis was done using Chi-square test, Regression, Correlation and Binomial test on study hypotheses. Interview schedules were administered to 12 Key informants drawn from Lorgorien sub-district hospital, NEMA, department of mines and geology, public health, water office, forestry, county council of Transmara, representative of Kilimapesa Gold, Agriculture office, Kenya Wildlife Service and Livestock office. Health records for a period beginning July 2009 to June 2010 were gathered from Lorgorien sub-district hospital to establish diseases associated with gold mining. This section gives a summary of study findings, draws conclusions, makes recommendations and suggests areas of further research.

## **5.2: Summary of findings**

The major findings of this study are presented as follows:

### **5.2.1: Demographic characteristics**

The study found more men than women to be engaged in small scale mining. Mining especially digging of gold ore is physically demanding and is a preserve for men. Nearly all women were engaged in the processing of gold. However, women double up their mining role as processors with domestic duties such as cooking, fetching water and taking care of children. More than 80% were found to be less than 40 years, a sexually active age. The population is of low literacy level with majority having not finished basic primary education. The largest portion of the mining population is immigrants as demonstrated by high tenancy. Miners get modesty monthly income of income averaging KSh 6,426.50 per month. Close to 80% are able to afford a semi-permanent house signaling average financial base. Roads in the entire Lorgorien division are in poor state and even worse while accessing mining sites.

### **5.2.2: Knowledge on mercury problems**

Mercury is widely used in the area for processing gold. It is considered to be highly available, affordable and easy to use. Miners have low knowledge that mercury has negative effects on ecosystem and human life. However, this does not guarantee alternatives as a good number still believe in amalgamation as the first option in processing of gold. Miners do not know what mercury does to human body. Less than a third of the respondents indicated to be employing precautionary measures against mercury poisoning. Some of the measures found out by the study included; use of protective clothing, outdoor blowtorching and dumping of wastes in tailing ponds.

### **5.2.3: Health effects of mercury**

Health effects of mercury use are immense and range from physical injuries to chemical poisoning, with corresponding consequences. Physical injuries found out by the study include body injuries, loss of hands and legs, wounds, head injuries and hearing problems. Consequently, some of the physical injuries have resulted to deaths. Mercury toxicity and carbon monoxide poisoning are widely experienced. Mercury impacts to health were associated with dermal toxicity, gastro-intestinal infections, renal toxicity and cases of central nervous system in the area. Health records also revealed several diseases related to mercury presence in the area such as rheumatism and joint pains. Key informants identified shaking of hands and skin infections due to mercury toxicity. Carbon poisoning is also pronounced due to use of generators in the mining holes to pump out water. It has led to suffocation, chest infections and sometimes results to death in the area. The use of competent health worker helped to confirm the health effects of mining. Binomial test results were significant and concluded that there exist potential health effects of mercury by artisanal gold miners.

### **5.2.4: Other factors that affect the health of the artisanal miners**

Environmental consequences of small scale mining are broad and related. Deforestation, soil erosion, biodiversity loss and siltation are common in the area. However, their impacts cannot be quantified separately from those attributed by other economic activities such as farming and charcoal burning. Air pollution and excessive noise and vibration were also mentioned to be generated by small scale miners. A noise measurement from the crusher was 91.1 db (A), higher than the maximum recommended value of 85 db (A).

Social instability was noted to be on the increase by the study. Most of the miners were noted to be men who have left their family in the ancestral homes. Some are engaged in prostitution and alcoholism. This has resulted to many cases of sexually transmitted diseases as established by health records. It is worthwhile to note that over 80% of the miners are less than 40 years and are sexually active. Women are at greater risk in the area. A couple of women indicated to have engaged in sexual activities to obtain gold ore for processing. Key informants cited high deaths of small scale miners, a compounding factor of mercury and HIV/AIDS. Children get early exposure to mercury and sexual activities due to deteriorating morals in the area leading to high dropouts.

