A STUDY OF ENVIRONMENTAL IMPACTS OF EXTRACTIVE INDUSTRIES:

A CASE STUDY OF GYPSUM MINING IN KAJIADO, KENYA

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A Thesis Submitted to the Institute of Postgraduate Studies and Research of Kabarak University in Partial Fulfillment of the Requirement for the Award of Doctor of Philosophy Degree in Environmental Science

KABARAK UNIVERSITY

NOVEMBER 2016

DECLARATION

The thesis is my own work and to the best of my knowledge it has not been presented for the award of a degree in any university or college.

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Signature………………………….

Admission No: GDES/M/1052/09/13

RECOMMENDATION

To the Institute of Postgraduate Studies and Research:

The thesis entitled "A Study of environmental impacts of extractive industries: a case study of gypsum mining in Kajiado, Kenya" and written by Kefa Misuko Omoti is presented to the Institute of Postgraduate Studies of Kabarak University. We have reviewed the thesis and recommend it be accepted in partial fulfillment of the requirement for the degree of **Doctor of Philosophy in Environmental Science.**

Sign---date---

Prof. Jackson John Kitetu (PhD)

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Prof. Joseph Mungai Keriko (PhD)

DEDICATION

To my parents, Livingstone Mose and Triza Gechemba for the good upbringing and mentorship

ACKNOWLEDGEMENT

With humility, I thank my supervisors Prof. Jackson J. Kitetu and Prof. Joseph M. Keriko who kindly shared their time and knowledge above and beyond providing excellent guidance which helped me to conceptualize and write this thesis. Their support, inspiration and patience made this expedition enjoyable. I'm equally grateful to Prof. James Awino, Dr. Kageni Njagi and Dr. Betty Tikoko who made the valuable courses offered in the PhD programme interesting and applicable to this study.

This scholarly journey started in the dusty classrooms of Nyairanga Primary School in Nyamira County and continues to be such a great source of learning and discovery for me, that I must thank my heavenly father - the Great Amen, friends, supervisors, family members, staff of Kabarak University and my employer, the Parliamentary Service Commission for the support extended to me during the study.

The study benefited from materials, words and thoughts obtained from various sources. Since it is not possible to precisely recognize all contributions, I honestly trust that those cited will accept this general acknowledgement in the good faith it is made. A huge debt of gratitude is owed to my respondents in the study area and the County Government of Kajiado officials for their cooperation and support during the data collection phase. I am equally appreciative of the entire Kabarak University members of staff who made my regular visits to the main campus memorable and pleasant. Finally, very special appreciation to my children; Ian, Neema, Leon and; the love of my life and source of inspiration in the journey, my wife Doris whose care, support and encouragement made the study dream a reality.

ABSTRACT

Kenya is endowed with a wealth of natural resources comprising minerals, land, soils, air, forests, wildlife and various other forms of biodiversity. In the recent past, the Country has witnessed increased attention in the exploitation of mineral resources such as titanium, gypsum and gold to just name a few. Exploitation of mineral resources is prone to bio-physical and socio-economic impacts. Due to regular violent protests by the local population on account of environmental degradation, there is need to identify the nature and scale of environmental impacts of gypsum mining in Kajiado. There is a gap in the analysis of extractive industry impacts because the discussions in the literature on impacts of gypsum mining on the environment are site specific and lack in details. The study sought to establish the impact of gypsum mining on livelihoods, landscape, water quality and particulate matter concentration in Kajiado County. The study employed the Mixed Method Research (MMR) design. Qualitative data was collected from 95 respondents and key informants using questionnaires and interview schedules through Simple Random Sampling (SRS), Stratified Random Sampling and purposive sampling. Quantitative data was collected through field analysis of water quality parameters, particulate matter (PM 2.5) sampling and satellite imagery evaluation. Administrative medical records of patients residing in the study area were examined for respiratory health effects and outpatient consultation rates. Qualitative and Quantitative data was analysed separately in descriptive and inferential statistics. It was established that gypsum mining had a considerable positive impact on livelihoods of study area residents, $\beta = 0.375$; p value = 0.000 and t value 3.679 and a significant negative impact on air quality with daily mean of 570 $\mu g/M^3$ of particulates against WHO (2005) recommended maximum of 25 $\mu g/M^3$. The impacts of gypsum mining to water quality were insignificant and indirect. The study advocates for location of mining sites away from residential areas, regular monitoring, awareness creation on the negative impacts of mining and a review of the mining policy. The study findings contribute to literature on extractive industry activities and inform policy development on environmental management in Kenya.

Key Words: Extractive Industries, Environmental Impacts, Livelihoods, Landscape

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LIST OF ABBREVIATIONS

AAQM – Ambient Air Quality Monitors

ACK – Anglican Church in Kenya

APHA - American Public Health Association

AQEG - Air Quality Expert Group

CAP - Chapter of the laws of Kenya

CPCB - Central Pollution Control Board

CSD - Commission for Sustainable Development

CSR - Corporate Social Responsibility

DRSRS – Directorate of Resource Surveys and Remote Sensing

EAPC – East Africa Portland Cement

EMCA - Environmental Management and Coordination Act

EPA - Environmental Protection Agency

FAO – Food and Agriculture Organization

GDP - Gross Domestic Product

GNNP – Green Net National Product

IBA – Impact and Benefits Agreements

KFS – Kenya Forest Service

MMR- Mixed Method Research

MRB – Minerals Rights Board

NAAQ – National Ambient Air Quality

NCSTI – National Commission for Science and Technology

NEMA - National Environmental Management Authority of Kenya

NERC – National Environment Research Council

NLC – National Land Commission

NTU – Nephelometric Turbidity Units

OECD - Organization for Economic Cooperation and Development

PCEA – Pentecostal Church in East Africa

PM10 - Particulate Matter 10

ROK - Republic of Kenya

SPA – Service Provider Agreements

SPSS - Statistical Package for Social Sciences software.

UCB – University of California Berkeley Air Sampler

URTI – Upper Respiratory Tract Infections

USDI – United States Department of Interior

UTI- Urinary Tract Infections

UTM – Universal Transverse Mercator

WARMA – Water Resource Management Authority

WBIFC – World Bank and International Finance Corporation

WBWDI – World Bank World Development Indicators

WGS – World Global System

WHO - World Health Organization

WLG – Western Lignite Corporation

DEFINITION OF TERMS

APHA Protocol – This refers to analytical methods, procedures and modern instrumental techniques used to measure the presence of various forms of impurities in water. The methods developed by the American Public Health Association (APHA), are appropriate and applicable in evaluation of environmental water quality concerns. They contain specified sampling conditions, appropriate sample containers, procedures for sampling and storage of samples.

Extractive Industries - Those industries that seek and exploit resources that are naturally stocked in the earth's crust including non-renewable resources such as crude oil and gas, solid minerals, salt, sand and aggregates. It is made up of mining, quarrying, oil and gas extraction that takes place on the earth's surface or underground.

Environment – In the context of this assessment, environment refers to the sum total of external conditions in which organisms exist, the organisms themselves and the physical surroundings such as landforms. It encompasses but not limited to air, water, land, vegetation, animals, landscape and geomorphologic features.

Environmental Impact Assessment - A tool used to identify the environmental, social and economic impacts of a project prior to decision making. It aims to predict the impacts and find means to reduce the impacts.

