# DUST POLLUTION AND ITS HEALTH RISKS AMONG ROCK QUARRY WORKERSIN KAJIADO COUNTY, KENYA.

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# DECLARATION

I hereby declare that this thesis is my original work and has not been presented for a degree in any other University or any other award.

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## DEDICATION

I dedicate this research work to my mother, Naomi, my daughter Maureen, my niece Jennifer and my nephew Jeff for their support and encouragement.

## ACKNOWLEDGEMENT

I acknowledge the Almighty God for the gift of life and the opportunity to pursue my dream. I am sincerely grateful to my supervisors, Dr. Gladys Gathuru and Dr. Esther C. Kitur for their tireless effort to guide me through the demanding process of research. I express my appreciation to the Commissioner of Mines and Geology and the laboratory staff at Mines and Geological Department, Nairobi, for their assistance. I also acknowledge the Directorate of Occupational Safety and Health for the assistance in dust sampling. Finally, I acknowledge my friend Anne for her encouragement and support; and the quarry operators for giving me the opportunity to carry out the study in their quarries.

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## ABREVIATIONS AND ACRONYMS

AAS – Atomic Absorption Spectrophotometer

ATS – American Thoracic Society

COPD – Chronic Obstructive Pulmonary Diseases

DV – Dependent Variable

DHHS – Department of Health Hazards Services

DOSHS – Directorate of Occupational Safety and Health Services

EEC – European Economic Community

HSE UK – Health and Safety and Executive United Kingdom

IARC – International Agency for Research on Cancer

ILO –IPEC - International Labour Organization- International Programme to Eliminate Child Labour

IV - Independent Variable

KNBS – Kenya National Bureau of Statistics

KMD - Kenya Meteorological Department

LUCID – Land Use Change Impacts and Dynamics

MGD – Mines and Geological Department

MIRO – Mineral Industry Research Organization

NIOSH – National Institute of Occupational, Safety and Health

OEHHA– Office of Environmental Health Hazards Assessment

USGS– United States Geological Society

OSHA – Occupational Safety & Health Administration

WHO – World Health Organization

XRD – X-Ray Diffractometer

XRF - X-Ray Fluorescence

## ABSTRACT

Dust pollution in quarries pose various health risks to the workers including respiratory ailments, skin and eye problems. Depending on the chemical composition and the concentration of the dust, the workers are exposed to inhalation of silica bearing dust thus being at risk of developing silicosis, a fatal lung disease. Information on the chemical composition of the quarry dust is important as it forms a vital baseline for among others the detection of the undesirable health effects among the quarry workers. The aim of the study was to find out the occupational health risks posed by the dust to the quarry workers in Kajiado County, Kenya. The specific objectives of the study were to find out the chemical composition of the limestone, phonolite and pozzolana quarry dust; concentration of silica, chromium, cadmium and lead in the dust; and to assess the quarry workers awareness of the safety and the health risks in the quarry. Purposive and random sampling was used to get 110 workers for the study and dust samples were collected at 0m, 25m and 50m from the point source of the dust using a dust sampling pump set at 2L/min and run for 120 minutes. The chemical composition of the quarry dust; and the concentration of silica and the heavy metals (chromium, cadmium and lead) were done using standard laboratory procedures. A questionnaire was administered to the workers to find out the occupational safety and health risks and the workers' awareness levels of the risks. The study revealed that the quarry dust was composed of various chemical compounds and naturally occurring elements at various concentrations, including$SiO_2$ (3.26% - 35.9%), Cr (9.0-22.18ppm) and Pb (15.5-41.14ppm). The study found that the dust concentration was 86.52mg/$m^3$, $SiO_2$ concentration was 0.62mg/$m^3$, that of Cr was 5.92mg/$m^3$ and of Pb was 9.24mg/$m^3$. The dust concentration showed a negative correlation with distance, r = -0.41227 and p-value of 0.0103. The comparisons of mean dust concentrations for$SiO_2$, Cr and Pb in limestone, phonolite and pozzolana showed p<0.0001, p=0.2071 and p=1460, respectively. The study showed that 60.55%) of the workers exhibited cough, 10% had skin irritation and 2.75%) experienced eye irritation. The study revealed that the quarry workers' awareness of the safety and health risks was 94.5%, but only 16.51% used protective clothing. The study concluded that the dust concentrations failed to meet the Occupational Safety and Health Administration, (OSHA) standards and therefore exposed the workers to the risk of respiratory, skin and eye health problems. It is recommended that measures should be put in place to mitigate the high dust generation at the quarries and the workers should be sensitized to use protective clothing while at work. Clinical research should be conducted on the quarry workers in order to ascertain any development of silicosis.

# CHAPTER ONE: INTRODUCTION

## 1.1 Background to the Problem

Stone quarrying is a multistage process by which rock is extracted from the ground and crushed to produce aggregate, which is then screened into desired sizes for immediate use or for further processing to manufacture secondary products (www.northstonematerials.com/filestore/documents/aggregates). Gravel and sand once quarried are used without any further processing while limestone, phonolite and Pozzolana are quarried, crushed and used as construction material and in the manufacture of Portland cement and lime products, respectively.

Aggregate resources are vital for our way of life because they are the major raw materials used in construction of roads, rail lines, bridges, hospitals, schools, air ports, factories and homes (Langer *et al.*, 2004). Agriculture and infrastructural development ensures the growth of the country's economy, thus the importance of the quarry industry.

Quarry industry is important because of its positive impact on economic development of the country being a source of construction materials, revenue for the government through taxation and royalties and employment especially of the rural population (Divya, *et al*., 2012). The industry also provides employment opportunities for both skilled and unskilled workers thereby supporting many urban and rural families as it contributes to their livelihood and socio-economic well being.

On the other hand, quarrying raises various environmental concerns including land disturbance, emission of dust, noise, and ground vibrations, the latter arising from movement of machinery and rock blasting (Langer *et al.,* 2004). Quarrying poses danger to the workers due to rock fall and machinery, while the dust produced is harmful to their health. The dust particle size, concentration, mineral composition and long-term exposure are factors considered in evaluating the health risks involved. The inhalation of the dust causes severe health problems including respiratory and pulmonary problems, while dust deposition causes skin and eye problems (Ugbogu *et al.*, (2009).

Geological studies of Kajiado area indicate the oldest rocks in the area are gneisses, limestone and quartzite of the basement system, the rocks having under gone series of deformation episodes and volcanic extrusions (Matheson, 1966). Various studies have shown that rock contains crystalline silica and heavy metals, which occur in varying quantities. Granitic rock contains up to71% crystalline silica while limestone and basalts contain up to 40% and 1% of crystalline silica, respectively (HSE UK, 1992).

The major health concern is inhalation of crystalline silica dust which lodges in human lungs thereby causing respiratory and pulmonary damage such as silicosis, increasing the risk for other lung diseases such as bronchitis, pneumonia, tuberculosis, and lung cancer (Last, 1998).Silicosis is rampant in developing countries and China recorded more than 500,000 cases of silicosis from 1991-

1995 and in Brazil, the state of Minas Gerais alone had more than 4,500 workers with silicosis (Galloway, 2007).

**1.2 Statement of the Problem**

The crushed stone quarries in Kajiado County, produce high concentrations of dust and therefore, expose the workers to various respiratory and pulmonary diseases due to dust inhalation. When deposited on the skin and in the eyes the dust may cause skin and eye irritation depending on the chemical composition and the concentration of the dust.

The health condition may worsen where the workers are ignorant of these risks and thus do not appreciate the importance of using protective clothing and gear when provided at work. The long exposure to crystalline silica dust, especially at the point sources, and the many years they have worked in the aggregate quarries expose the workers to respiratory and pulmonary diseases and are also at high risk of developing silicosis (Langer *et al.*, 2004).

Studies have shown that silicosis predisposes workers to lung cancer and tuberculosis. In 2002 NIOSH concluded that there is sufficient evidence in humans for carcinogenicity of inhaled crystalline silica from occupational causes (NIOSH, 2002). In their study Pelucchi *et al.* (2006) concluded that there is an association between silicosis and lung cancer (Pelucchi *et al.*, 2002). This conclusion is in agreement with other studies and meta-analysis.

## 1.3 Research Questions

The study sought to answer the following research questions:

1. What are the chemical compositions and concentrations of the dust produced from limestone, phonolite and pozollana rock quarries?

2. Do the quarry workers exhibit any dust related health problems?

3. Are there any mitigation measures in place to protect the workers?

## 1.4 Research Hypotheses

The research hypotheses were:

1) There is no significant difference in the chemical composition and the concentration of the quarry dust from the three rock types.

2) The quarry workers do no not show any signs of respiratory problems

## 1.5 Objectives of the Study

The specific objectives of the study include:

1. To determine the chemical composition of the quarry dust from limestone, phonolite and pozzolana rock types.

2. To determine the particle concentration of the elements and compounds in the dust from limestone, phonolite and pozzolana rock types at the quarries.

3. To find any dust related health risks posed to the quarry workers through inhalation.

4. To identify the mitigation measures in place to reduce health risks to the quarry workers resulting from crushed stone quarry dust.

### 1.6 Significance of the Study

Dust inhalation by the workers exposes them to respiratory and pulmonary problems. The workers may develop silicosis if they are exposed to the dust containing crystalline silica over long periods. It is therefore, necessary to study the dust and address the health risks that the dust poses to the quarry workers. It is envisaged that this report has come up with information and results that are useful to different users. Policy makers and the regulators of the quarry industry could use the results of the study to review policy and guidelines for the regulation of quarry operations. The outcome of the study may be useful literature for other similar or further studies.

### 1.7 Scope of the Study

The study focused on the limestone, phonolite and pozollana crushed stone quarries within Kajiado County in Kenya. The study analyzed the dust concentration, chemical composition and the concentration of the elements identified in the quarry dust. The study also assessed the occupational health risks posed to the quarry workers by the dust generated from the quarry activities. The awareness level of the workers on the health risks they are exposed to was also assessed. Although the study area had several stone quarries, only eight were covered. All their quarry activities including rock drilling and crushing, known point sources of the dust were at the study area. The other stone quarries excavated the rock at the study area but the excavated rock was transported to the neighbouring county for crushing.

**1.8 Limitations of the Study**

The study was limited to 110 workers in 8 limestone, phonolite and pozzolana quarries in Kajiado County. The study dealt majorly with the chemical composition and concentration of the quarry dust and was therefore limited in carrying out a further interrogation of the response on the health problems presented by the respondents.

**1.9 Conceptual Framework**

The conceptual framework is drawn from the relationship between the quarry dust, the health risks and the factors that influence the health risks.

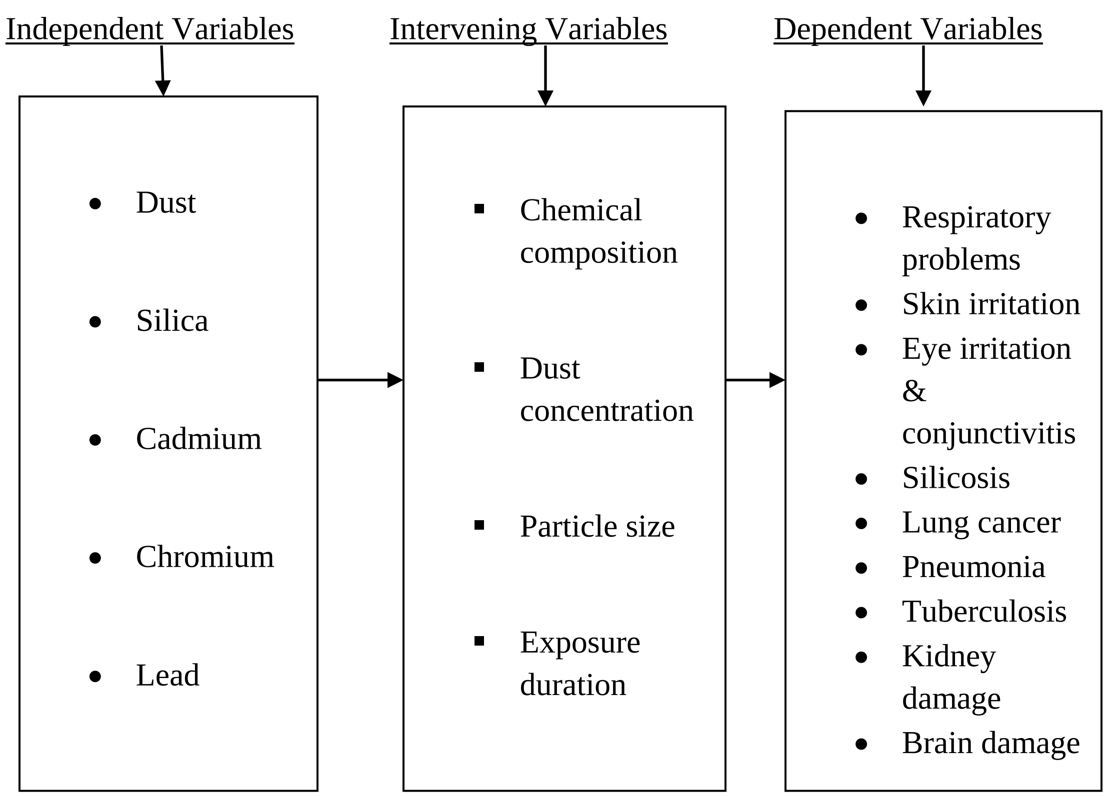


**Figure 1.1: Conceptual Framework**

The heavy metals found in crushed stone dust are carcinogenic, while long exposure to silica causes silicosis. Deposition of dust on the skin and eyes will cause irritation and the eyes may develop conjunctivitis (Figure 1.1).The type of chemical compounds or elements that compose the rock compounds the effect on human health. Other factors that influence the health risks posed to quarry workers include particle size, composition and concentration of the dust, deposition location within the respiratory tract and the exposure duration (NIOSH, 2002).