Economically, artisanal mining pays almost double to casual workers in the farms. Miners are able to afford school fees for their children and provide for the families. Gold prices are generally low compared to the prices at the stock exchange. Nevertheless, miners opt for quick cash and sell to brokers. Some of the brokers are conmen who under weigh gold, supply low quality or contaminated mercury and at times, provide fake currencies to the miners. Almost all miners rely on their personal savings to carry out mining activities.

Artisanal gold mining activities are individual centered. Small scale miners have a single prospecting from the department of mines and geology. Miners then enter into agreements individually with land owners. County council of Transmara considers small scale miners to be illegal despite of collecting revenues of single business permits. NEMA, public health and livestock department only come to fore when

incidences of their area of expertise arise. Key informants stated lack of government involvement in artisanal gold mining. No representative of the department of mines and geology in Lorgorien and the greater Trans-Mara district. Monitoring by government is random raid and arrest without enforcement of environmental, health and safety regulations. None of the NGO's are specifically involved in the micro-managing small scale mining but are engaged in HIV/AIDS awareness and advocacy. Small scale miners have welfare that tries to cushion members from uncouth brokers and cartels. The welfare also participates in other social activities including organization of miners' funeral, education of children and negotiations where conflicts arise.

### **5.3: Conclusions**

Miners had low awareness of side effects of gold panning using mercury. Knowledge about the effects of mercury on human health was inadequate. None of the respondents said to have adequate knowledge on the effects of mercury. Most of sampled miners would still opt for gold panning even when presented alternatives. This is despite immense health implications. Specifically, amalgamation using mercury would be first option for miners. Reasons for mercury use and preference of amalgamation process are described in this study. However, these reasons are merely corroborated. There is need for empirical studies to zero-down reasons for preference of amalgamation process.

The result on the symptoms of mercury exposure amongst artisanal gold miners rejects null hypothesis ( $H_0$ ) and concludes that there are predominant health effects of mercury amongst artisanal gold miners in Lorgorien study area.

Mining activities in the study area were individually centered. This makes it difficult to put in place safety and intervention measures at co-operate level. This calls for robust measures at individual levels. These measures include out-door working, use of tailing ponds and wearing protective gears such as dust masks, gumboots, air filters and gloves. Protecting equipments are partially worn and no mechanisms for timely replacement.

Although most miners said that their activities were legally binding, the absence of permits or licenses makes this position redundant. This can be inferred to mean the sector lacks strong institutional framework to guide working. In the absence of government machineries to streamline the playground, one expects NGO's and other philanthropic organizations to fill this gap. However, the presence of NGO's and informal groups was thinly spread. This leaves room for wanton destruction of environment with immeasurable health consequences.

In the lieu of foregoing discussions, the following recommendations are made by the researcher:

#### **5.4: Recommendations**

- a. There is need to scale up campaign to bolster awareness on what mercury does to human health. Special attention should be given to environmental health challenges resulting from gold panning using mercury and how they are intertwined with human health.

- b. It's acknowledged that the effects of mercury poisoning are difficult to delineate. They differ based on duration and intensity of exposure. This calls for the equipping of nearby health centers with highly trained personnel and modern clinical equipment to assist in monitoring short, medium or long term effects of mercury exposure.
- c. The most viable and sustainable response to environmental and health effects of gold panning is to train local staff. This will assist in monitoring, diagnosis and support to miners to cope up with the challenges of their work.
- d. There is need for on-site training of miners on safe mining.
- e. Since co-operate measures may be difficult to institutionalize due to fragmented nature of mining, there is need to strengthen individual precaution measures. This is against mercury poisoning. Such measures include the use of dust masks, air filters and heavy chemical gloves.