Livelihood Resources – These refer to the stock of capital available to the household for use in the event of vulnerability and under the influence of transforming structure and processes to obtain viable livelihoods.

Landscape – Refers to a heterogeneous land area composed of a cluster of interacting ecosystems. The groups of ecosystems interact as they provide man with services necessary for biological diversity, recycling of nutrients, sequestering carbon and producing clean water

Livelihoods - Means of making a living. It encompasses people's capabilities, assets, income and activities required to secure the necessities of life.

Mining – The act, process or activities of extracting minerals from below the natural bed of the earth and transporting them to a point of benefication or consumption

Natural resources - The gifts of nature including land, biodiversity, forests, climatic conditions and mineral deposits among others that are used to produce goods and services

Net Benefit Stream - The perceived present value of direct, indirect and induced positive economic, social and environmental impacts, minus the direct and indirect cost of reducing the negative impacts to acceptable levels.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Kenya is endowed with a wealth of natural resources including minerals, forests, wildlife, water, dry lands, hydropower, wetlands, fisheries and biodiversity among others. Mineral resources found in the Country include titanium that is available in commercially viable quantities in Kwale County at Mrima Hill. Substantial deposits of gold are believed to exist in Western Kenya; at Macalder mines in Migori County and Ikolomani in Kakamega County (RoK, 2016) while huge deposits of coal have been established at the Mua Basin in Kitui County. Commercially viable mineral oil deposits are suspected to exist in Turkana and Baringo Counties.

Other minerals found in Kenya include Soda Ash and Trona that are mined in Lake Magadi, in Kajiado County and Halite (salt) believed to exist in massive amounts at the same region, Ngomen and Fundi Isa in Malindi County. Gemstones extraction potential exists at Mrima hill and some parts of Taita Taveta County, while Diatomite harvesting is possible at Kariandusi, Elmentaita, Naivasha and Lake Magadi in the Rift Valley. Steam (geothermal energy) is available in the Rift Valley at Kapedo and Suguta Valley in Baringo County, Solai in Nakuru County, the Mua basin in Kitui County and Homa Hills of Homa Bay County (Ogola *et al*, 2001). Gypsum availability has been confirmed in Wajir County, Mandera County at Rahmu and Konza in Machakos County. Iron free, excellent quality gypsum in commercial quantities is also available at Isinya in Kajiado County (RoK, 2016).

Kenya has in the recent past witnessed increased investment in the mining sector, with new Multi-national mining companies coming on board. The cumulative effect of the attention in the mining sector was the intensification and expansion of extractive activities across the counties culminating in the discovery of the oil deposits in Turkana County and the commencement of titanium extraction in Kwale County (Abuodha, 2010). The extraction of Mineral resources across counties culminating in the discovery of oil in Turkana County and first shipment of 25 tones of titanium in 2014 was expected to translate into economic growth and reduce the current high unemployment and poverty levels (RoK, 2016).

The Country's intention to attain faster economic growth based on natural resources exploitation is captured in chapter 5 of the Constitution of Kenya 2010 (Articles 69 and 72) which places heavy responsibilities on both the executive and legislature by outlining specific obligations in respect to environmental management. Article 69 of the Constitution requires the state to ensure sustainable exploitation, utilization, management, conservation of the environment and equitable sharing of environmental benefits. Articles 71 and 72 require parliament to enact legislation that would give effect to the provisions of Article 69 and ratify transactions that involve the granting of rights or concession for the exploitation of natural resources in Kenya (Runge and Shikwati, 2011).

The important role of the extractive industries in development is further amplified in the Mining Act (2016) and the country's development blueprint, the Kenya Vision 2030 (RoK, 2007). The vision has three pillars namely the economic pillar, the political pillar and the Social pillar. Under the social pillar, the vision gives prominent recognition of health and Environment. These underscore the Kenyan people's recognition of the importance of the extractive industry in national development. The renewed interest in the extractive industry supported by existence of vast deposits of high quality Gypsum and other minerals could reduce dependency on foreign supplies and generate economic growth. Even though mining is regarded as an important economic activity, it tends to have significant ecological footprints as the extraction moves to more fragile areas. Open cast mining, particularly could cause serious impacts on landscape, drainage, air quality and vegetation. Open cast mining also has potential to suppresses or prevent vegetation regeneration, thereby affecting ecosystems' equilibrium through the destruction of habitats, death of species of animals and interruption in genetic flow (Reid *et al*, 2006; Sanches, 2010 and Erdiaw-Kwasie *et al*, 2014).

1.2 Problem Statement

The attention in gypsum mining in Kajiado County and the consequent increase in spatial scale resulted in violent protests and demand for compensation by the host community. Gypsum production is dominated by open cast mining and manual quarrying methods, which involve the removing of top soil up to the bedrock, effectively making the mining areas bare and devoid of vegetation. Open cast mining further entails the drilling of holes, blasting using explosives, loading using shovels, transportation and initial processing using heavy machines. The heavy mining gear and blasting materials used have potential to not only cause instability on the mining surface but also vibrations and noises that could negatively impact on the communities surrounding the mining sites.

Owing to the protests, environmental health and safety concerns related to gypsum mining activities were matters of concern within the public domain in Kajiado County. In literature, there was no consensus however, on the nature and significance of the environmental impacts of gypsum mining due to lack of detailed and quantifiable information on specific geo-biophysical and socioeconomic impacts. For instance, impacts discussed in Environmental Audit reports submitted to the county NEMA office by gypsum mining companies in support of mining license applications tended to be mere estimations of broad environmental impacts and did not document matters of particulate matter deposition and its possible health effects in relation to the World Health and NEMA Standards. A thorough research into the prevailing environmental impacts of gypsum mining was for that reason a necessity and this study sought to address this gap.

1.3 Significance of the Problem

Mining activities cause disorder and destruction of the environment with potentially far reaching ramifications. However, lack of specific impact data hinders future planning and development of environmental policies that could reduce environmental effects of extractive industries. A study by Maest *et al* (2006) on the reliability of predicted water quality impacts at Hardrock mining site in America, established that in all cases, the EIA reports underestimated the eventual impact to the environment. It is probable that the EIA reports submitted to NEMA did not therefore; provide a reliable basis for extractive industry planning and environmental management. Kenyan authorities could not therefore reliably make use of available data to mitigate the impacts. Without sufficient information, it was equally difficult for the County and National Governments to design appropriate policies for gypsum mining and related activities (Abdelaal, 2014). A comprehensive assessment of the geo-biophysical and socio- economic impacts of gypsum extraction was thus indispensable.

1.4 Study Objectives

1.4.1 Broad Objective

The main objective was to identify the environmental impacts of gypsum mining in Kajiado County.

1.4.2 Specific Objectives

The specific objectives were as follows:

1. To assess the impacts of gypsum mining on livelihoods in Kajiado County
2. To investigate the impact of gypsum mining on landscape in Kajiado County
3. To establish the impact of gypsum mining on water quality in Kajiado County
4. To examine the impact of gypsum mining on particulate matter (PM 2.5) concentration in Kajiado County.