Deposition of the heavy metals may cause kidney and brain damage, and lung cancer (Martin & Griswold, 2009).Shortness of breath, chest pain, cough and wheezing are indicative of the onset of silicosis. Silicosis predisposes people to pneumonia, lung cancer and tuberculosis (Larson, 2005).

### 1.10 Definition of terms used in the study

| | |
|---|---|
| **Aggregate:** | Refers to sand, gravel and crushed stone |
| **Blasting:** | Using explosives to break rock |
| **Carcinogenicity:** | Potential of causing cancer |
| **Chemical compound** | relative amounts of elements that constitute a substance |
| **Crushed stone:** | Rock that has been broken into smaller, irregular fragments of specific particle size |
| **Crystalline silica:** | Crystal shaped silicon dioxide |
| **Drilling:** | Boring of holes into the rock mass in preparation for blasting |
| **Heavy metal:** | Metallic elements having an atomic weight higher than 40.04g (the atomic mass of Ca) |

| | |
|---|---|
| **Inhalable dust particles:** | Materials that are hazardous when deposited in the respiratory tract including the nose and the mouth |
| **Limestone:** | Sedimentary rock primarily composed of calcium carbonate ($CaCO_3$) |
| **Overburden:** | Earth material removed to expose the rock |
| **Phonolite:** | A fine grained and compact igneous rock |
| **Point source:** | Dust generated and can be captured and controlled |
| **Pozzolana:** | Volcanic ash used as mortar or hydraulic cement |
| **Quarry:** | A pit where aggregate is excavated |
| **Respirable dust particles:** | Materials that are hazardous when deposited in the gas exchange region |
| **Thoracic dust particles:** | Materials that are hazardous when deposited within the lung airways and gas-exchange region |
| **Silicosis:** | An incurable lung scarring disease caused by inhalation of crystalline silica |

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Preview

This chapter provides an overview of types and trends of quarrying in the world, Kenya and the rest of Africa. The chapter also discusses the impacts of quarrying and the available mitigation measures together with the acceptable standards and best practice in quarry industry.

## 2.2 Crushed Stone Quarrying

Aggregate quarrying is described as the extraction of the rock from the earth and processing the rock to the finished product of desired sizes (Langer *et al*., 2004). The extraction begins with removal of the overburden in order to expose the rock. The bedrock is ripped or is first drilled and blasted. The blasted rock is then hauled to the crushing plant for crushing and screening in order to produce the required aggregate sizes (Langer *et al*., 2004).

During these operations dust is the most visible, invasive and with potentially irritating impacts. Dust arising from quarrying, if not controlled may lead to increases in dust concentrations beyond the site boundary, which may affect the neighbouring communities (MIRO, 2011). Dust may occur as fugitive dust from haul roads, storage and from blasting, or can be from point sources, such as drilling, crushing and screening (Langer, 2001). It has been found that dust generation and its dispersion is a major concern in air quality modeling of open cast mines (Casella, (2006).

## 2.3 Types of Quarries

There are two types of rock quarries namely; crushed stone quarries and dimension/building stone quarries, as listed by the Mines and Geological Department in Kenya. "Crushed stone" refers to rock that has been broken into small irregular fragments of specific particle size. Crushed stone quarries produce aggregates for construction industry and cement factories, while dimensioned stone quarries produce building blocks and ornamental stone for construction of buildings (USGS, 2006).

This type of quarrying involves drilling, blasting and crushing and screening. The overburden is removed to expose the rock surface. The rock is drilled in preparation for blasting. During blasting explosives are used to break the rock into fragments, which are then hauled and fed into a crushing plant for crushing, screening, washing and stockpiling (Langer *et al.*, 2004).

Bedrock, the source material for crushed stone, is classified on the basis of origin as sedimentary, igneous or metamorphic. Loose sediments form sedimentary rocks by chemical, biochemical, or mechanical processes. Chemically or biochemically deposited carbonate sedimentary rocks, such as hard, dense limestone (calcium carbonate), commonly known as "limestone" in the aggregate industry, are known to make good source of crushed stone (Langer *et al.*, 2004). In Kenya limestone quarries produce aggregates used in cement manufacturing and other lime products.

## 2.4 World Trends in Rock Quarrying

Crushed stone was reported as the material of choice for making durable roads of good quality as early as in the $19^{th}$ century. At the time trap rock, granite and metamorphic rock, limestone, sandstone and shale were used for road metal. This industry grew as a result of high demand for construction materials (Langer, 2001).

The World Bank (2001) identifies over 40 percent of the World population as poor and that about 75 percent of the rural population in developing countries experience absolute poverty. These people are regarded as the landless, powerless, marginalized, vulnerable and disadvantaged. The poor rural dwellers usually seek livelihood opportunities in the informal sector of the economy especially in subsistence farming, small scale mining and quarrying (Birabwa, 2006).

In Malaysia, it is estimated that the informal sector employs the services of over 70 per cent of the population with the quarry industry alone employing about 30 per cent. Quarry operators have been identified as a key contributor to Malaysian economy providing job opportunities to the poor. The quarry industry has expanded significantly in thirteen different states with Perak and Sabah states operating 55 and 62 quarries, respectively (Ibrahim, 2007).

In 2010, stone-crushing industry in Pakistan was estimated to have an annual turnover of around US$ 1 billion and provided direct employment to over 0.5 million people (Ilyas & Rasheed, 2010). The report records that Pull 111 Market in Sargodha constituency is the largest market of stone crushing in Pakistan, and that the stone crushing units are located around or near the Kirana Mountains (Ilyas & Rasheed, 2010).

**2.5 Stone Quarrying in Kenya and some African Countries**

In Africa, it has been noted that dependence on agricultural output could no longer provide year round financial security due to continuous decline in farm yields. Since non agricultural activities in many instances yield as much returns as subsistence farming the only option for those without access to productive farmlands is stone extraction and mining (Wells, 2000).

In Kenya, both urban and rural populations depend on gathering and breaking stones for sale. Small-scale stone extraction in rural Kenya is a major source of livelihood despite the dangers it poses to the environment (Wells, 2000).

There is a wide range of quarrying activities including crushed stone quarrying for the production of ballast used for concrete and bitumen for roads. Building stone and dimension blocks are quarried for building; gravel and sand for construction industry. Rock is also crushed to be used as raw materials for factories and industries; for instance limestone and gypsum are crushed for use in cement manufacturing. The methods of quarrying are mainly through the use of heavy machinery and blasting of the rock. There are168crushed stone quarries operating in Kenya, 16 of which are in Kajiado County (MGD, 2012).

The number of quarries in Kenya is likely to increase due to the upcoming infrastructural projects in the country, especially the construction of roads and railway line. Extraction of gypsum, limestone and pozollana for the manufacture of cement is likely to intensify as the demand for construction materials also increase (Kenya Vision 2030, 2008).

In Mukono District of Uganda, Birabwa (2006) observed that poor individuals and households seek livelihood alternatives from small-scale stone extraction, especially those close to the hills of Kasenge (Birabwa, 2006).

In Ghana, 55.5 percent of the working population is employed in agricultural activities (Ghana Statistical Service, 2008). About 80 per cent of economically active population in Ghana works in the informal sector. Diversification into the informal sector provides countless opportunities for the poor seeking livelihoods in rural and peri-urban areas. In most rural and the peri-urban Ghana people engage in non-farm activities to supplement family incomes. At Buoho stone quarrying provides varying benefits to the local economy. The majority of the local people depend on small scale quarrying as a livelihood strategy (Asante *et al.*, 2014).

Records kept by Department of Transport and Community Services (DTCS) of North West Province in South Africa show that there are quarries for granite, slate, dolostone and limestone, and gravel and aggregates. There are a number of large and small granite quarry operations in North West Province, primarily in the area to the north ofBrits, Marikana and Rusenburg. The total estimated output of aggregates is 100,000 tons per year. Large quantities of dolomite and limestone are produced at Beestekraal, Zeerust and Dudfield areas, primarily for the cement industries in both North West and Gauteng regions. Gravel and aggregate products are based on quartzite (DTCS, 2009)

Quarrying is a very old industry in Nigeria’s quarry industry grown overtimehaving been established during the British colonial administration. Quarrying activities are widespread and less capital intensive compared to mining. The abundance of granite in Abeokuta is responsible for the large number of quarry companies operating around the city. This industry has engaged the services of the many rural population (Oguntoke *et al*., 2009).

### 2.6 Chemical Composition of Quarry Dust

Quarrying of stone produces significant fugitive dust emissions as a result of drilling and blasting, crushing, transportation and stock piling of the crushed stone.  Quarry dust is generated as a result of force applied to bulk material for economic extraction, handling, processing, storage and transportation (Beychock, 2005). The dust emissions can be a nuisance to the structures and vegetation. If these dust emissions are unmanaged they can cause serious environmental and health impacts on both site personnel and the neighboring communities (Billerica, 1998).

The mineralogy and chemical properties of granitic rock show a mineral composition of $SiO_2$ occupying a bigger percentage of 76.3%, $Al_2O_3$10.4% and the rest , $K_2O$, $Na_2O$, CaO, FeO, $Fe_2O_3$, $TiO_2$, $P_2O_5$ and MnO sharing the remaining 13.3% (Chappel& White, 2001). Chemical analysis of quarry dust showed 70.74% of SiO2, 20.67% of Al2O3, Pb at 625ppm and Cr at 125ppm (Naik & Vyawahare, 2013). A study by Madungwe & Mukonzvi (2011) on the assessment of distribution of quarry mine dust in Harare carried out the chemical analysis of quarry dust which showed the concentration of $SiO_2$ as 0.752mg/cm$^3$ and that of $Al_2O_3$ as 0.102mg/cm$^3$.

Quarry dust is composed of small particles of stone and based on the size the dust is categorized as inhalable ($PM_{10}$) or respirable $PM_{2.5}$). Inhalable dust is deposited in the airways while respirable dust is deposited in the gas exchange area of the respiratory tract. The recommended safe levels of $PM_{10}$ is 180mg/m$^3$ and $PM_{2.5}$ is 35mg/m$^3$ (EPA, 2003)

**2.7 Impacts of Quarry Activities**

Quarrying is a very important industry since it provides the means by which earth resources are extracted, processed and used for construction, agricultural and manufacturing industries. Different types of rock are quarried and crushed for different purposes. For instance, limestone is quarried and the rock processed for use in agriculture and cement production, while granitic or sandstone rock is quarried for use in the construction industry (Langer, *et al*., 2004).Despite the low value of crushed stone products, the crushed stone industry is a major contributor to and an indicator of the economic wellbeing of a nation (USGS, 2007). The demand for the crushed stone products depends on the level of construction activities and the corresponding demand for construction materials, (USGS, 2013).

http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/stat/index.html.

Production costs are determined by cost of labour, equipment, energy and water; and the cost of compliance with environmental and safety regulations. According to the statistical data given by the USGS, 1.72 billion tons of crushed stone worth $ 13.8 billion was produced and used in 2006. Out of this total production, 1.44 billion tones were used as construction aggregate, 74.9 million tons for cement manufacture and 18.1 million tons as agricultural lime for soil treatment. Despite their positive contribution to the socio-economic development of a country, its negative impacts on health, safety and the environment are a cause for concern (USGS, 2007).

**2.8 Impacts of Stone Dust on Health**

The main sources of dust in a quarry operation are drilling, crushing and road haulage. The workers are at risk of inhaling the emitted dust, which is injurious to their health. Inhalation of the dust can cause severe health problems including respiratory and pulmonary problems, while dust deposition causes skin and eye problems (Mengesha & Bekele, 1998). New Zealand Workplace Exposure Standards as an 8-hour time weighted average is $10mg/m^3$ for total dust, 5mg/m$^3$forrespirable dust and0.2mg/m$^3$ for respirable quartz dust (Glass, *et al*., 2003).

The fifty crushing stone units situated in Pammal, Tamil Nadu, which generated high level of dust in the vicinity of the crushing plants and the communities surrounding them(Sivacoumar, 2006). In a study conducted on pulmonary problems among quarry workers by Nwibo *et al.*, (2012) found out that the workers had various respiratory problems including chest pain, cough, wheezing and shortness of breath. The study found out that up to 98.3% of the workers had no safety measures. Data from the study suggests that chronic exposure to dust from crushing of rocks may increase susceptibility to respiratory problems and impaired lung function with tobacco or cigarette smoking and increased length of service as additional risk factors.

Ugbogu, *et al.*, (2009) studied the occurrence of respiratory and skin problems among manual stone workers and found out that up to 85% of the workers had respiratory symptoms while 77% had skin infection. The study also observed that although there was high level of awareness of effect of dust on their health, use of protective clothing and gear was not popular.

In a study by Ilyas *et al.*, (2010) it was established that dust related problems were exacerbated by cases of owners of the crushing stone unit not providing appropriate measures to protect the workers. The study also suggested that self-medication is the most preferred way of treatment and that health insurance was not at all available to the workers.