### **5.5: Areas of further research**

Several gaps in knowledge or practice were identified in the study area, including:

- a. An economic analysis of mercury pollution from artisanal gold mining in Lorgorien.
- b. A proper analytical study of the behaviour of mercury in the environment due to gold mining in the area.
- c. A broad epidemiological study on exposure to mercury and the resulting health effects that is, characterization of human health risks from mercury exposure.
- d. Quantification of sediment load from artisanal gold mining within the waterways

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HOUSEHOLD QUIZ

AUGUST 2010

**APPENDICES****Appendix 1: Household questionnaires**

**A STUDY ON THE HEALTH EFFECTS OF MERCURY USED BY  
ARTISANAL GOLD MINERS IN LORGORIEN, TRANSMARA DISTRICT**

**HOUSEHOLD QUESTIONNAIRE**

**AUGUST 2010**

**THIS STUDY IS AIMED AT GATHERING INFORMATION FOR ACADEMIC PURPOSES ONLY AND ALL INFORMATION WILL TREATED WITH CONFIDENTIALITY.**

Hallo, my name is Aduwo Dickson from Kenyatta University, Nairobi-Kenya. I am currently doing my postgraduate studies in **Environmental Health and Disaster Management**, Public Health Department. At the moment, I am carrying out a survey on the “**Health effects of Mercury used by small-scale miners in Lorgorien mine area**”.

Your assistance will be helpful in making people, especially those in authorities, to formulate appropriate policy in the management and coordination of small-scale Gold mining activities in Kenya. Be assured, therefore, that the research is strictly for academic purposes only and the information gathered will be treated with utmost **CONFIDENTIALITY**.

With thanks.

RESEARCH ASSISTANT \_\_\_\_\_ INTERVIEW DATE/\_\_\_/\_\_\_/\_\_\_

RESPONDENT'S NAME \_\_\_\_\_

RESPONDENT'S POSITION IN THE HOUSEHOLD [ ] (code)

1 = Head                      2 = Spouse

**A. Socio-economic and Demographic data**

**A1. Personal details about the respondent**

SEX [CODE: 1 = MALE, 2 = FEMALE]	
Main occupation;	
Activity in the mining; 1=MINER 2=PROCESSOR	
Age of the respondent	
Years of stay in the study area	

**A2.** What is the house type? Traditional [ ] Semi-permanent [ ] Permanent [ ]

**A3.** What is the ownership status of the house?

Owned [ ] Rented [ ] other, specify: [ ]

**A4.** How many persons live with you in the household under the following categories?

< 5yrs [ ] 6-10 years [ ] 10-19 [ ] 20-35 [ ] >35 [ ]

**A5.** What is your level of education/training?

a. None [ ] b. Primary [ ] c. Secondary [ ] d. Post Secondary [ ]

**A6.** Are public health clinics and hospitals accessible? Yes [ ] No [ ]

**A7.** Are there good roads which link your area to the trading centre?

Yes [ ] No [ ]

**A8.** Approximately, which of the categories considers your monthly income (KES)?

a. below 5,000( ) b. betw'n 5,001 -10,000( ) c. betw'n 10,001-15,000( )

d. Between 15,001-20 000 ( ) e. between 20001 -30000 ( ) f. above 30000

**B. Involvement in Gold mining**

**B1.** How long have you been working as a small-scale miner?

\_\_\_\_\_

**B2.** How did you get started?

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**B4.** How many employees do you have for this activity? \_\_\_\_\_

**B5.** In your opinion, does Gold mining contribute to the following in this area?

a. Deforestation            b. Soil Erosion            c. Biodiversity Loss

d. Siltation and Sedimentation of Downstream Water Bodies

**B6.** What are the roles played by women in Gold mining?

- i. Labourers (e.g. panners, ore carriers and processors),
- ii. Providers of goods and services (e.g. cooks, shopkeepers)
- iii. Domestic chores.
- iv. Mineral processing; crushing, grinding, sieving, washing and panning, amalgamation and amalgam decomposition
- v. Concession owners,
- vi. Mine operators,
- vii. Dealers and buying agents
- viii. Equipment owners