1.5 Study Hypothesis

The research focused on systematic collection, analysis and interpretation of geo-physical and socio-economic data to test the following hypotheses:

H_o1**:** Gypsum mining has no significant impact on livelihoods of Kajiado residents

H_o2: Gypsum mining has no significant impact on landscape in Kajiado County

H_o3: Gypsum mining has no impact on water quality in Kajiado County.

H_o4: Gypsum mining has no significant impact PM 2.5 concentrations in Kajiado

1.6 Scope

The study focused on gypsum mining activities in Kajiado County as an illustrative case of extractive industry. Mining activities including extraction, transportation, on site storage and processing were analyzed with a view to identifying the stream of benefits and negative geo-biophysical impacts to the environment. The study did not include radioactive impacts. Even though Gypsum is known to occur in a number of Counties in Kenya such as Kilifi, Garissa and Kajiado (RoK, 2016), Turkana, Mandera, Wajir, West Pokot, Homa Bay, Machakos and Mombasa, fieldwork was concentrated in Kajiado County. The County was selected because it had witnessed decades of mining activities including the mining of Soda Ash at Lake Magadi and gypsum at the current study area. The County was also selected because of her high quality gypsum deposits suitable for cement manufacturing.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of literature on extractive industries. It contains a synopsis of the extractive industry in Kenya in general and a presentation of gypsum mining activities in Kajiado. A brief description of the County is included alongside the current mining policy framework. Latent impacts of gypsum mining on livelihoods, landscape, water quality and air quality are discussed in detail.

2.2 The Extractive Industry in Kenya: An Overview

Extractive industries can be defined as those endeavors that exploit natural resources by extracting raw materials from the environment. These include fishing, hunting, logging, oil and gas, metals and water. Research is in agreement that principally, extractive industries facilitate development by wresting resources and wealth from nature (Wilk, 2003; Bebbington, 2010). The industries broadly encompass economic activities that remove natural resources from the environment, submit the same to marginal or no processing, and then sell it on. More recent studies too allude to the element of processing and utilization by consumers as they define extractive industry as processes that involve different activities that lead to the extraction of raw materials from the earth (Sigam and Garcia, 2012; Tengler, 2014).

The extractive industry sector is very diverse (Klop, 2009). The taxonomy may refer to the scale of operations, nature of activity, material extracted or degree of capitalization. Mineral extraction is achieved through four main mechanisms namely; open cast mining, which involves the harvesting of mineral materials from the surface mines, open pits, quarries or other diggings open to the sky; underground mining, where mines are accessed through shafts and tunnels; recovery of minerals through boreholes and under water mining (Klop, 2009). Open cast mining is the most preferred form of extraction in situations where the ore size, location and grade make it cost effective to remove the overburden.

For the purposes of this study, extractive industries are defined as those that seek and exploit resources that are naturally stocked in the earth's crust. The resources extracted are non-renewable such as crude oil and gas, solid minerals, salt, sand and aggregates. It is made up of mining, quarrying, oil and gas extraction. Extraction can take place on the earth's surface or underground. In addition, mining is defined as the process of extracting metallic and non-metallic mineral deposits from the earth's surface (Palacios-Berrios, 2006).

Extractive industries have boomed in the last decade, spurred by a cyclical rise in commodity prices. With the growth of the extractive industry, developing countries in Africa, Asia and South America have been swamped by a wave of foreign investment in mines deemed marginal when prices were low (Zarsky and Stanley, 2013). The growth has raised concerns that the extractive industry could engender negative environmental impacts including pollution and land degradation (Escudero, 2015). Among developing countries, there are those who hold the view that the extractive industry is essential for development and that it has immediate and important benefits including helping the poor gain some of the benefits of the modern society. Although the developing countries have also expressed fears of negative impacts in terms of health, safety and social decay, of immediate concern is how to build strong sustainable communities and lift majority of the population out of poverty (Fatah, 2008). The extractive industry activities therefore, present both opportunities for development and potential negative environmental impacts.

2.3 Mining Potential in Kenya

Mining in Kenya has been dominated by the production of a variety of Industrial Minerals such as Soda Ash, limestone and fluorspar as demonstrated in 1. The table indicates a steady rise in earnings from KES. 12.5 Billion in 2008 to KES. 27.6 Billion in 2012 and eventually slightly declining to KES. 24.2 Billion in 2015 (RoK, 2013 b, RoK, 2013 c).

Table 1: Value and Quantities of Minerals Produced in Kenya between 2008 and 2015

Mineral	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Fluorspar	130100	5500	40750	95051	91000	71987	97156	70096
Salt	24345	24125	6194	24639	9980	8895	18936	21201
Soda	865788	984076	959160	1054236	882801	947074	851906	614055
Carbon D.	12317	15097	16152	15197	19919	18436	19450	19750
Diatomite	72	231	224	2165	1731	1054	1195	1090
Gold	0.3	1.1	2.4	1.6	3.6	2.1	0.2	0.3
Gemstones	20.9	39.4	167.6	310.1	120.9	563	247.3	442
Gypsum	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10
Titanium	-	-	-	-	-		374131	549897
Total (Ton)	1,555,202	1,408,587	1,506,339	1,690,652	1,454,825	1,516,226	1,773,867	1,572,103
Value (M)	**12,483.10**	**9618.9**	**15,131.40**	**18,394.40**	**27,650.50**	**19,260.50**	**21,080.50**	**24,197.80**

Source: Republic of Kenya, 2013 b, c

From Table 1, it is evident therefore, that the development of the Kenya mining sector had the potential to significantly contribute to the country's gross domestic product (GDP) through provision of tax revenues and employment opportunities while providing a base for the manufacturing industry.

2.3.1 Gypsum Mining

The word Gypsum is derived from a Greek word *Gypsos* meaning plaster. It is mainly mined in open pits by large mobile grinders. Explosives are used on occasion to break apart more compact layers within deposits. Gypsum, also known as hydrous calcium sulphate is a common mineral which occurs in both massive and crystalline form (Heldal *et al* 2009; Orti *et al*, 2012; Cooper and Gutierrez, 2013; Korna *et al*, 2013). It has the chemical formula of $CaS0_42H_2O$, implying that is calcium united with sulphuric acid and holding water of crystallization.

Gypsum is extracted, processed and used by man in construction or decoration in the form of plaster since 9000 BC (Delgado *et al*, 2014). The colour of gypsum when reduced to powder is white. In its natural form and purity, gypsum is usually white when massive and pearly when crystallized. When it contains impurities however, it may be brown, red or redish brown and sometimes black (Roy *et al*, 2010). It occurs as a rock gypsum, gypsite, selenite and satin spur. Rock gypsum or massive gypsum is of greatest economic value and occurs interbedded with sedimentary rocks, in layers of up to sixty feet thickness extending for many miles. When mined, rock gypsum breaks into irregular shaped lumps, white in colour, composed of small brightly shining elongated crystals. It is saccharoidal and distinctly fragile being easily crumbled to fragments resembling granulated sugar (Fig. 1). Rock gypsum contains impurities such as clay, carbonate of lime and silica that are all variable in colour. Selenite however is very clear and transparent with the characteristic pinacoidal cleavage (USDI, 2011).