Developing countries are more prone to ill health and environmental damages compared to developed countries. This is due to unsatisfactory quality of work environment and health care support in developing countries (Ilyas & Rasheed, 2010). This study also found that due to under privileged livelihood patterns, the health effects of the dust impacts differently in poor working conditions, an increasing trend in respiratory diseases is related to decreasing air quality which is resulting from various types of environmental pollution. There is evidence that children are involved in hazardous work in the small-scale mining industry and that it is highly likely that these young workers catch the dust related diseases relatively quickly (ILO-IPEC, 2007).

Various studies have shown that rock contains crystalline silica which occurs in different quantities depending on the type of rock. For instance granitic rock contains up to 71% crystalline silica while limestone and basalts contains up to 40% and 1% of crystalline silica, respectively (HSE UK, 1992).

The report on the Geology of the Kajiado Area, records analyses of limestone rock samples indicating varying silica contents, the highest being 11.38% in a sample collected at the Kenya Marble Quarry(Matheson, 1966). However, little research has been conducted on the impact of the limestone quarry dust on the workers' health and therefore the magnitude of the problem has not been documented.

**2.9 Crystalline Silica and Human Health**

The major health concern is the inhalation of crystalline silica, which lodges, in human lungs thereby causing respiratory and pulmonary damage such as silicosis, bronchitis, pneumonia, tuberculosis and lung cancer (Last, 1998). The silica related diseases are preventable although once present they are incurable. The National Institute of Occupational Safety and Health (NIOSH, 2002) recommends exposure limit of 0.005g/$m^3$for respirable quartz bearing silica. Disease risk is related to both the total dose and the duration of exposure.

The onset of the disease might occur several years after exposure. It appears to be a low level of risk of contracting silica related disease from background levels of exposure (OEHHA, 2005), there remains significant concern over the risk of environmental exposure near peak sites e.g. crushing plants (Roperto *et al.*, 1995).

Oguntoke *et al.*, (2009) studied the impact of granite quarrying on the health of workers and nearby residents in Abeokuta Ogun State, Nigeria and found that frequent dust generation from the quarries was the most outstanding negative impact of quarrying operations identified by the respondents. The study was carried out in four selected quarries, recorded the mean suspended particulate matter levels ranged from 26.06 mg/$m^3$to 11.03 mg/$m^3$ at the drilling sites and 14.09mg/$m^3$ and 7.97mg/$m^3$ at the crushing sites of the quarries.

The factors of significance in the development of silica disease include size of the particle, concentration of the silica particle in the air, duration of exposure, particle surface characteristics including the age of the particles and the concentration of trace metals such as iron (NIOSH, 2002). Long exposure to crystalline silica causes silicosis or other severe respiratory illness (Langer *et al*, 2004).

The onset of silica disease, the hardening of the lung tissue, is a function of the concentration of the respirable silica particles and the duration of the exposure. It is due to the exposure to silica dust over a long period that one may develop silicosis, a fatal lung disease, (Rosner & Markowitz, 2006).According to Health and Safety Executive (HSE, 2000)silicosis is hardening or scarring of the lung tissue with consequent loss of lung function caused by inhalation of crystalline silica dust over long period exposure.

Silicosis is classified into three types; chronic, accelerated and acute silicosis. Silicosis can arise from long duration exposures at low concentrations from shorter exposure at higher concentrations (accelerated silicosis) and at very short duration exposure to very high concentration (acute silicosis) (NIOSH 2002).

Occupational Safety and Health Administration (OSHA) publication "Crystalline Silica Exposure" Health Hazards Information for General Industry Employees https://www.osha.gov/Publications/osha.3176.html,(accessed on 23 July 2013)has described chronic silicosis as the most common of the three and it occurs after 15-

20 years of exposure to respirable crystalline silica. Accelerated silicosis occurs after 5-10 years of high exposure to respirable crystalline silica and acute silicosis occurs after a few months to 2years following exposure to extremely high concentrations of respirable crystalline silica (OSHA, 2004).

A study byAzandand *et al., (*2006) on the quarrying industry around Delhi has described three types of silicosis depending upon the airborne concentration of crystalline silica to which a worker is exposed. Chronic Silicosis usually occurs after ten or more years of exposure. Accelerated silicosis results from higher exposures and develops over a period of five to ten years. Acute Silicosis occurs where exposures are the highest and can cause symptoms to develop within a few weeks or up to five years

Chronic silicosis can occur in workers exposed to fairly high levels of silica dust for an extended period of time (Hessel, 2007). Silicosis is the most common occupational lung disease worldwide; it occurs everywhere but is especially common in developing countries. According to the World Health Organization (WHO), the annual death toll from silicosis in China ten years ago was over 24,000 (CLB, 2005).

Expert Law publication has classified silicosis into similar types but different critical exposure periods. Chronic silicosis results from exposure to low silica dust for a period of 20 years and more; accelerated silicosis results from exposure to large amounts of silica over a short period of 5-15 years; and acute silicosis results from short term exposure to very large amounts of silica dust. Silicosis can increase the risk for other lung diseases, including tuberculosis (Larson, 2004).

According to American Lung Association, about 200 people die of silicosis each year. To date an estimated 2 million workers are believed to have been exposed to free crystalline silica dust, and approximately 250 die each year and hundreds more are disabled from silicosis. Longitudinal studies suggest that loss of lung function occurs with exposure to silica dust at concentrations between 0.1 and $0.2 mg/m^3$ (Lesley, 2011).

In the United States, it is estimated that one million to two million workers have had occupational exposure to crystalline silica dust and 59,000 of these workers will develop silicosis sometime in their lives (WHO, 2000). In the United States a 1930 epidemic of silicosis due to the construction of hawk's Nest Tunnel, West Virginia caused the death of at least 400 workers. The disaster is known as America's worst industrial disaster (Thomas& Kelly, 2010).

Although protective measures such as respirators have brought steady decline in deaths due to silicosis in the Western World, unfortunately, this is not true of the less developed countries where work conditions are poor and respiratory equipment is seldom used. Further, quarry workers from the less developed countries are oblivious of the occupational health risks they are exposed to in their work environments (Ali *et al*., 2010).

Studies of lung cancer in relation to silica exposures in occupational settings have been inconsistent (Bridge, 2009). It is also important to note that studies that have looked at the change in risk of lung cancer in relation to change in exposure to crystalline silica have generally not found that risk of lung cancer increases with increased silica exposure (Soutar *et al.*, 2000; Hessel *et al.*, 2000). Studies in which silicotic patients were not identified from compensation registries and in which enumeration was complete did not support a causal association between silicosis and lung cancer, which further negates the carcinogenicity of crystalline silica (Hessel *et al*., 2000).

Other studies confirmed that there is a strong body of evidence for causal relationship between exposure to crystalline silica and disease (Rosner & Markowitz, 2006). Other studies by Goldsmith (2006); McDonald *et al.*, (2005); and Steen land, (2001), have identified that exposure to crystalline silica can result in psychological changes, disease and death in exposed populations. The exposure caused a range of diseases, which include silicosis, lung cancer, renal disease, kidney cancer, chronic obstructive pulmonary disease (COPD) and rheumatoid arthritis (Bridge, 2009).

In a study to investigate the association between silica dust and lung cancer, it was concluded that the risk of getting lung cancer may be restricted to subjects with silicosis and is not directly linked to silica dust (Ulm *et al.*, 1998). One study suggested that silicosis, rather than silica itself, increased lung cancer risk in silica exposed workers. Therefore, to reduce lung cancer incidence in silica exposed workers there is need to focus on prevention of silicosis (Kurihara & Wada, 2004). Smoking accounts for 10% - 20% of the lung cancer excess (Steen land, & Sanderson, 2000). The joint effects of silica and smoking were both additive and multiplicative (Vida *et.al*, 2001).

**2.10 Heavy Metals and Human Health**

'Heavy metals' is the generic term for metallic elements having an atomic weight higher than40.04g (the atomic mass of calcium) (Ming-Ho, 2005). These metals enter the environment through natural and anthropogenic processes. Such sources include; natural weathering of the earth's crust, mining, soil erosion, industrial discharge, urban runoff and many others (Ming-Ho, 2005).

Chronic exposure to heavy metals and metalloids at relatively low levels can cause adverse effects (ATSDR, 2003b, 2007, 2008; Gonzales & Armenta, 2008).The results of a study on the elemental analysis of granitic rock dust indicated the presence of cadmium, chromium and lead, with chromium having a higher occurrence (Ugbogu *et al.*, 2009).

Generally, humans are exposed to these metals by ingestion, by drinking contaminated water or inhalation of dust and fumes bearing heavy metals (Martin & Griswold, 2009). Rock bearing arsenic, cadmium, chromium, selenium and lead when crushed produce dust exposing the workers to risks of inhaling the heavy metals, which are known carcinogens. Inhalation of cadmium-contaminated air severely affects the respiratory system causing shortness of breath and destruction of mucus membrane (Godt *et al*., 2006). The studies have shown that patients who were chronically exposed to cadmium suffer kidney damage and that there was proof that cadmium is carcinogenic (Godt *et al*., 2006).Inorganic arsenic can cause cancer of the skin, liver, lungs and the bladder, while cadmium and cadmium compounds can cause lung cancer.

Although, Chromium (III) is an essential nutrient, long exposure to Chromium (VI) compounds can cause damage to the liver, kidney circulatory and nerve tissues, as well as skin irritation. On the other hand exposure to high lead levels can cause severe damage to the brain and kidneys and ultimately cause death (Martin & Griswold, 2009).

There has been increasing concern, mainly in the developed world, about exposures, intakes and absorption of heavy metals by humans. Populations are increasingly demanding a cleaner environment in general and a practical implication of this trend, in the developed countries, has been the imposition of new and more restrictive regulations (EEC, 2006; Figueroa, 2008)

Regulatory exposure limits of heavy metals have been put in place for drinking water and workplace air. Environmental Protection Agency (EPA) limits arsenic at 0.01 ppm, cadmium at 0.005ppm, chromium at 0.1ppm and lead at 0.015ppm in drinking water. Occupational Safety and Health Administration (OSHA, 2004) puts the limits of 10ug/$m^3$ for arsenic, 5ug/$m^3$for cadmium, 0.0005mg/$m^3$ for chromium and 0.15ug/$m^3$ for lead in workplace air (Martin & Griswold, 2009).

OSHA limits for cadmium, chromium and lead are 5ug/m$^3$, 0.5ug/m$^3$ and 50ug/m$^3$, respectively.

**2.11 Quarry Management Practices**

The dust generated at the crushed stone quarries can be mitigated through minimization and or respiratory protection. Many quarries in the developed countries have developed quarry management plans or dust management plans. These plans or schemes are developed in line with the provisions contained in the legal framework for each country.

In Texas the operations are regulated under the Edwards Aquifer rules (Title 30, Texas Administration Code, chapter 213, or 30 TAC 213.The report describes among other issues, quarry dust control measures including use of vegetative cover in the quarry perimeter, mulching of the ground, windbreaks, tarping of haul vehicles, dust suppressors and sprinkling the ground surface with water (Barret & Eck, 2012).

MinEx Health and Safety Council had issued guidelines for the control of dust and associated hazards in surface mines and quarries (www.minex.org.nz). The guidelines give priority to dust reduction through dust collection and suppression systems, over respiratory protection. The latter is recommended where suppression of dust is not practical. The guidelines recommend dust control measures at drilling to include a drill rig fitted with a cyclone pneumatic dust collector, a dust shroud and a closed cabin for the drill rig operator. Dust control measures at the crusher include water spray system that directs water onto the input and dust extraction hoods and cyclone collectors at the output chute.

Sebright quarry in the City of Kawartha Lakes in Canada has developed a dust management plan that includes dust control measures at every dust emission point. This plan was prepared in line with the requirements of the Ontario Ministry of the Environment “Best Management Practices Plan” (Church &Trought, 2011).

The Town Farm quarry in Devon, South West England has put in place a Dust management Scheme developed in 2010 by Hanson Heidelberg Cement Group, the operators of the quarry, as an Environmental Management System. This has been done in line with Condition 23 and 24 of the planning permission (Mineral Planning Authority).

In Kenya, the legal framework for dust control is provided for by the Environmental Management and Coordination Act, 1999 and Occupational Safety and Health Act, 2007ensures the protection of workers as provided for under section 89(1) of the Act. Parts VI and VII of EMCA require the proponent of a quarry project to carry out an Environmental Impact Assessment, where the impacts of quarrying and the possible mitigation are identified. An Annual Environmental Audit and Monitoring reports are provided for under section 68 and Subsection 4, which requires the owner of the quarry project to take all reasonable measures to mitigate any undesirable effect (EMCA, 1999).

# CHAPTER THREE: MATERIALS AND METHODS

## 3.1 Preview

This chapter discusses the study area, research design, population of study, sampling design, data collection methods and instruments and analysis techniques. It also gives a brief on the geology of the study area, and the economic activities in the area.

## 3.2 Study Area

The study area is considered in terms of location, climate, geology and socio-economic activities. There are three types of quarries based on the rock type, namely limestone, phonolite and pozzolana quarries.

### 3.2.1 Location of the Study Area

The study area is located in Kajiado county and lies between latitudes $1^0$30’ and $2^0$00’ S. and longitudes $36^0$ 30’ and $37^0$ 30’ E, and it is at an altitude of 1710m above sea level (Figure 3.1). The county covers an area of 21,292.7 $Km^2$ and hosts a population of 687,312 people (KNBS, 2009).