**C. Knowledge, attitudes & Institutional Information**

**C1.** Is mercury used in the operation? Yes  No

**C2.** Are you aware that mercury can be dangerous to health?

Yes  No

**C3.** If yes, of which of the following health complications?

- **Central Nervous System (CNS)** toxicity includes erethism with symptoms of shyness, emotional lability, nervousness, insomnia, memory impairment, and inability to concentrate. Other CNS symptoms may include encephalopathy, peripheral neuropathy, Parkinsonian symptoms, tremor, ataxia, impaired hearing, tunnel vision, dysarthria, headache, fatigue, impaired sexual function, and depression.
- **Renal toxicity** includes proteinuria, renal syndrome, and acute renal failure.
- **Gastrointestinal symptoms** include nausea, vomiting, diarrhea, and colitis.
- **Dermal toxicity** includes allergic dermatitis, chelitis, gingivitis, stomatitis, and excessive salivation.

**C4.** Are there precautionary measures to reduce the impacts of mercury?

**C5.** If Mercury use is to be substituted for an alternative, which of the following code best describes your position?

SA= Strongly Agree, A= Agree, N= Neither agree nor disagree, D= Disagree,

SD= Strongly Disagree

**D. Occupational Hazards Information**

**D1.** Do you require protective equipment (overalls, gloves, respirators) in the handling of mercury and other chemicals? Yes  No

If Yes, state \_\_\_\_\_

**D2.** Is there a tailings pond in the processing area? Yes  No

**D3.** If no, how are the tailing wastes disposed? Explain;

**D4.** Is blowtorching (heating) of the amalgam done indoors or outdoors?

Indoor  Outdoor

**D5.** Have you heard people getting sick because of mercury in this area?

Yes  No

**D6.** Have you heard people getting of injuries and accidents during the course of your mining activity?

Yes  No

If yes, list three main injuries/accidents;

a.

b.

c.

**D7.** Are their toilets in the mining area?

**E. Institutional & Legal Information**

**E1.** Are local governments monitoring small-scale mining activities in the area?

Yes  No

**E2.** Is the national government involved in small-scale mining related activities in this area? Yes  No

**E3.** Are there NGOs in the area concerned with small miners? Yes  No

**E4.** Is the operation legal? Yes  No

**E5.** What permits are required to operate as a miner? List, 1. \_\_\_\_\_

2. \_\_\_\_\_ 3. \_\_\_\_\_ 4. \_\_\_\_\_

**E6.** Are there mining rights conflicts between the miners and Mining Company? Yes  No

**E7.** Are there conflicts between your mining activities and agriculture-based activities? Yes  No

**E8.** Incase of conflicts, how do you address the issues?

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**F. Social & economic issues**

**F1.** Are there worsening social instability e.g. prostitution, immigrants, etc in this area due to small-scale mining? Yes  No

**F2.** Is access to basic services such as water, health, shelter etc limited due to small-scale mining in this area? Yes  No

**F3.** In your opinion, is their exploitation of women and children in small-scale mining in Lorgorien area?

**F4.** How do you consider the price for Gold received by miners?

Low  Average  High

**F5.** In your opinion, is there loss of Gold by the country due to illegal Gold Trading? Yes  No

**F6.** Do you have access to formal sources of credit? Yes  No

**F7.** If yes, which ones?

i. Banks

ii. SACCOs

iii. Informal Credit Facilities

iv. Other, Specify \_\_\_\_\_

**F8.** Apart from small-scale mining, do you have alternative or supplementary employment opportunities? Yes  No

**G. Technology-related issues**

**G1.** Is amalgamation the first option considered by miners to extract gold?

Yes  No

**G2.** Is mercury readily available to miners? Yes  No

**G3.** Gold placers, colluvium, laterite deposits and abandoned tailings are usually neglected by companies due to low grade. Are miners currently working on these types of deposits? Yes  No

**G4.** Do miners make frequent improvements in the amalgamation process to increase gold recovery and reduce mercury emission? Yes  No