Figure 1: Freshly Mined Rock Gypsum in Study Area

Gypsite is soft and ranges from materials so powdery that it resembles wood ashes while selenite occurs in distinct crystals or folia. Satin spur is more crystalline and comprises of needle like fibres in narrow veins and seams. Pure rock gypsum is white while Selenite is colourless, transparent and in some cases translucent (Fig. 2). Much of the pure gypsum found around the world is in form of white compact rocks containing very thin beds of dark grey limestone. Impure gypsum ranges through gray to black, from fresh pinkish to redish or brownish while in other cases, it appears yellowish or pale blueish (Cooper, 2000; Eckardt, *et al,* 2001; Sharpe and Corck, 2006; Escudero *et al,* 2015).

2.3.2. World Gypsum Production: an overview

Gypsum deposits are distributed throughout the World. Large scale exploitation uses standard open pit methods by large mobile grinders even though explosives are used on occasion to break apart more compact layers within deposits (Gasques *et al* 2013). The People's Republic of China is the leading producer of Gypsum in the World, followed by the Republic of Iran. In the year 2009, the world's gypsum production stood at 148 M tonnes, which made gypsum the 7th largest mineral commodity mined in the world after aggregates, iron ore, lime, salt, bauxite and phosphate rocks (USDI, 2011).

Gypsum deposits in China are distributed throughout most of the provinces and autonomous regions. Gypsum is particularly exploited in Shandong, Inner Mongolia, Xinghai, Huan, Hebei, Ningxia, Anhui and Sichuan. European Countries, particularly Germany, the United Kingdom, France, Spain, Italy, Turkey and Poland have huge Gypsum deposits. In France, Gypsum Occurs in the Paris Basin, while in turkey it is mined at Guardak (Esmaeili, 2008). The main producers of Gypsum outside the European Union are the United States of America, Canada and Thailand. In the United States, Gypsum deposits occur in Michigan and the Appalachian Basins of New York, Pennsylvania, West Virginia, Ohio and Michigan (Sahawnah and Madanat, 2015. Another important producer of Gypsum is Afghanistan which has Gypsum deposits of commercial Value at Surkhrod in the Nangarhar Province. In Africa, Gypsum deposits are confirmed to exist in Morocco, South Africa, Nigeria, Libya, Tunisia and Ethiopia. Kenya is among the least producing countries alongside Sudan, Tanzania and Eretria (Table 2) (Osei-Kojo and Asamoah, 2016).

Table 2: Gypsum Production for Selected Countries 2010

Country	**tonnage (000)**
China	46000
Iran	12000
Spain	11500
Thailand	8000
Canada	5740
Egypt	2000
South Africa	571
Ethiopia	40
Kenya	9.6
Eritrea	0.5

Source: USDI, 2011- United States Commodities Summaries.

2.3.3 Gypsum Mining Technology

Most of the World's gypsum is produced by service mining operations where the overburden is removed from the gypsum using various striping methods (Obiri, 2014). The stripping is done by a pan scraper, truck and excavator, fronted loader or hydraulic excavator and truck, drug line and bulldozer. As shown in Fig 2, gypsum is removed from top to bottom of the deposit, leaving single benches of 10 – 12 M high and 70^0 dip in order to guarantee the stability of the face (Bonetto *et al*, 2007). The maximum economic stripping thickness is about 30 M. Final clean-up of the stripped gypsum is important depending on the intended final product. If the quarried rock is intended for use in manufacture of agricultural raw materials, Portland cement or wallboard, then any remaining impurities can be removed during the finer stages of crushing and screening.

Figure 2: Benched Open Cast Mining Activities at Kibini Mine

Blasting and drilling are the main methods of gypsum extraction with hydraulic rotary drilling and auger drilling being the most commonly used technology. Blast holes are generally about 50 to 100 mm in diameter and relatively close together to distribute the explosive forces through the rock mass (Sharpe and Corck, 2006). The blasting machinery includes ammonium nitrate and fuel oil blasting agent, cast boosters and non electric blast ignition systems. Quarry haulage trucks transport the broken gypsum from the quarry site to the primary crusher.

2.3.4 Gypsum Mining in Kenya

In Kenya, gypsum exploitation at commercial scale occurs in the counties of Kilifi, Garissa and Kajiado. As shown in Fig. 3, other Counties with established occurrence of gypsum include Turkana, Mandera, Wajir, West Pokot, Homa Bay, Machakos and Mombasa (RoK, 2016)

2.3.4.1 Commercial Value of Gypsum

The commercial value of gypsum is derived from its ability to set or harden once calcined and mixed with water. Man has known the value of gypsum for certain purposes for so long that the date of the discovery of its peculiar properties is not recorded (Desutter and Cihacek, 2009). The ancient Assyrians used it for sculpture while Egyptians used it four thousand years ago to make plaster. In Europe, the white rock has been used for centuries in the ornamentation of buildings and sculpture (Chen and Warren, 2011).

Camarin and Milito (2011) assert that gypsum has several principle uses. In cement manufacture, ground gypsum is added to the cement to slow the setting time of cement and in agriculture, it is used as a soil conditioner and animal food additive. There is evidence in literature (Davies, 2006) that when applied to alkaline soils, gypsum is very successful in increasing the yield of some food crops such as wheat, sweet potatoes, corn, alfalfa and rice.