The limestone quarries including Kenya Marble Quarries, Athi Minerals andE.A Portland Co. Ltd. (Kibini)quarries are located to the south of Kajiado town. While pozzolanaquarries of KarsamRamji& Sons and Sparetech,together with phonolite quarries of Hi-Tech Granite, Shivdhan Enterprises and KarsanRamjiare to the north.

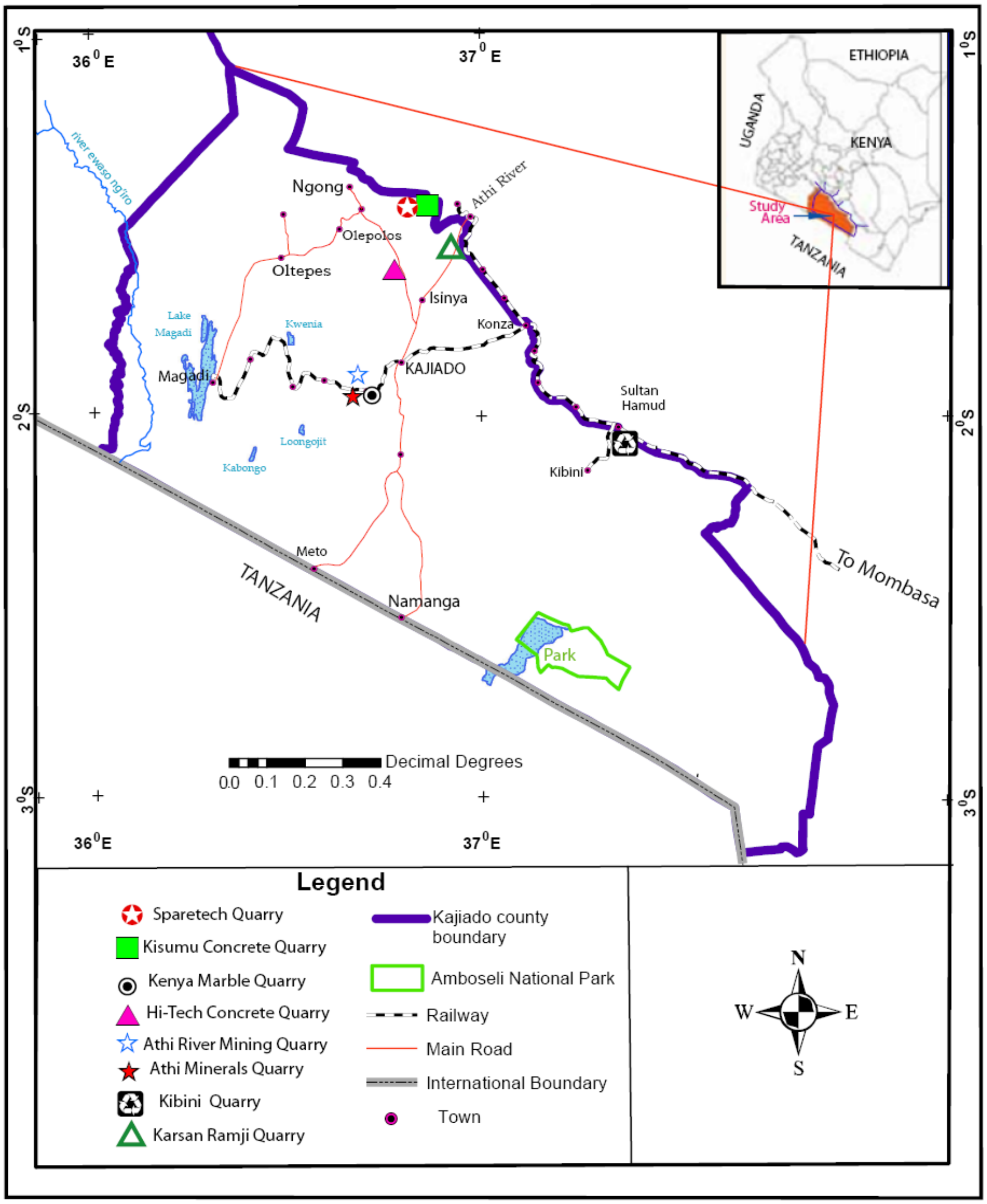


**Figure 3.1: Map of Kajiado County Quarries (Source: MGD 2014)**

### 3.2.2 Climate

Rainfall is bimodal and variable across the county with an average annual rainfall of 685mm.Long rains are experienced in April/May and short rains in November/January (Ogutu*et al.*, 2014). The general wind direction is South

Easterly with an average speed of 7.5ms$^{-1}$. The area experiences an average maximum temperature of 23$^{0}$C and a mean minimum of 11.58$^{0}$C (KMD, 2012).

The potential to emit dust is greatly affected by weather. Rainfall decreases dust emission due to both surface wetting and removal of dust from the air. Conversely, strong, warm drying winds increase the rate at which dust is lifted and spread www.sustainableaggregates.com accessed on 3/6/2014.

**3.2.3 Geology**

The oldest rocks in the area are the gneisses, limestone and quartzite of the basement system. They are of sedimentary origins and have undergone series of deformation episodes and volcanic extrusions. The basement system in the area is composed mainly of metamorphosed rock (Matheson, 1966). The major rocks found in Kajiado are the volcanic, the oldest being the Kapiti phonolite which occur to the east of Kajiado and whose age range between 23 and 65 million years (Matheson, 1966).

Volcanic rocks found in various parts of the area include the tuffs, basalts and agglomerates (welded tuffs) that are quarried for building stones.Phonolitic rock which is part of the tuffs is found in the northern part of the county. The rock is used for the production of aggregate for construction industry. Some tuffs are also used as pozollana for the manufacture of cement (Matheson, 1966) (Appendix V).

Crystalline limestone, which forms part of the basement system, is being quarried as raw materials in cement manufacture, chicken feed and soil conditioners. At the Kenya Marble Quarries site, the thickness of the marble is estimated to be 100 meters while the width of its exposure is about 350 meters. The prominent colours of the marbles are grey and brownish grey and rarely blue (Matheson, 1966).

### 3.2.4 Economic Activities

Shrubs and grassland generally suitable for ranching dominate the vegetation in Kajiado Countyandit ishome to a large number of wildlife and livestock. The County lies majorly in Ecological Zone V. The main socio-economic activity is traditional pastoralism, though there is a shift to other economic activities especially mining and rain fed and irrigated agriculture (Bosire, 2007).

The population of Kajiado County is cosmopolitan having attracted other ethnic groups because of mining, trade and agriculture. The geology of Kajiado describes the major rock formations, which bear various minerals accounting for the mineral potential of the county (Matheson, 1966). The mineral wealth of this county includes soda ash, limestone, gemstones, gypsum, pozollana, marble, feldspar, mica and various stone products for construction.

Tata Chemicals produced soda ash worth about 7 billion Kenya Shillings ($79 million) in 2011 (Mines and Geology Records, 2012). The mines and the quarries provide employment opportunities and therefore, support peoples’ livelihoods. The land is generally suitable for livestock production and wildlife. Amboseli game reserve provides revenue from the tourist industry while the livestock is supplied to the Kenya Meat Commission and other local abattoirs. The zone supports little rain fed agriculture, however, horticulture and floriculture is widely practiced through irrigation agriculture. Flowers are produced for export and vegetables are produced for local consumption and export.

## 3.3 Research Design

The research adopted a descriptive research design using quantitative methods to collect the data. The descriptive research design describes the characteristics of the variables in the study. Descriptive statistics such as the mean will be used in the analysis of the descriptive data (Mbwesa, 2006).

## 3.4 Target Population

The target population for the study is 288 workers (Table 3.1).

**Table 3.1: Crushed stone quarries sampled**

| | QUARRY OPERATOR | MATERIAL QUARRIED | NUMBER OF WORKERS |
|---|---|---|---|
| 1. | E.A. Portland Cement Co. | Limestone | 146 |
| 2. | Athi Minerals Ltd. | Limestone | 31 |
| 3. | Kenya Marble Quarries Ltd. | Limestone | 30 |
| 4. | KarsanRamji Ltd. | Phonolite | 20 |
| 5. | Shivdhan Enterprises | Phonolite | 13 |
| 6. | Hi-Tech Granite Ltd. | Phonolite | 8 |
| 7. | Sparetech Co. Ltd. | Pozollana | 20 |
| 8. | KarsanRamji& Sons | Pozollana | 20 |
| **TOTAL NO. OF WORKERS** | | | **288** |

The total population of the workers in all the 16 crushed stone quarries in Kajiado County was 750 (Mines and Geological Department, 2013). Although there were 16 quarries mining in the study location8 of them extracted the rock in the study location but transported it to the neighboring Machakos County for crushing. The remaining 8 quarries with drilling and crushing activities in the study location employed a total of 288 workers. The target population for the study was therefore, 288 as listed in the table below. The variation in the numbers of workers depended on the size of individual operations and the diversity of the activities (Table 3.1).

**3.5 Sampling Procedure and Sample Size**

There were 16 quarries in the study area of which only 8 quarries drilled and crushed at the study area. The remaining 8 quarries quarried in the study location but crushed outside the study location. All the 8 rock quarries were included in the sample due to their small number. The sample size of the quarries was therefore found to be 8 quarries. The quarries were then stratified into three according to the rock types for comparison of the dust concentrations. The strata consisted of 3 limestone quarries, 3 phonolite quarries and 2 pozollana quarries.

The 8 quarries had a total of 288 workers who were grouped according to their job specifications and workstations. The workers were then stratified into three in order to capture the different dust exposure levels; the quarry pit workers forming one stratum, those working at the crushing plant, forming the second and the mechanics and the office workers forming the third stratum.

**Table 3.2: Workers sampled**

| | CATEGORY OF WORKERS | TOTAL NO. OFWORKERS | SAMPLE |
|---|---|---|---|
| 1. | Drillers | 15 | 15 |
| 2. | Quarry pit | 72 | 26 |
| 3. | Crusher | 61 | 21 |
| 4. | Garage and office | 140 | 48 |
| | **Total** | **288** | **110** |

Since the number of workers in each stratum varied, disproportionate sampling was applied to the population. Through census it was found that the 8 quarries had a total of 15 drillers and due to the small number purposive sampling was used to get the sample of 15. Sampling of the remaining three working stations was done with a view to getting similar proportions from the target populations of the different groups. Simple random sampling was conducted for each group and a result of 26,21 and 48 workers, respectively was found. A sample size of 110 workers was selected out of the sample population of 288 (Table 3.2).

### 3.6 Data Collection Instruments and Procedures

Quantitative data was collected using the questionnaires and the chemical analysis of the dust samples collected. Quarry dust was collected using a 224-PCXR4 Sample Pump connected to a cassette holding a 47mm diameter filter of pore size of 8 microns. An Analytical Digital Balance, model number AE680902 was used to measure the weight of the dust sampleswhilea Varian AAS, model SpectrA A-

10was used to analyze the chemical composition and concentration. The XRF was used to analyse for the occurrence of radioactive elements.

### 3.6.1 Sample Labeling

Sample cassettes were labeled for ease of identification. Gummed paper labels were used and affixed on the cassettes at the point and time of collection (APHA, 2005). The details on the labels included unique sample number, sample point, sample type, date and time of collection (ALPHA, 2005).

### 3.6.2 Dust Sampling

The sampling media used to collect the dust samples at the quarries were membrane filters of pore size 0.8micron, fitted in 47mm diameter cassettes sealed on both ends. The Universal Sample Pump, model 224-PCXR4 was used for dust sampling.


**Plate 3.1: Cassettes with the filter in the desiccator**

A membrane filter used as the medium for collecting dust was placed in a tightly closed cassette in order to keep it dry. The Universal SamplePump was connected to a cassette to form the sampling equipment used to collect the dust from the various sampling points at the stone quarries (Plate 3.3).

The filters were desiccated for about 15 hours and weighed using an Analytical Digital Balance at the Directorate of Occupational Safety and Health (DOSH) laboratories and the weight recorded (Plates 3.1 and 3.2). They were then placed in the cassettes and plugged on both sides in order to keep the cassette airtight. The cassettes together with the dust sampling pumps were transported to the dust collection sites ready for use.

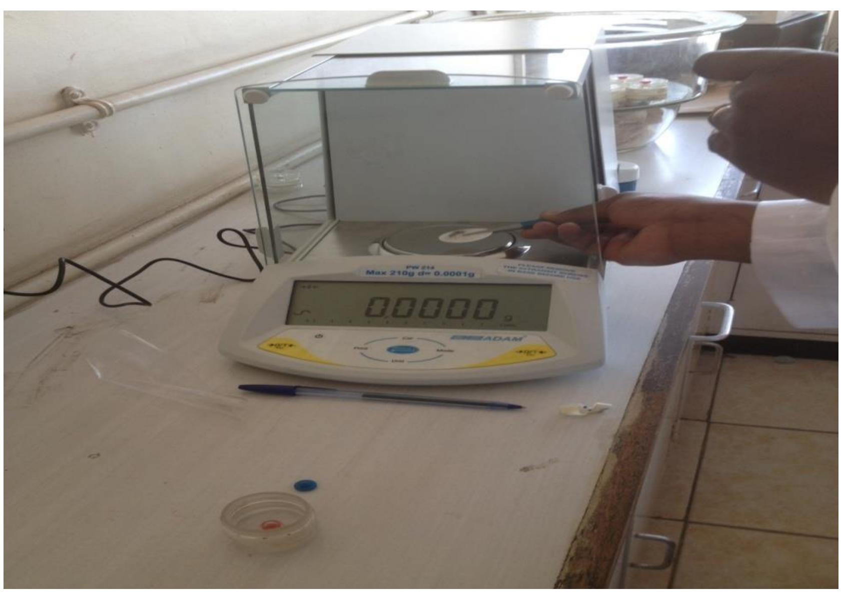


**Plate 3.2: Weighing the filter paper**

In every quarry the dust collection pumpswereset at 2L/minandwere each connected to a cassette containing a filter (Plate 3.3). The set of dust sampling equipment was each stationed at the four cardinal directions from the source of dust at successive distances of 0m, 25m and 50m away from the crusher. The pumps were allowed to run for two hours at every collection point.