**G5.** Is it easy to introduce new gold extraction technologies? (Miners can assimilate easily?) Yes  No

**G6.** Are you aware of the side effects of mercury? Yes  No

**G7.** Do you receive any specialized technical support?

Yes  No

**Appendix 2: Key informants guide**

Questionnaire No \_\_\_\_\_ Respondent's code No \_\_\_\_\_

Interviewer's name \_\_\_\_\_ Date of interview \_\_\_\_\_

Place of interview \_\_\_\_\_ Occupation of the respondent \_\_\_\_\_

1. Are there legal requirements for small-scale miners in this area?

\_\_\_\_\_

\_\_\_\_\_

2. What is the government/local authority's role in small-scale mining?

\_\_\_\_\_

\_\_\_\_\_

3. Is there use of Personal Protective Equipments such as gloves, respirators or overalls in mercury handling?

\_\_\_\_\_

\_\_\_\_\_

4. What is the general awareness and knowledge of mercury health impacts by miners?

\_\_\_\_\_

\_\_\_\_\_

5. What are the environmental problems associated with small-scale mining in this area?

\_\_\_\_\_

\_\_\_\_\_

6. Are there mining rights conflicts between the miners and the licensed Mining Company?

\_\_\_\_\_

\_\_\_\_\_

7. Has mining interfered with access to basic services e.g. health centers, water, housing etc?

\_\_\_\_\_

\_\_\_\_\_

8. Have you witnessed degradation of social stability due to miners in the region?

\_\_\_\_\_

\_\_\_\_\_

9. Is exploitation of women and children rampant with the miners?

\_\_\_\_\_

\_\_\_\_\_

10. In your opinion, what the contribution of small-scale miners to the country and illegal trading?

\_\_\_\_\_

\_\_\_\_\_

11. Are there alternative or supplementary employment opportunities for miners in the area?

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12. Do the miners have access to any specialized technical support?

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**Comments;**

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\* State of passage ways

Sealing

Working Posture

\* Air Conditioning

\* Storage

Comments

Sanitation/Welfare (State as present or absent)

\* Sanitary facilities

\* Changing rooms

Water for drinking/washing

Severe, moderate or above

(i.e. fumes, humidity)

**Appendix 3: Health and safety checklist**

General conditions of the amalgamation area (state as good, fair or poor)

- State of walls
- State of floor
- State of roof

Comments \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Housekeeping (state as good, adequate, fair or inadequate)

- Cleanliness
- Overcrowding
- State of passage ways
- Seating
- Working Posture
- Lighting
- Ventilation
- Air Conditioning
- Storage

Comments \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Sanitation/Welfare (State as present or absent)

- Sanitary facilities
- Changing rooms
- Water for drinking/washing

Comments \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Hazards (State as Excessive, moderate or absent)

- Toxic agents (dust, fumes, liquids)

- Physical agents (Noise, heat, vibration)

Comments \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Safety Regulations (state as adequate or inadequate)

- Protective Clothing (Helmet, earmuffs, goggles, face shield, glove, boots)
- First Aid box
- Firefighting equipment

Comments \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## Appendix 4: Research authorization

REPUBLIC OF KENYA



### NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Telegrams: "SCIENCETECH", Nairobi  
 Telephone: 254-020-241349, 2213102  
 254-020-310571, 2213123.  
 Fax: 254-020-2213215, 318245, 318249  
 When replying please quote

P.O. Box 30623-00100  
 NAIROBI-KENYA  
 Website: www.ncst.go.ke

Our Ref:

NCST/RR1/12/1/MAS/170/3

Date:

20<sup>th</sup> August 2010

Mr. Aduwo Dickson Okumu  
 Kenyatta University  
 P. O. Box 43844  
 NAIROBI

Dear Sir,

#### RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on "*Health effects of mercury used by artisanal gold mining in Lorgorien, Transmara District*" I am pleased to inform you that you have been authorized to undertake research in **Transmara District** for a period ending **31<sup>st</sup> December 2010**.

You are advised to report to the **District Commissioner and the District Education Officer, Transmara District** before embarking on the research project.

On completion of the research, you are expected to submit **two** copies of the research report/thesis to our office.

**P. N. NYAKUNDI**  
**FOR: SECRETARY/CEO**

Copy to:

The District Commissioner  
 Transmara District

The District Education Officer  
 Transmara District