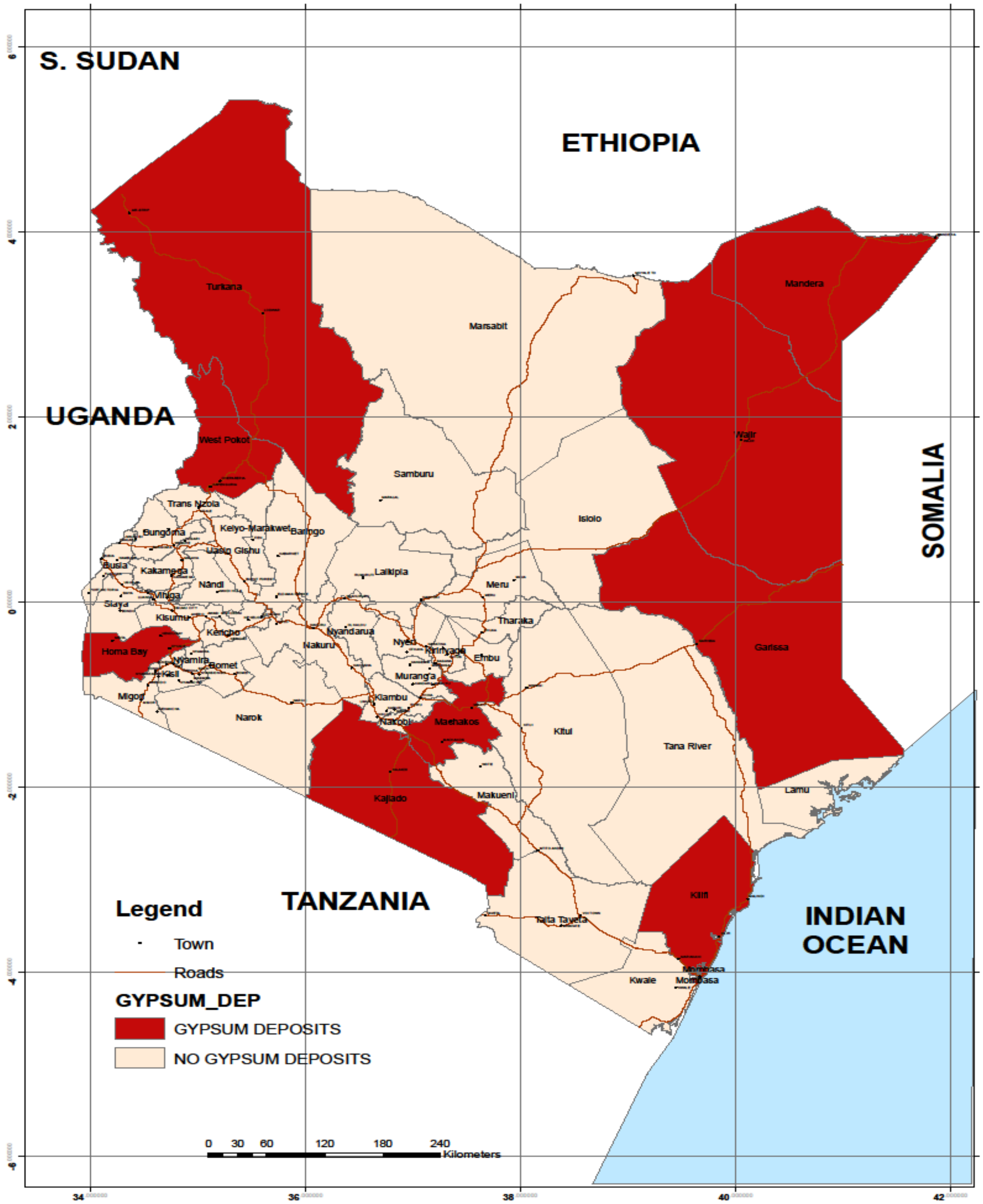

Figure 3: Counties with Confirmed Gypsum Deposits

The improvements in crop yields is attributed to the ability of gypsum to decrease the crusting of soils and erosion by raindrop impact, reduction in acidity, improvement in water penetration and amelioration of the limitations to plant root growth. It is therefore the most preferred method of soil amendment because of its low cost and ease of handling (Davis, 2006). In the construction industry, gypsum is used as filler in materials such as paper and paint (Yu *et al*, 2003; Arnonkitpanich, 2009; Lee *et al*, 2012; Mohandesi *et al* 2012). The best known principle use of gypsum however, is its use as an ingredient in the manufacture of wall board and plaster, which makes it a critical construction material (Sharpe and Corck, 2006). Gypsum could also be used in food processing and pharmaceutical industry especially in beer brewing, baking and food canning. Other important uses include glass manufacture, ceramics and pottery plasters (Ghafoor *et al* 2001; Sharpe and Corck, 2006; Chen *et al*, 2012). Gypsum is also used in manufacturing of sulphuric acid, blackboard chalk and coloured pencils (Arnonkitpanich, 2009).

2.4. Kajiado County Overview

2.4.1 Location and Size

Kajiado County is located in the Southern part of Kenya, bordering the United Republic of Tanzania to the South West, the County of Taveta to the South East and Machakos and Makueni Counties to the East. It borders Nairobi County to the North East, Kiambu County to the North and Narok County to the West, Stretching over an area of 21,900.9 Km^2. It lies between longitudes 360 5’ and 370 5’ E and between latitudes 19 0’ and 30 0’ S (Fig 1. and Fig 4).

2.4.2 Dominant Land Use

Kajiado County is home to a wide range of wildlife, which makes wildlife habitats a major land use. This has led to the creation of wildlife conservation areas in the county including, Amboseli National Park and the Kyulu conservation area among others. Other important users of land in Kajiado include livestock farming and crop production in the high potential zones of Olooitokitok and Ngong. Rapid urban development in areas bordering Nairobi County has necessitated change of land use from agricultural to industrial, housing and commerce (RoK, 2013**a**).

2.4.3 County Administrative Units

The County occupies an area of 21,418.9 Km^2 and is divided into five sub counties, namely Kajiado North, Kajiado Central, Isinya, Mashuru and Olooitokitok (Table 3). The study area falls within Isinya and Mashuru Sub Counties.

Table 3: County Administrative Units per area and Locations

Sub County	Area (Sq. Km)	Divisions	Locations	Population 2009
Kajiado North	6,344.9	4	30	202651
Kajiado Central	5186.0	3	32	102978
Isinya	1056.0	2	16	137254
Mashuru	2903.0	2	11	106933
Olooitokitok	6411	6	16	137496
Total	**21,900,9**	**17**	**105**	**687312**

Source: Republic of Kenya (2013**a)**: Kajiado County Development Profile.