The same procedure was repeated for the drilling point source, and in the quarry pit (Plate 3.3). Dust samples were collected at 0m, 25m and 50m from each of the eight quarries.

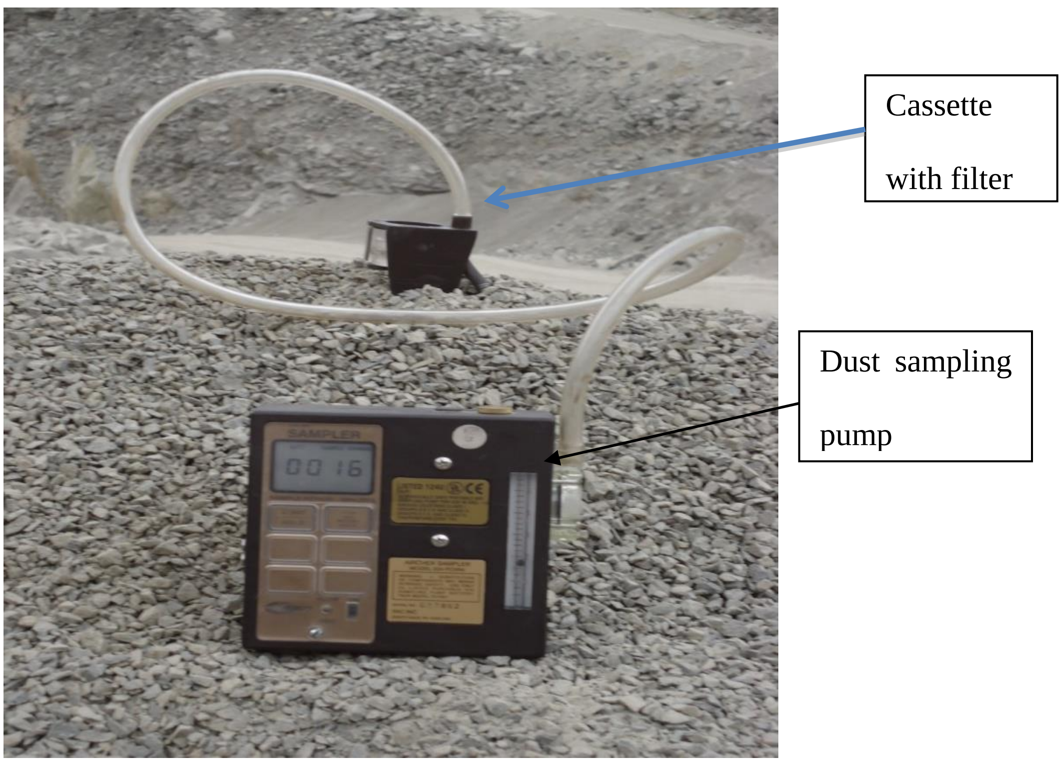


**Plate 3.3: Dust sampling**

The cassettes containing the dusty filters were carried to the DOSHS where they were again desiccated in order to remove any moisture that the filter may have collected during dust sampling (3.1). Using a digital weighing balance placed in an enclosed room the final weight of the dusty filterswas taken (Plate 3.2).

**Plate 3.4: Weighing the dusty filter**

The difference between the dusty filter and the blank one gave the weight of the dust sample. The dust concentration was calculated using a standard procedure formula.

### 3.6.3 Chemical Analysis of the Dust

The dust samples collected from the first quarry were then transferred to Mines and Geological Department's laboratory for the analyses (Plate 3.5).

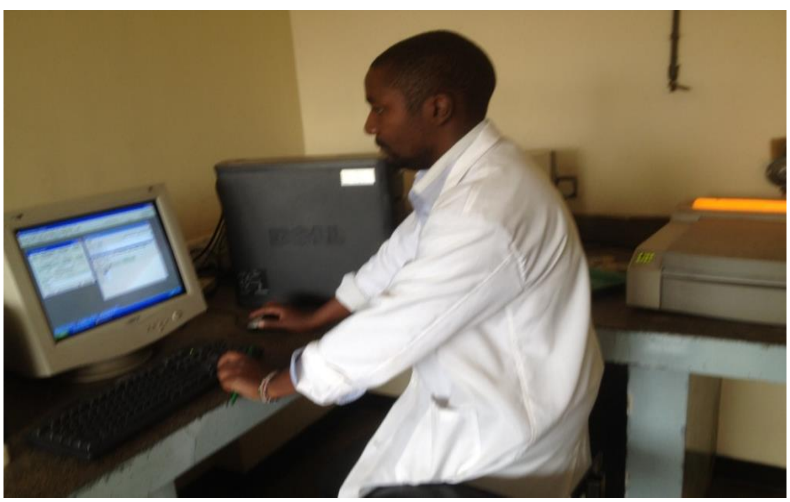

**Plate 3.5: Analysis of the dust sample by AAS**

The samples were analysed using the standard analytical procedures. The samples were analysed for their chemical composition, any radioactive elements and heavy metals including using an XRF and AAS (Plate 3.5).A dry analysis for any radioactive elements was done using the XRF while the AAS was used to analyse the chemical composition and concentration of the dust samples. The dust samples were digested using hydrochloric acid + nitric acid (aqua-regia), and then fed into the AAS and computerized results read against the standard solution.

### 3.6.4 Administration of the Questionnaire

A sample of 110 workers was interviewed (Table 3.2). Each worker was issued with a questionnaire and was then guided by the researcher with regard to the ethical issues and answering the questionnaires. The questionnaires that were marked with unique numbers were administered to the stone quarry workers at their workstation and given adequate time to fill them. The ethical issues that were considered with regard to the administration of the questionnaire were informed consent and confidentiality (Appendix I).

### 3.6.5 Informed Consent

All the participants underwent a standard verbal consent consistent with international recommendations. The purpose of the study was explained to the participants including the duration of the interview and the procedures to be followed during the interview. They had an opportunity to choose whether to participate in the study.

### 3.6.6 Confidentiality

The questionnaires were assigned unique numbers and names of the participants were not to be used. The research assistants were trained on the importance of maintaining confidentiality and that all participants were to remain anonymous.

### 3.6.7 Permission to Collect Data

Permission to carry out the study was sought from National Council of Science and Technology (NACOSTI). And permission to conduct the interviews on the workers and to collect dust samples for analysis was granted by the quarry operators. The workers were assured of the interviewer's full cooperation and the need for them to cooperate with the interviewer.

### 3.6.8 Risk/Benefit Information

The participants did not have any direct benefit for participating in the study but they were assured of their protection during the interviews. However, they would benefit from the implementation of the recommendations of the study.

## 3.7 Data Analysis

The collected data were cleaned, edited for accuracy and analyzed using descriptive statistics in order to give numerical summaries of central tendencies and measures of dispersion. The quantitative data was analyzed using computer packages including ANOVA and Bonferroni Method of Multiple Comparison, in order to get the mean values, variance and significance at 95% significance level.

# CHAPTER FOUR: RESULTS AND DISCUSSION

## 4.1 Preview

This chapter presents the results of the study, which have been discussed under thematic areas and sub- sections in line with the research objectives. The thematic areas include the chemical composition of the quarry dust analyzed, the particle concentration of dust produced at the quarry as well as the dust related safety and health problems affecting workers. It also includes the demographic characteristics of the quarry workers interviewed and their level of awareness of the negative effects of a dusty work environment. Although the sample of the workers was 110 only 109 were interviewed since 1 crusher worker was indisposed.

## 4.2 DemographicCharacteristics

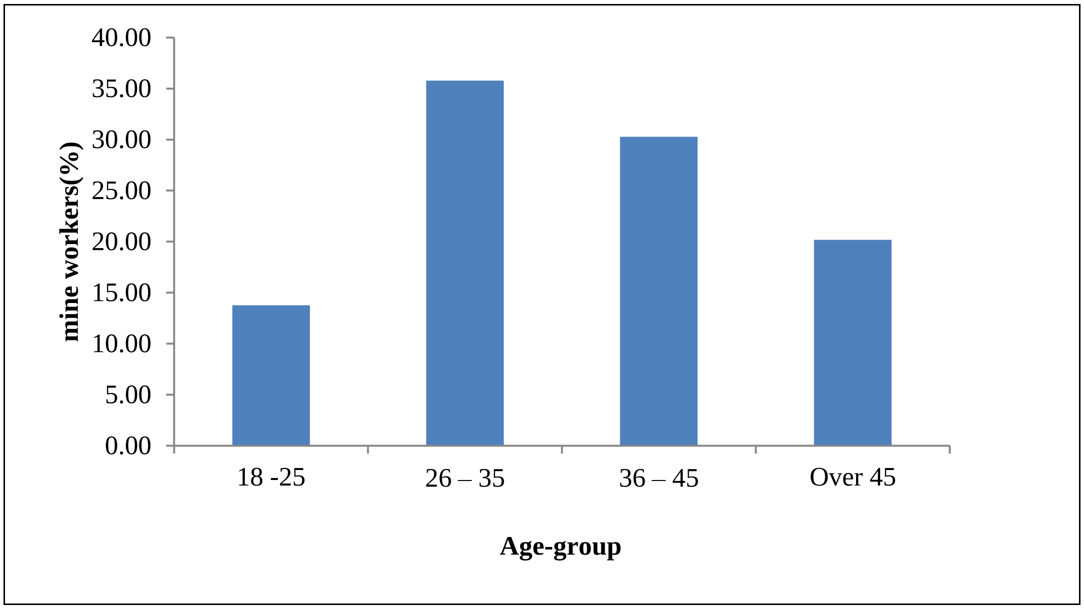


**Figure 4.1: Age group of workers**

The study found out that 65% of the workers were in the productive age group of between 26-45 years (Figure 4.1).

**Table 4.1: Demographic characteristics**

| Characteristics | Numbers of workers | Percentage |
|---|---|---|
| **Gender (n=109)** | | |
| Male | 104 | 95.4 |
| Female | 5 | 4.6 |
| **Marital status (n=109)** | | |
| Single | 16 | 14.7 |
| Married | 93 | 85.3 |
| **Highest level of education (n=109)** | | |
| None | 26 | 23.9 |
| Primary | 29 | 26.6 |
| Secondary | 44 | 40.4 |
| Post-secondary | 10 | 9.2 |

The study showed that out of a total of 109 workers interviewed, 95.49% were male (Table 4.1).

### 4.3 Major Sources of Quarry Dust

It was observed that the major sources of dust in the quarry operations were at drilling and crushing. During drilling the rock is cut and ground in confined space thereby producing fine dust. Crushing fragments the rock into desired sizes and releasing dust into the atmosphere (Plates 4.1 and 4.2).

**Plate 4.1: Drilling at a quarry**

**Plate 4.2: Crushing the rock**

### 4.4 Chemical Composition of Dust from Different Rock Types

The study found out that the chemical composition of the dust from the different rock types showed varying percentages of the constituent compounds. Limestone showed a higher percentage (10.43%) of CaO, pozollana had the highest levels of $SiO_2$ (35.92%) while phonolite had the highest percentage of $Na_2O$ (17.3%) in their composition (Table 4.2).

The dust samples neither contained any detectable cadmium nor radioactive elements. The chemical composition of the rock determines what type of rock it is. The percentages of the different compounds forming the rock confirm the differences in limestone, phonolite and pozzolana rock types.

**Table 4.2: Chemical composition of the dust**

| **OCCURRENCE IN PERCENTAGE (%)** | | | |
|---|---|---|---|
| **Compound/element** | **Limestone** | **Phonolite** | **Pozzolana** |
| $SiO_2$ | 3.26 | 6.66 | 35.92 |
| $Al_2O$ | 6.17 | 6.86 | 4.83 |
| CaO | 10.43 | 1.71 | 2.36 |
| MgO | 1.65 | 0.33 | 1.02 |
| $Na_2O$ | 4.18 | 17.30 | 18.02 |
| $K_2O$ | 1.76 | 2.18 | 3.42 |
| $TiO_2$ | 12.41 | 1.51 | 2.48 |
| MnO | 3.4 | 0.60 | 0.34 |
| $Fe_2O_3$ | 5.19 | 4.32 | 5.10 |
| **ppm** | | | |
| Cu | 28.75 | 43.17 | 55.13 |
| Cr | 9.0 | 9.80 | 22.18 |
| Pb | 15.5 | 41.14 | 23.08 |

### 4.5 Concentration of Dust in Different Rock Types

The study found out that different rock types produced dust of varying concentrations. Dust from pozollana rock type had a higher concentration compared to the other two rock types. Even at different distances from the dust source pozzolana had high dust concentration.

**Table 4.3: Concentration of dust from different rocks**

| **Type of rock** | **Concentration of dust (mg/m$^3$)** | | |
|---|---|---|---|
| | **0m** | **25m** | **50m** |
| Limestone | 0.092 | 0.026 | 0.006 |
| Phonolite | 0.161 | 0.055 | 0.003 |
| Pozollana | 0.305 | 0.115 | 0.032 |

The variation in dustiness of the three types of rocks is mainly due to the difference in their hardness. Pozzolana, otherwise known as pozzolanic ash crumbles easily into powder (Table 4.3).

**4.6 Concentration of the Elements and Compounds in the Dust**

The study revealed the varying contents of silica and the heavy metals in the dust from the three different types of rock analyzed. Theconcentration of silica was highest (35.92%) in pozollana and least (3.26%) in limestone (Table 4.2).

The results were higher than the results of this study although the trend was similar. The high concentration of silica in Pozzolana is due to its volcanic origin. Pozzolana is formed from a combination of minerals consisting of silica and alumina (www.buildingconservation.com/articles/pozzo/pozzo.htl). Analysis of rock samples on the chemical composition of various samples of limestone in a quarry in the study area showed the concentration of silica varying between 2.17% and 11.38%Matheson, (1966). HSE (2006) noted that silica content in limestone is up to 2%. Limestone contains low concentration of silica compared to the volcanic tuffs of phonolite and pozzolana.

**Table 4.4: Concentration of the elements in different rock types**

| Element/ Compound | Limestone | | Phonolite | | Pozollana | |
|---|---|---|---|---|---|---|
| | Stone | Dust | Stone | Dust | Stone | Dust |
| Silica (%) | 4.65 | 3.26 | 51.17 | 6.66 | 64.45 | 35.92 |
| Chromium ($mg/m^3$) | 8.73 | 5.41 | 12.25 | 0.73 | 21.25 | 16.97 |
| Lead ($mg/m^3$) | 24.94 | 8.74 | 17.2 | 5.10 | 14.88 | 18.20 |

The concentrations of silica and the heavy metals varied in the three rocks studied with pozollana containing the highest silica concentration. Although the dust from limestone had lower concentration of silica, the exposure due to the long working hours made the workers vulnerable and risked developing silicosis and cancers caused by the heavy metals identified in the quarry dust. The high concentration of dust generated at drilling and at crushers depicts these areas as peak sites and therefore hazard zones (Roperto *et al.*1995).

The concentration of Cr was high at 16.97$mg/m^3$ in pozollana, and was least (0.73$mg/m^3$) in phonolite. The study also found out that the concentration of lead (Pb) was high at18.20$mg/m^3$ in pozollana and low at5.10$mg/m^3$inphonolite. Pozollana had the highest concentration of silica, chromium and lead compared to the other two rock types (Table 4.4). The variation in the silica content is attributed to silica being the dominant compound in pozzolana as shown by results from other studies (www.uonbi.ac.ke/faculties/turntopdf.php.project).

### 4.6.1 Comparison of Particulate Concentrations

The mean silica concentrations of the dust from limestone, phonolite and pozzolana were compared using ANOVA statistical method, which registered $p<0.0001$ showing that the mean concentrations for silica weresignificantlydifferent, thereby confirming the null hypothesis. On the other hand the mean concentrations of Cr and Pb yielded results showing $p=0.2071$ and $p=0.1460$, respectively. This result showed no significant difference Cr and Pb concentrations in limestone, phonolite and pozollana rock types rejecting the null hypothesis for Cr and Pb. The second hypothesis was however expunged due to the limitation to establish the health problems at the study area.

### 4.6.2 Comparison of Mean Concentration of Dust from Pairs of Rocks

Dust concentration from pairs of rock types was compared using Bonferroni Method of Multiple Comparisons, in order to find out whether there was any significant difference between them. Using the principle of Null Hypothesis Pozollana and phonolite were found to be significantly different. Pozollana and limestone also showed significant difference. The null hypothesis is therefore rejectedin the two cases. However, limestone and phonolite did not show any significant difference confirming the null hypothesis (Table 4.5).

**Table 4.5: Comparison of dust concentration of pairs of rock types**

| Type of Comparison | Difference between means | Simultaneous 95% Confidence Limits | | |
|---|---|---|---|---|
| Pozzolana–phonolite | 28.149 | 20.070 | 36.228 | *** |
| Pozzolana-Limestone | 32.105 | 23.598 | 40.613 | *** |
| Phonolite -Limestone | 3.957 | -2.752 | 10.665 | |

**Comparisons significant at 0.05 levels are indicated by *****

### 4.6.3 Dust Concentration and OSHA Limits

Themeandust concentration was86.21mg/m$^3$which was higher than the allowed limit of 10mg/m$^3$ for inhalable dust. Silica concentration was 0.62mg/m$^3$, higher than limit of 0.2mg/m$^3$ for respirable silica (OSHA). The concentrations for chromium and lead were also comparatively high (Table 4.6). The workers were therefore at high risk of developing respiratory problems and silicosis from exposure.

**Table 4.6: Dust particle concentration in the quarry**

| | Mean value | OSHA Limits(2005) |
|---|---|---|
| Conc. of dust | 86.521mg/m$^3$ | 10mg/m$^3$ |
| Silica ($SiO_2$) | 0.62mg/m$^3$ | 0.2mg/m$^3$ |
| Chromium (Cr) | 5.916mg/m$^3$ | 0.5mg/m$^3$ |
| Lead (Pb) | 9.244mg/m$^3$ | 0.05mg/m$^3$ |

Inhalation of these high levels of lead exposed workers to kidney and brain damage while inhalation of chromium-laden dust exposed the workers to the risk of damage to the livers and the kidneys as well as skin irritation (Martin & Griswold, 2009).

### 4.6.4 Dust Concentration at Drilling, Crushing and Quarry Pit

The study showed that the concentration of dust varied at the three working areas.

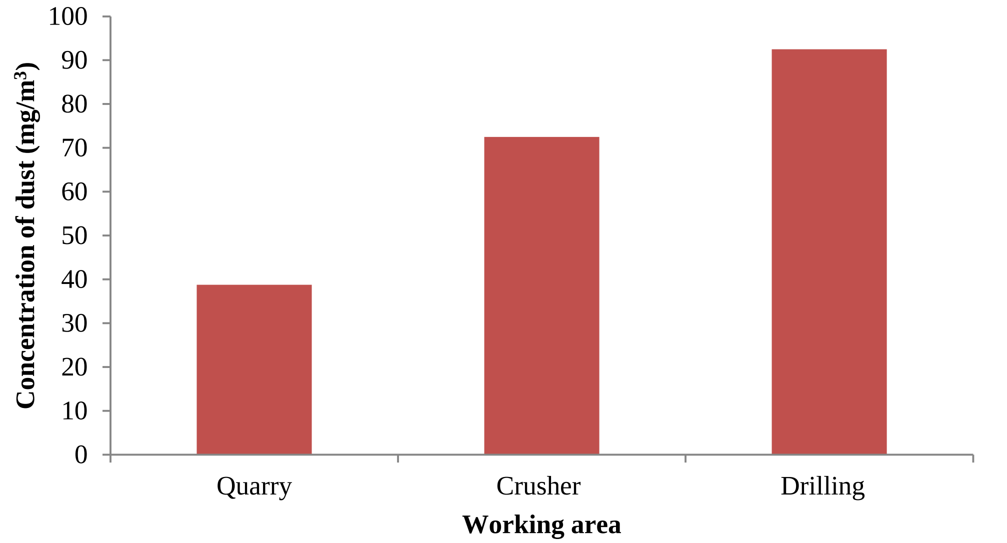


**Figure 4.2: Dust concentration in working areas**

The concentration ranged from 38.75mg/m$^3$ at the quarry pit, 75.0mg/m3 at the crushing plant and 92.50mg/m$^3$ at drilling (Figure 4.2).

The three working areas had high dust concentrations compared to the time weighted average limit of 10mg/m$^3$ for total dust, 5mg/m$^3$ for respirable dust and 0.2mg/m$^3$for respirable silica (New Zealand Workplace Exposure Limit). A similar study on impact of granite quarrying on the health of workers (Oguntoke, *et al*., 2009) showed similar results of higher concentrations of dust at drilling than at crushing, 26.03mg/m$^3$ and 14.09mg/m$^3$, respectively. Drilling and crushing of rock are peak points in dust production.

### 4.6.5 Dust Concentration by Distance from the Source

The mean concentration of the dust varied with distance from the source. The mean concentration was 0.165mg/m$^3$ at 0m, 0.04mg/m$^3$ at 25m and 0.005mg/m$^3$ at 50m from the source (Figure 4.3).

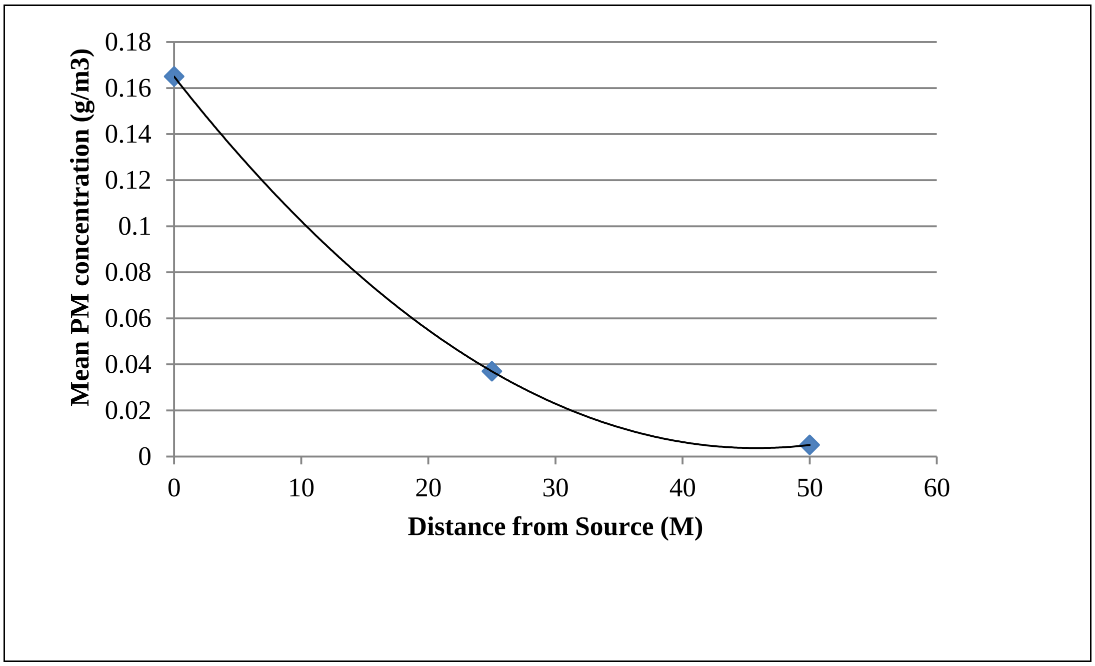


**Figure 4.3: Dust concentration with distance**

The correlation coefficient between dust concentration and distance was -0.41125 and the p-value were 0.00103. The negative correlation confirmed a decrease of dust concentration as the distance increases. As the dust is blown away from the source by the wind the dust concentration is reduced due to the dilution effect. The p-value being less than 0.05 showed significant difference. Results from another study byBabatunde (2013) showed that mean dust concentrations reduced significantly with distance. There is significant concern of the risk of exposure near peak sites at the crusher (Roperto, *et al*., 1995).

Work areas that were 50m away from the source of dust, especially the office and the garage, were safe since the dust concentration was less than the NIOSH limit of 5mg/$m^3$. However, 78% of the workers were located less than 50m away from the source of dust and were therefore, at risk of developing health problems (Figure 4.3).

### 4.7 The Health Symptoms Exhibited by the Workers

The study found out that the health symptoms exhibited by the respondents were respiratory, skin and eye ailments. The results showed that 60.55% of the workers suffered from cough, 10.09% and 2.75% suffer from eye and skin irritation, respectively (Figure 4.4).

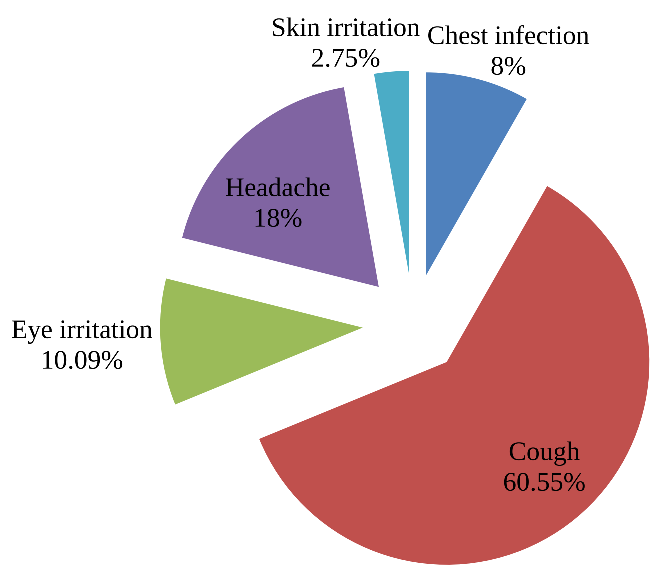


**Figure 4.4: Ailments exhibited by workers**

In a similar study it was found out that the inhalation of the dust causes severe health problems including respiratory and pulmonary problems, while dust deposition causes skin and eye problems (Ugbogu, *et al*., 2009).