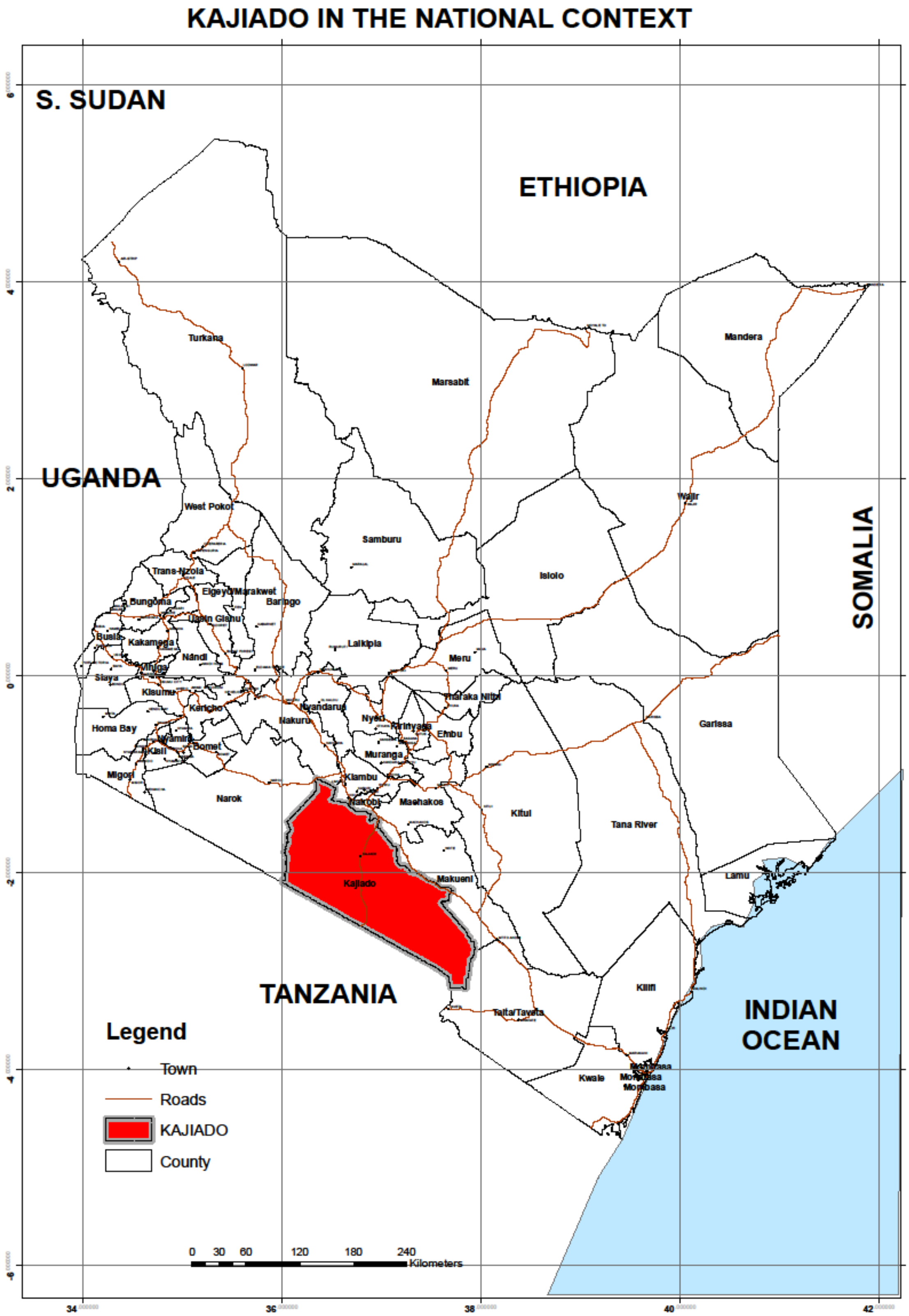

Figure 4: Kajiado County in Regional Context

2.5 Environmental Impacts of the Gypsum Mining Industry

2.5.1 Impacts of Gypsum Mining on Livelihoods

Hinojosa (2013) defines livelihood as that which comprises of the capabilities, assets and activities required for making a living. In the definition, he breaks down household assets into various forms of capital including social capital, human capital, natural capital, financial capital and physical capital. These forms of capital enable the households to develop a dynamic set of activities and functions. Hinojosa (2013) builds on an earlier definition by Ekins *et al* (2003) who suggest that social capital included social networks and connections among the community membership, associations and organizations. Human capital on the other hand was defined to include the different aspects of people such as skills, knowledge and ability to labour and make a living, while natural capital was explained in terms of the resources that the household uses to cater for living needs at any time including land, rivers and biodiversity. Ticci and Escobal (2014), expounded the conceptualization of capital in relation to livelihoods by describing financial capital as the resources households use to achieve financial objectives and; physical resources as the basic infrastructural services including roads, water supply and other tools that enable households perform and meet basic needs.

Livelihoods therefore, depend on the range of assets and capabilities at the disposal of the household but are prone to changes occasioned by external forces such as unexpected loss of income or other capital (Hinojosa, 2013). Simply put, livelihoods are a collection of activities performed on a daily basis with the objective of meeting household needs such as food, housing and securing financial earnings. In the context of the current study, the activities included livestock production, local procurement and trade, crop production and wage employment.

The natural resources and livelihood assets that people have access to have potential to influence their socio-economic outcomes. Rural communities in mineral rich areas are thus emerging as keen participants in the exploitation of mineral resources and thereby securing their own mineral based extraction livelihoods, albeit with varied environmental and socio-economic impacts (Lahiri-Dutt *et al,* 2014). Exploitation of natural resources is expected to bring with it rapid development and significant change, such as opportunities for employment, a large influx of capital and in some cases in-migration and resettlement (Kemp, 2009). Ticci and Escobal (2012), emphasize that populations in close proximity of mines are likely to enjoy potential benefits of the mining industry including direct job creation, construction of new infrastructure with local multiplier effects.

A similar argument is advanced by Amankwah (2013) who declares that mining has some benefits which cannot be ignored. Among the benefits is employment which brings income to the miners and their families; which in turn improves livelihood opportunities by allowing local traders to sell goods and services around the mining sites and make a living out of the mining enterprise. This is an important impact that could bring further socio-economic development and reduce rural poverty. Geenen and Claessens (2013) however, caution that the levels of employment opportunities offered to members of host communities are in most cases too low to make meaningful contribution to household resources since the jobs on offer are mainly in the casual labour category that attracted low pay.

In literature, there is no consensus therefore on the influence of the extractive industry on household livelihoods. While most scholars acknowledge the contribution of mine employment to livelihood enhancement and boosts to the local economy, others pinpoint the accompanying environmental degradation emanating from the air and water pollution which degrades the stock of natural capital available to rural households (Adjei, 2007; Heikkinen et al, 2013). The support and benefits accruing from gypsum extraction are therefore important substitutes to the loss of nature and related livelihoods. Zarsky and Stanley (2013) argue that for the sustainability of the extractive industries, mining must maximize economic and social benefits for humans, because communities living near mining sites expect the mines to offer well paying jobs in exchange for lost livelihood opportunities.

The World Bank (2011), is categorical that mining projects in developing countries need to deliver sustainable benefits to local populations and the governments at the regional and national levels and further warns that the expectation for compensation and employment opportunities tend to be higher in remote mining operations. With supportive policy, the extraction of minerals is thus expected to lead to achievement of sustainable development goals by creating wealth and helping to alleviate poverty particularly at community level where the mining operations take place. The host communities have expectations of their own as regard to the contributions of mining. The community expectations play a significant role in livelihood change and in relation to mining, a significant component of mining conflicts (Hinojosa, 2013). For livelihood sustainability, it is therefore important to manage expectations as a basis for a socially sustainable mining industry.

Researchers are in agreement that mining operations generate both negative environmental impacts and socially acceptable benefits and that it is necessary to share the benefits. The sharing of the mining benefits and compensation for the damage generated by mining activities within rural communities enhances livelihood opportunities (World Bank, 2011). With the forgoing, it is safe to argue that the extractive industry can contribute to the growth of livelihood opportunities under certain circumstances and that, the goal of exploitation should be the conversion of the natural capital into other forms of capital and more sustainable livelihood opportunities (Klop, 2009; Sen, 2013). Zarsky and Stanley (2013) support this approach by asserting that mines generate a wide range of social, health and cultural impacts whose benefit can be estimated by considering three metrics:

1) The share of total revenues and earnings captured by the host Government and local communities as royalties and taxes as well as voluntary social investment by the mining company.
2) The total cash injected into the local communities during the operational life of the mine, including via direct and indirect wages and local procurement.
3) Investment in future production capacities including spillovers to other industries and public (and private) in physical or social infrastructure.

Pro-mining studies claim that increased investment in the mining sector in Africa is a key strategy to leverage growth and development in the continent (Akabzaa *et al*, 2013). This is backed by success stories in development literature, which present examples of developing countries that have exploited natural recourses for development. By analyzing the socio-economic impacts of large scale mining in low and middle income countries, Dane (2010) established that mines in South Africa achieved positive contributions in terms of procurement, employment, human capital development, community development and economic contributions to government revenue, Gross Domestic Product (GDP) and Exports. The resultant positive contributions benefited previously disadvantaged South Africans (Dane, 2010).

In a comparable study, Bainton and Macintyre (2013) explored the social changes generated by large scale mining in Papua New Guinea and came to the conclusion that mining provided significant economic opportunities for the local communities through employment, local trade and procurement. There are also other positive social impacts associated with mining that come from the demographic changes that result in structural and functional transformation of the local environment (Petrora and Marinova, 2013; Siegel, 2013; Ticci and Escobal, 2014; D'Angelo, 2014).

Host communities welcome extractive industry activities to their region with the hope of increased opportunities for local development. In a study aimed at reflecting community perceptions and interpretations of impacts as well as qualitative changes in the local social setting and their implications for a sustainable future, Petrora and Marinova (2013) established that mining led to the mobilization of community recourses which in turn enabled host communities to capitalize on opportunities associated with mining.