### 4.7.1 Respiratory ailments

A high prevalence of respiratory problems was noted in the study; the most common ailments were occasional dry and productive cough at 41% and 52%, respectively. The other worker showed symptoms including breathlessness and wheezing (Table 4.7). The symptoms exhibited by the workers were an indication of risk of developing silicosis (OSHA, 2007).

A similar study on pulmonary problems among quarry workers of stone crushing industrial site at Omuoghara, Ebonyi State, Nigeria (Nwibo, *et al*., 2012),gave a similar trend. This study by Nwibo *et al.*, (2012) showed7.4% of the workers had occasional cough, 5.2%were wheezing while6.4% experienced shortness of breath.

**Table 4.7: Respiratory ailments**

| Ailments suffered | No. of Workers | Percentage |
|---|---|---|
| Cough for 3 months in a year | 55 | 50.5 |
| Cough and clearing throat in the morning | 49 | 45.0 |
| Productive cough | 57 | 52.3 |
| Wheezing in the chest | 29 | 26.6 |
| Breathlessness when climbing | 35 | 32.1 |

### 4.8 Workers Exposure to Dust

The period of exposure of the workers in terms of their residence, area of work, the number of years worked, the number of days worked in a week and the number of hours worked in one week was determined with a view to establish the relationship between exposure and the ailments presented by the workers. The area where they worked would indicate the concentration of dust the workers were exposed to (Figure 4.5).

#### 4.8.1 Quarry Working Areas

The study results showed that 50% of the workers were stationed in the quarry, while (28%) of the workers worked at the crusher. Only22% of the workers worked indoors, 11% at the office, and a similar percentage worked in the garage (Figure 4.5).

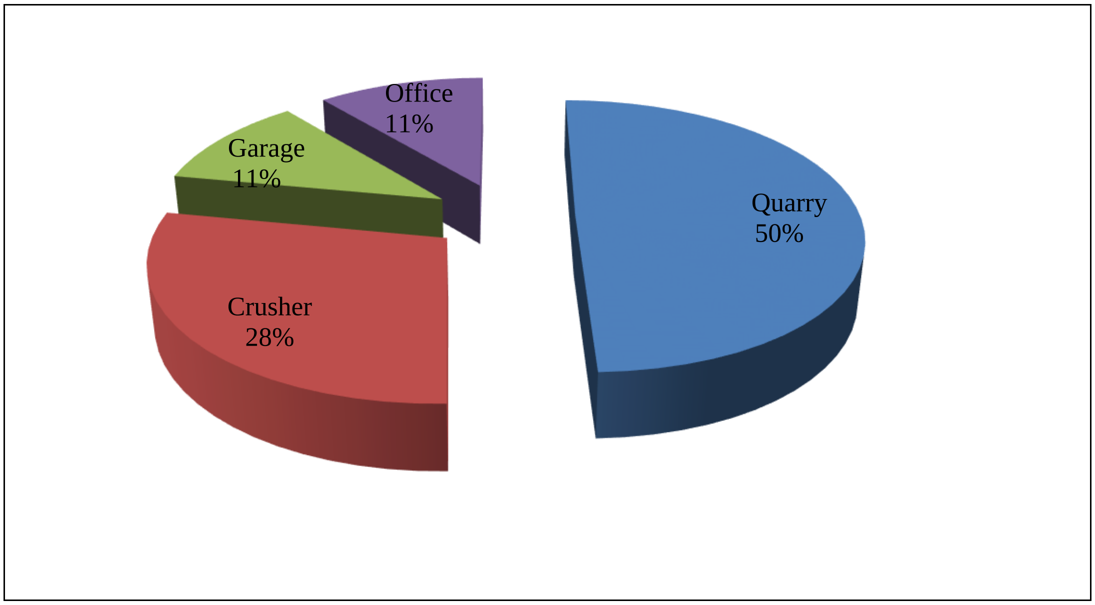


**Figure 4.5: Distribution of workers by workstation**

### 4.8.2 Exposure Duration at the Quarry

The study considered the length of period the workers had been exposed to the dust at the quarry.

**Table 4.8: Period worked in years**

| **Period** | No. of workers | Percentage |
|---|---|---|
| Less than 1 | 24 | 22.02 |
| 1-5 | 30 | 27.52 |
| 6-10 | 15 | 13.76 |
| 11-15 | 14 | 12.84 |
| 16-20 | 13 | 11.93 |
| More than 20 | 13 | 11.93 |
| | **109** | **100** |

The study showed 49.54% of the workers had worked for up to 5 years (Table 4.8). The study also found out that 60.6% of the workers worked for 6 days a week at an average of 8 hours a day. The exposure period in one year therefore, was 2496 hours; hence the high vulnerability to the dust related health risks (Table 4.8).

The study revealed that up to 50.46% had worked in the quarries more than 6 years (Table 4.8), where they were exposed to concentrations of 0.62mg/$m^3$ of silica, 5.92mg/$m^3$ of Cr and 9.24mg/$m^3$ of Pb (Table 4.6). Exposure of dust especially when it contains silica predisposes workers to various types of silicosis depending on the number of years exposed. Workers, who are exposed for 5-15 years may develop accelerated silicosis (Azandand*et al*., 2006).

### 4.8.3 Comparison of Ailments by Workstations

The study found out that despite being stationed at different work areas most workers suffered from cold and cough. Those working at the crusher and the quarry had higher incidence of ailments compared to the other work areas (Figure 4.6).

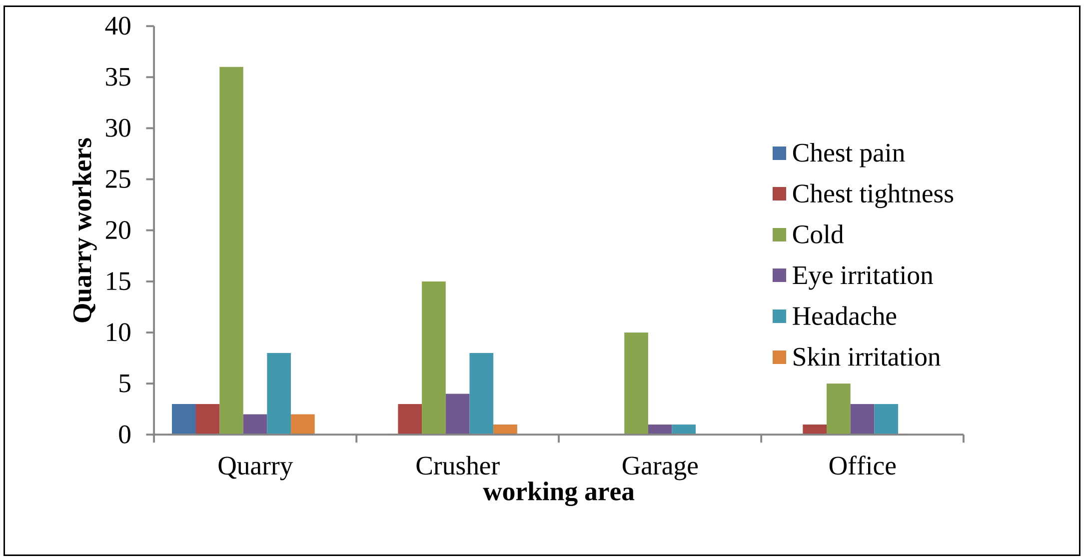


**Figure 4.6: Ailments exhibited in relation to work area**

The results show a high incidence of ailments at the quarry and the crusher than the office and the garage. The crusher and the quarry pit have high incidences of dust generation the latter being due to drilling and movement of machinery. The study revealed that drilling generated high dust concentrations compared to the rest of the work areas (Figure 4.2). In a study by Roperto *et al*.,(1995) it was revealed that the crusher was a peak site considered to present high risk of exposure to the workers .

**4.9 Use of Protective Clothing and Equipment**

The study results showed that few workers protected themselves from the effects of dust. There were only 22% who wore overalls/dustcoats, 17% used dust masks and 15% wore eye goggles (Figure 4.7).

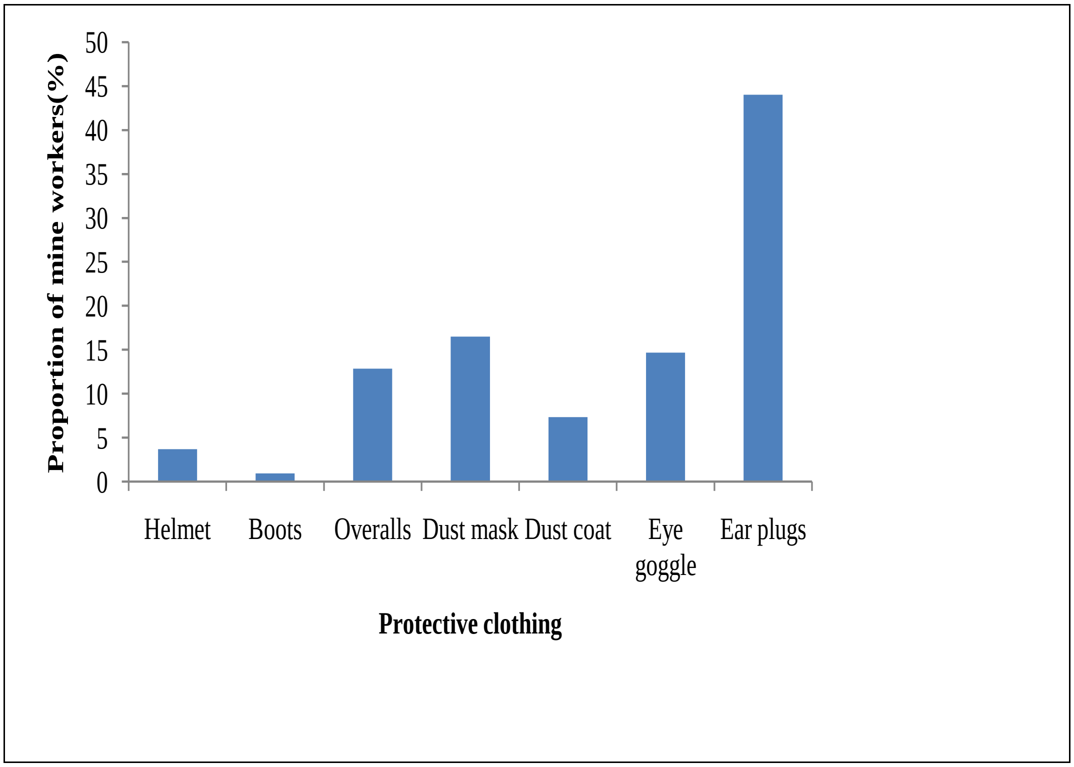


**Figure 4.7: Use of protective gear/clothing by quarry workers**

Ugbogu *et al*., (2009) studied the occurrence of respiratory and skin problems among manual stone-quarry workers and found out that there was poor use of dust masks (6%), overalls (12%), eye goggles (0%). Another study by Nwibo *et al.* (2012) found out that 98.3% of the workers had no safety measures and that the workers listed various respiratory problems including chest pain, cough, wheezing and shortness of breath. The three similar studies show poor use of protective clothing among crushed stone quarry workers.

The study revealed that the workers awareness of the health risks was high (94.5%), but only 16.51% wore protective clothes when at work. In a similar study by Ilyas *et al.*, (2010), it was found that the owners of the crushing stone unit did not provide appropriate measures to protect the workers thus increasing the high incidence of non-protection from the dust.

# CHAPTER FIVE: CONCLUSIONS ANDRECOMMENDATIONS

## 5.1 Preview

This chapter represents the conclusions drawn and the recommendations given in line with the study objectives and the hypotheses. The study examined the effects of crushed stone dust from the quarries on human health in Kajiado County. The study sought to find out the chemical composition of the quarry dust in order to identify any elements and compounds and their particulate concentration. The study also determined whether the quarry workers exhibited any ailments related to exposure to quarry dust.

## 5.2 Conclusion

The study revealed that the dust was composed of various chemical compounds, including silica, chromium and lead all of which have human health impacts. However, the dust was cadmium free.

The concentration of the quarry dust, silica, chromium and lead were higher than the OSHA limits. The negative correlation between the dust concentration and the distance from the source of the dust confirmed that the workers at drilling and the crusher were exposed to high concentrations.

The dust concentration depended on the type of rock that was mined or quarried. Pozollana produced higher concentration of dust than limestone and phonolite. The concentrations of silica and the heavy metals varied in the three rocks studied with pozollana containing the highest silica concentration.

Limestone dust had lower concentration of silica but the long exposure made the workers vulnerable and risked developing silicosis and cancers caused by the heavy metals identified in the quarry dust. The high concentration of dust generated at drilling and at crushers depicts these areas as peak sites and therefore hazard zones.

The workers' awareness levels of the health risks they are exposed to at the quarry was high but use of protective clothing while at work was poor. The exposure of workers to the high concentrations and the poor use of protective clothing and gear predispose them to respiratory, skin and eye ailments and silicosis, the ailments which they exhibited.

## 5.3 Recommendations

1. Environmental management systems, which include a dust management plan, should be employed at the quarries in order to mitigate dust generation.
2. Regular environmental audit and monitoring of quarrying activities should be enforced in order to ensure adherence to the standards and limits of the concentrations of the dust generated from the different stages of their operations.
3. The quarry workers should be adequately sensitized on adverse health effects of exposure to quarry dust and the importance of using personal protective equipment while at work.

4. The sector regulators, NEMA and DOSHS, should enhance enforcement and ensure compliance.

### 5.4 Area for Further Study

1. The study found that the workers exhibited respiratory, skin and eye ailments and therefore there is need to carry out further research in these areas. A medical study should be carried out on the quarry workers in order to establish whether the workers suffer from silicosis due to silica inhalation.
2. Another medical study should be carried out to find out thehealtheffects of chromium and lead on the quarry workers.
3. A study should be carried out to find out why despite the high levels of awareness of the workers' they do not use protective gear and clothing.

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# APPENDICES

## APPENDIX I: WORKERS MAIN QUESTIONAIRE

**Research on the Health Risks of Crushed Stone Dust on the Quarry Workers in Kajiado County.**

Thank you for accepting to take part in this study. Your answers are very important to us. We would like you to be honest and truthful. Your name will not be included in this questionnaire. Your answers will be kept confidential. Your answers will not be shared with anybody outside the study. Your answers will not be used against you in any way. We will ask you questions about yourself and your health in relation to your work place.
Please mark the right box.

### PART I: DEMOGRAPHIC DATA

1. Gender
   - Male ☐
   - Female ☐
2. Age
   - Below 18 ☐
   - 18 -25 ☐
   - 26 - 35 ☐
   - 36 - 45 ☐
   - Over 45 ☐
3. Formal education
   - None ☐
   - Primary ☐
   - Secondary ☐
   - Tertiary ☐
4. Marital status
   - Single ☐
   - Married ☐
   - Divorced ☐
   - Widowed ☐

5. How far away do you live from the crusher?

- < 100m ☐
- 100m – 250m ☐
- 251m - 500 ☐
- > 500m ☐

**PART B: WORK AND HEALTH RELATED DATA**

6. Job specification

- Accountant ☐
- Clerical Officer ☐
- Gatekeeper ☐
- Loader ☐
- Truck Driver ☐
- Mechanic ☐
- Driller ☐
- Blaster ☐
- Stone breaker ☐
- Crushing plant operator ☐

Other (specify)…………………………………………………………..

7. Termsof employment

- Permanent ☐
- Contract ☐
- Temporary ☐

8. Period worked for

- <1 year ☐
- 1 – 5 years ☐
- 6 – 10 years ☐
- 11- 15 years ☐
- 16 – 20 years ☐
- > 20 years ☐

9. Workingarea

| | |
|---|---|
| Office | |
| Garage | |
| Crusher | |
| Quarry | |

Other (specify)…………………………………………………………..

10. Duration at work per day

| | |
|---|---|
| < 5 hours | |
| 6 – 8 hours | |
| > 8 hours | |

Other (specify)…………………………………………………………….

11. How many days per week do you work

| | |
|---|---|
| Less than 5days | |
| 5 days | |
| 6 days | |
| 7 days | |

12. Do you often suffer from any of the following ailments?

| | |
|---|---|
| Headache | |
| Chest pain | |
| Cold | |
| Chest tightness | |
| Eye irritation | |
| Skin irritation | |

Other (specify)…………………………………………………………

13. Do you usually cough or clear your throat in the morning?

| | |
|---|---|
| Yes | |
| No | |

14. Do you have a cough for 3 months or more in total during a year?

| | |
|---|---|
| Yes | |
| No | |

15. Dou you have phlegm when coughing?

Yes ☐
No ☐

16. Are you breathless when you walk and ascend a hill at an ordinary pace?

Yes ☐
No ☐

17. Do you wheeze in your chest?

Yes ☐
No ☐

18. Do you have any skin infection?

Yes ☐
No ☐

19. Have you noticed any skin infection/rash you feel is related to your work?

Yes ☐
No ☐

20. Where do you seek medical attention when you feel unwell

District Hospital ☐
Local health centre ☐
Private health clinic ☐
Company dispensary ☐
Self medication ☐

Other (specify)……………………………………………………………..

21. Which of the following protective clothing/gear do you wear while at work?

Gloves ☐
Helmet ☐
Boots ☐
Overalls ☐
Dust Mask ☐
Dustcoat ☐

None (why)………………………………………………………….
Other (specify)……………………………………………………..

24. Do you know that exposure to dust in the quarry environment can affect your health negatively?

Yes ☐
No ☐

25. Do you wear protective goggles for your eyes?

Yes ☐
No ☐

26. Do you cover your nostrils from dust while quarrying?

Yes ☐
No ☐

27. Do you wear overalls during your work hours?

Yes ☐
No ☐

28. Do you wear earplugs when working?

Yes ☐
No ☐

This is the end, is there anything you would like to add/ thank you very much for taking your time to answer the questionnaire.

## APPENDIX II: INFORMED CONSENT

### Introduction

My name is Jennifer AtienoHalwenge, a Masters student at the Kenyatta University and I would like to carry out a study on “Occupational Health Risks of Crushed Stone Dust to Quarry Workers in Kajiado County”. The outcome of the study will be used by the quarry operators to improve the working environment and protect the workers from inhalation of the quarry dust. The relevant Government Departments will also use the results of the study to enforce the provisions of the laws that ensures protection of the workers against the risks posed by the quarry dust.

### Procedure to be followed

The questionnaire will be given to individual participants at their work place to read and understand what is expected of them or a research assistant shall assist the participant if where necessary. The participants will be expected to answer the questions to the best of your knowledge on your own free will.

### Discomforts and risks

The risk that may be presented to the participant is with regard to job security since the participant will take time off from his work and from some answers that the company might view negatively. This will be taken care of anonymous filling of the questionnaire and the management not made privy to the information in the questionnaires. Permission will be sought and granted by the management to interview the participants.

**Benefit**

If the quarry works agree to participate in the study they will benefit from the outcome since those who are found to be sick from inhalation of the quarry dust will be referred to a medical facility for treatment. The workers will also benefit from effective protection from dust inhalation.

**Reward**

Since the study will be carried out at the work place the participants will only be provided with refreshments during the interviews.

**Confidentiality**

The questionnaires will be administered in a private setting and the names of the participants will not be recorded. The questionnaires will be identified through special numbers assigned to participants when describing the results in the study report. The questionnaires will be kept in a locked safe Kenyatta University.

**Participant's Statement**

The information regarding the study is clear to me and I have been given a chance to ask questions. My participation is entirely voluntary and I understand that my record will be kept private.

Name of Participant…………………………………………………….

| | |
|---|---|
| ………………………….. | ………………………….. |
| Sign | Date |

**Investigator's Statement**

I, the undersigned have explained to the participant, in a language she/he understands, the procedures to be followed in the study, the risks and benefits involved.

Name of the Interviewer……………………………………………………….

………………………….

…………………………..

Sign Date

## APPENDIX III: Consent to Collect Data at the Quarries

BLUE TRIANGLE Cement

**THE EAST AFRICAN PORTLAND CEMENT COMPANY**

*Holding Life Together*

Athi River Off Namanga Road
P O Box 20-00204 Athi River
Tel: (254) 045 6620627, 22777
Fax:(254) 045 – 6620406, 22378
E-mail: info@eapcc.co.ke
Website: www.eastafricanportland.com

*Ref: EAPCC/hr.train/research/lm*

June 11, 2013

Jennifer Halwenge,
Kenyatta University
**NAIROBI**

Dear Sir,

**RE: RESEARCH PROJECT**

We are in receipt of your letter dated **May 28, 2013** on the above subject.

East African Portland Cement Company Limited acknowledges with appreciation your request to collect data on the **mineral composition of the dust emitted at drilling & crushing in various quarries in Kajiado County** from our Company.

Kindly get in touch with the Training Officer for details and other modalities.

Please also ensure that the information collected is kept confidential and provide the company with a report of your research findings after completion.

We look forward to fruitful working relations.

Please sign your acceptance of the research on those terms by signing and returning a copy to the Training Officer immediately.

Yours faithfully,
**For: E.A. Portland Cement Co. Ltd**

**ELIZABETH KIMANI**
**HR PLANNING & CHANGE MANAGER**

Cc: Head of Production Operations

Signature .................................... Date 19/6/2013

**APPENNDIX IV: RESEARCH PERMIT**

THIS IS TO CERTIFY THAT:
*MS. JENNIFER ATIENO HALWENGE*
of KENYATTA UNIVERSITY, 0-100
nairobi,has been permitted to conduct
research in *Kajiado County*

on the topic: *OCCUPATIONAL HEALTH RISKS OF CRUSHED STONE DUST TO QUARRY WORKERS IN KAJIADO COUNTY, KENYA*

for the period ending:
*28th September,2015*

Permit No : NACOSTI/P/15/7924/4528
Date Of Issue : 26th February,2015
Fee Recieved :Ksh 1,000

..............................
*Applicant's Signature*

..............................
Secretary
*National Commission for Science, Technology & Innovation*

**CONDITIONS**

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one(1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

**REPUBLIC OF KENYA**

NACOSTI

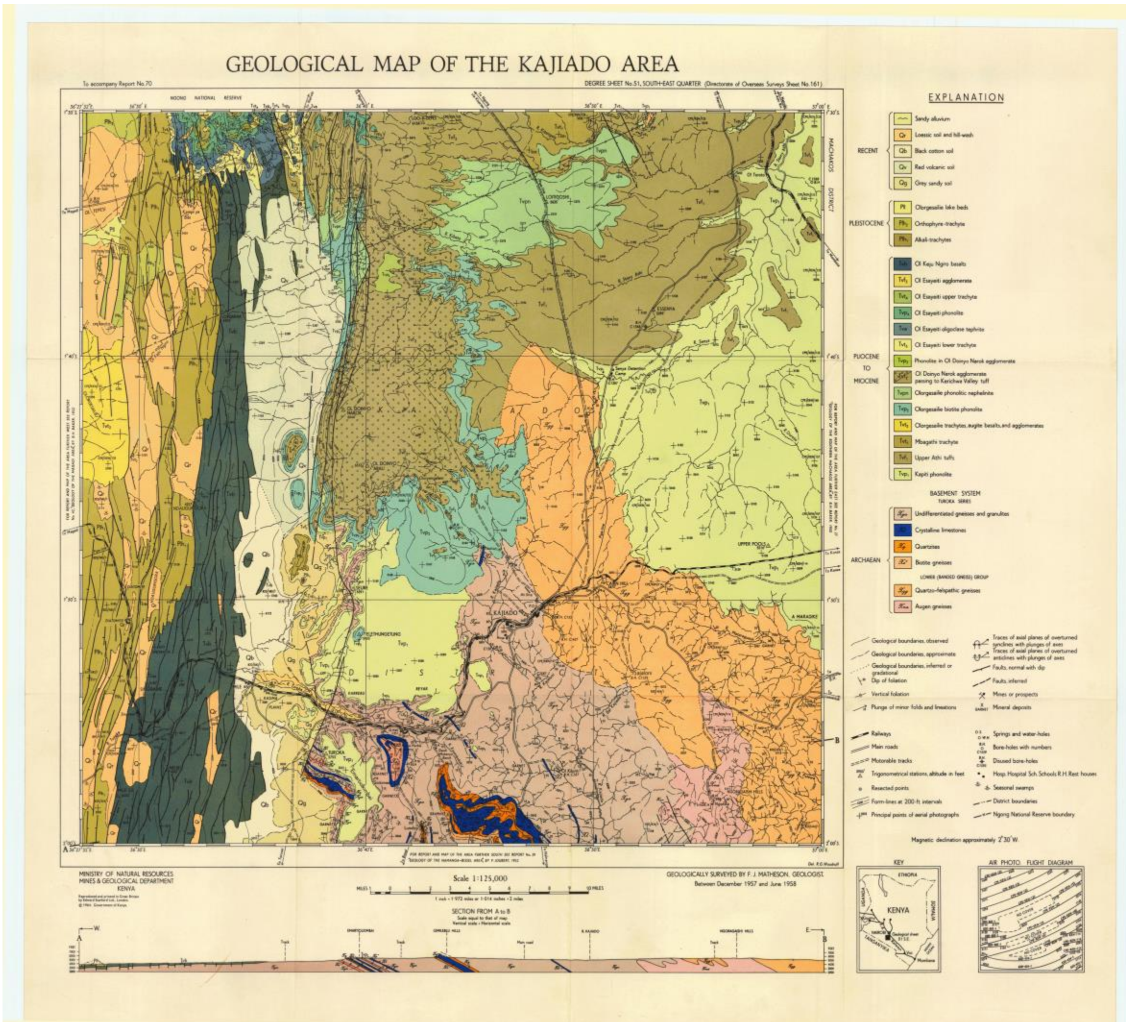
**National Commission for Science, Technology and Innovation**

**RESEARCH CLEARANCE PERMIT**

Serial No. A 4300

CONDITIONS: see back page

**APPENDIX V: GEOLOGICAL MAP OF KAJIADO**



**APPENDIX VI: PROGRAM TIMELINE**

The following is the proposed work plan for the study

| TASK | Jan'13 | Feb' 13 | Mar' 13 | Apr'-13 | May-July' 13 | Aug-Dec 13 | Jan-Oct '14 |
|---|---|---|---|---|---|---|---|
| Develop the proposal | ▬ | ▬ | | | | | |
| Submit proposal to Supervisor for clearance | | ▬ | | | | | |
| Submit proposal to University for clearance | | | ▬ | | | | |
| Defend proposal | | | ▬ | | | | |
| Train research assistants | | | | ▬ | | | |
| Pilot test research tools | | | | ▬ | | | |
| Collect data | | | | | ▬ | | |
| Data cleaning and analysis | | | | | | ▬ | |
| Data presentation | | | | | | ▬ | |
| Submission of research report | | | | | | | ▬ |