The ability of the host community to benefit from mining activities is however, dependent on the prevailing legal and structural framework since mining is believed to be more beneficial to the local economy when conducted within the tenets of transparency and accountability. Rees (2014) emphasizes that if the public knows what payments are made to government by mineral extracting companies, they hold the government more accountable in their spending which mitigates the risk of misappropriation of mining revenues. In terms of sustainability, mining could be considered to promote growth if it gives rise to long term benefits that equal or exceed the values that existed prior to exploitation (Zarsky and Stanley, 2013).

The contribution of mining industry to livelihood development could also be assessed by the level of its inclusion in the local economy through forward and backward linkages (Broad and Cavanagh, 2015). In forward linkages, the mining industry could be assessed on the scale to which it purchases products and inputs from the local sectors of the local community. Forward linkages could on the other hand, describe the extent to which products of the extractive industry serve as goods, products or supplies to other industries in the host community (Broad and Cavanagh, 2015).

Nevertheless, natural resource extraction does not always confer widely shared benefits on the people from whose territory they are extracted (Fatah, 2008; Thorvaldur *et al*, 2011). There are instances in literature where mining is reported to have negatively impacted on the social and physical environment of the affected state. For example, there are suggestions that when mining leads to rapid deterioration of the environment and the mine earnings continue to be concentrated in the hand of few people and mining companies, progress and hope for sustainable development remains an illusion for the local population (Fatah, 2008). This tends to be the norm in areas with weak or inappropriate policy framework and poor local leadership (Kamalu and Wokocha, 2011). Other studies (Sarangi, 2004) further warn that mining companies extract minerals in large quantities for industrial growth without considering the life and livelihoods of local communities. As a result, local communities in mining areas have lost their symbiosis with nature and community lives of most people have been destroyed (Sen, 2013).

Mining activities moreover tend to have an impact on vegetation diversity and agricultural production. In a study of the impacts of mining in Nigeria, Aigbedion and Iyayi (2011) observed that the dust generated during the mining activities negatively affected agricultural activity. It is noted that as the dust was emitted to the atmosphere, it eventually settled on leaves and flowers of plants and the soil surrounding the plants. This reduced the photosynthetic and fruiting ability of the trees and crops, and indirectly reduced the livelihood opportunities of the population in the study area.

A different serious negative consequence of mining is immigration. In examining the operations of a copper-Nickel mine in Botswana, Asare and Darkor (2001) established that the mine had led to rapid growth of population, outstripping the mine capacity for social services. Further, Erdiaw-Kwasie, *et al (*2014) suggest that the development of mining activities in rural areas might open the subject area to both migrant and resident sex workers, which would increase the incidence of diseases such as HIV/AIDS. They also noted that although employment creation tended to increase significantly, income levels of the people remained low, with high income disparities among the population. Literature is full of examples of socio-ills that arise in areas dominated by extractive industry activities such as prostitution in host communities. In a review of research on mining prostitution and other social histories of mining communities, Laite (2009) demonstrated that commercial sex was present and prominent as the mining industry and mining communities developed, and was accompanied with serious social impacts including violence and crime (Carrington *et al*, 2011; Sen, 2013).

A similar study by Petrora and Marinova (2013) in the mining settlements of Western Australia, established that the opening of large scale mining operations triggered significant demographic changes which resulted in structural and functional transformation of the local environment. The Asare and Darkor (2001) allegation was supported by Karlson (2009) who argued that allowing mining on lands owned by indigenous people would lead to loss of indigenous lands and open the region to large scale influx of non-tribal people. Other scholars however, disagree with this assertion and instead credit immigration for having positive effects over educational indicators.

Extractive industry activities are sometimes suspected as the main cause of armed conflict. Research on mineral rents and the financing of social policy (Collier and Hoeffler, 2005; Gross, 2007; Scott, 2012; Rasch, 2012) confirms that commodity exports substantially increase conflict risk as a result of the opportunities such commodities provide for extortion, making rebellion feasible and attractive. Various studies have demonstrated that mining areas have indeed turned into conflict areas (Lange, 2011). In the small West African state of Sierra Leone, it has been suggested that diamonds (*the blood diamonds*) played a key role in fuelling a brutal civil war during the 1990s (Maconachie and Binns, 2007; Siegel, 2013).

The *blood* Diamonds line of argument is not without support. In a study titled the recourse boom's underbelly, Carrington *et al* (2011) established that in the midst of a natural resource boom, the rate of crime in some towns in Western Australia was more than twice the state average, and had risen almost three times since the beginning of the mining resource boom. Scholarly investigations have also associated mining with the practice of sorcery and witchcraft. While Bryceson *et al* (2010), link the frequent murders of Albinos in the mining districts of northern Tanzania to efforts of Diamond miners to secure luck for finding minerals and protection while mining, Siegel (2013) claims that the miners believed in the power of sorcery to protect them from competition and theft of diamonds by other miners.

The foregoing indicates that mining not only provides significant economic opportunities for the local communities and the national government but also generates serious environmental and social effects. Although the value of cash inputs in mining areas increases significantly, many features of the local economy witness little change (Filer, 2012). This is attributed to the dysfunctional internal processes, mismanagement and corruption (Barton, *et al,* 2012; Akabzaa *et al,* 2013). These perspectives were of special interest to the current study since the subject county is inhabited by the indigenous Maasai community and immigrants from other Kenyan communities. It therefore provided a good opportunity to understand the contribution of mining to local trade, education and labour force participation and how that generally impacted on livelihoods of the local population.

2.5.2 Impacts of Gypsum Mining on Landscape

Monitoring landscape changes occasioned by anthropogenic activities is important because the changes might alter the ability of the landscape to function efficiently in the provision of environmental services such as water, food and livelihood opportunities. Understanding the direction and magnitude of the changes in time helps in drafting suitable policy responses and mitigation measures to curb degradation (Wang *et al*, 2009; Kennedy, *et al* 2009). Literature contains examples of negative landscape effects on the subject area and immediate user communities related to mine exploration and extraction activities. The impacts so documented range from alterations to the landscape structure to ecological functions of the subject area such as changes to the topography and landforms, changes in vegetation cover, disturbance of the dominant biodiversity forms and the resultant response by the local communities in terms of local resource needs and livelihoods (USDI , 2011 **a**).

Further evidence exists in literature to the effect that some gypsum deposits constitute unique habitats that are home to a number of endemies. The gypsum based ecosystems are indeed some of the most sensitive habitats, particularly when exposed to climate change and mining exploitation (Palacio *et al* 2012; Escudero *et al*, 2015) .Not all changes in landscape are attributable to anthropogenic factors since other factors such as increase in population and poverty have potential to produce the same results. The influence of anthropogenic activities is catalyzed by global forces that amplify or attenuate local factors (Lambin *et al*, 2001). Scholars are in agreement that as people respond to economic opportunities created by global forces and mediated by institutional factors, they drive landscape changes. The resultant disruptions in the landscape patterns compromise its functional integrity by undermining the ecological processes that are necessary for the existence and maintenance of ecosystem health (Li and Mander, 2009; Gathuru, 2011).

In other words, the overburden removal, drilling and development of support infrastructure for mining activities disturbs the abundance, species diversity, geographical distribution and productivity of vegetation communities in the mined areas. The inevitable deforestation causes the elimination of some plants and an exodus of the animal species that depended on the plants for food and cover (Aigbedion and Iyayi, 2011).

Debate on the identification of anthropogenic conditions that catalyze landscape changes is not settled in literature. Lambin *et al* (2001), suggest that institutional factors play a catalyst role in landscape changes. The influence of institutional factors on landscape changes near mining sites was however not clearly demonstrated in the study by Lambin *et al* (2001). In maintaining that global forces such as increased international demand for minerals have the potential to influence land use changes, Lambin *et al* (2001) ignore the role of public perception and expectations of communities living near mining sites. Elsewhere it has been argued that communities near mining sites are often alive to the potential threats to conservation due to spatial distribution and extent of mining concessions and the environmental impacts that mines often cause (Gardiff and Adriamanalina, 2007; Martinez *et al*, 2007; Castellanza *et al* , 2010).

Mining causes serious land degradation. In an examination of the impacts of natural contaminants and mining activities on surface water and agricultural soils, Rahimsouri *et al* (2011) observed that mining and natural sources contributed significantly to soil pollution that in turn reduced agricultural productivity because of the toxicity of the chemical compounds which adversely affect biological functions. The source of the soil pollutants in the form of trace elements can either be geo-genic or anthropogenic. Once in the soils, the pollutants are mobilized by physical, chemical and biological vectors such as volatization, dissolution, leaching or erosion and enter organisms when they are in a soluble form (Gonzalez *et al*, 2011).

The soil degradation argument has further been expounded by Gonzalez *et al* (2011) who claimed that the abnormally high concentrations of trace metals in the soils around mining sites usually comes from metal ores such as sulfides and oxides. Because the mining activities tend to produce huge amounts of waste each year, the cumulative effect was the releases high concentrations of trace metals into the environment. Soils around mining sites therefore, tend to have higher than normal concentrations of trace metals. Farmers who stay near the mining sites respond to losses in agricultural land by shifting livelihoods from agriculture to mining related work which could be viewed as an indicator of development (Mushra and Pujari, 2008). While this assertion might hold in agriculturally high potential areas, the study methodology (the total factor productivity pattern in mining villages) did not incorporate pastoral communities. Pastoralists such as the Maasai of Kajiado County, who entirely depend on livestock for livelihood, might find it difficult to shift to mining related activities if pasture land is reduced by mining activities.

Landscape impacts have the potential to initiate negative ripple effects. As mining sites increase in size, they tend to eat into agricultural land thereby threatening production and livelihood systems since opencast mining affects all landscape components and functions (Sklenicka, 2004). Altering landscape characteristics such as land cover and land use because of open cast mining tends also to impact on surface and subsurface water quality. The deforested landscape is exposed to soil erosion and ultimately leads to sedimentation and contamination of water bodies (Abdelaal, 2014). The loss of agricultural land both in quantity and quality, could lead to negative economic growth as a consequence of decreased agricultural production, loss of water resources and eventually reduced tourism related earnings (Palmer *et al*, 2010).

Other scholars have argued that mining activities cause loss of vegetation cover. Schuler *et al* (2011) used landsat satellite images to map land cover change as a result of gold mining in Western Ghana and came to the conclusion that surface mining resulted in deforestation and led to fast loss of livelihoods as a result of compromised farmlands. As the affected farmers relocated to more fragile areas, it increased the environmental and social costs of mining. Erdiaw-Kwasie *et al (*2014) suggest that when communities loose valuable lands such as farmlands and forests, their livelihood opportunities and consequently their living standards got impacted.

There is no agreement in literature however, regarding the effect of opencast mining on fauna and flora. It has been argued by various scholars that mining activities negatively impacted on fauna and flora and consequently disturbed the forest eco-system around mining sites (Lameed and Ayodele, 2010). This deprives the local community the ecological diversity upon which to a large extent the distribution of bio-productive resources and the nature of economic activities undertaken depend (Castellanza *et al* 2010). The notion that mining causes negative impacts to fauna and flora has been criticized by other scholars. In a study of bird species abundance and richness in mined and non-mined sites in the Jos plateau in Nigeria, Dami and Okafor (2009) concluded that the number of bird species in mined sites was greater than in non-mined areas as the former supported wetland birds.

From literature, it is unmistakable therefore, that by putting pressure on the ecological base, mining results in land degradation and deforestation. Deforestation further results in loss of soil and a decline in microbial diversity while the resultant decline of vegetation cover leads to serious loss of plant and animal species. This allegation is affirmed by Gyang and Ashano (2010) who argue that mining, particularly open cast mining takes place on the earth's crust which is home to organisms whose life patterns get disturbed when mining is undertaken. They hint that mining consequently leads to loss of biodiversity and could in fact lead to extinction of some bird and animal species. This position was reinforced in a study toward a World monograph of Nepenthes Ramos, where it was established that the species had not been recorded since 1919, despite much exploration in the recent years specifically for the nepenthes (Cheek and Jebb, 2013). It was probably extinct as a result of open cast mining.

The economic activities in rural areas that directly or indirectly depend on the vibrancy of the ecological system include livestock farming, horticulture and ecotourism. The success of tourism also directly depends on the availability of wildlife resources, which in turn depends on biodiversity richness. Additionally, the impact of mining on the quality of soils around the mines cannot be ignored as the cumulative effects of pollution loads on the soil and water resources alter the land use in the host communities (Cockell, *et al*, 2010; Ezeaku, 2012). In a study aimed at evaluating the influence of open cast mining of solid minerals on soil, land use and livelihood systems, it was established that soils around the mine sites were coarse textured and acidic with a PH of 4.8. Mine soils were found to be strongly acidic with a PH of 3.5 which affected the indigenous vegetation (Chauhan, 2010).

Similar results had previously been obtained by Gyang and Ashano (2010), who while investigating the effects of mining on water resources and the wider environment observed that because of the open cast mining technologies employed, mining caused extensive man-made environmental damage, resulting in the destruction of vast pastoral lands and the dependant flora and fauna. The current study area borders a wildlife migratory corridor which provided a good opportunity to understand the impact of gypsum quarrying on forestry, agriculture and livestock development, conservation and biodiversity.

2.5.3 Impacts of Gypsum Mining on Water Quality

An assessment of pollution levels in water bodies in mining areas due to accumulation of metals and other pollutants is important as it has the potential to reveal environmental and human health risks associated with the extractive industries. Changes in metal concentration above acceptable levels, whether as a result of natural or human activities can result in serious environmental and health challenges to the local population (Odira *et al*, 2012; Ternjej *et al*, 2014).

Negative water impacts can be described as those that lead to a decline in the quality of natural water to the extent that it is not suitable for use by man or other forms of live. The impacts degrade water by alteration of biological, Physical and chemical properties of water (Magombedze, 2006). The extraction of mineral ores affects the hydrology of the catchment area by influencing the quality of water available. Water related impacts can arise at nearly every stage in the mining process (Miranda and Sauer, 2010). Previous research associates the presence of chemical pollutants in water in water bodies around mining sites to the extraction industry. In a study conducted in a relatively dry part of South Africa, it was established that mining had a significant likely impact on ground water resources with potential for generation of acid mine drainage (Vermeulen and Bester, 2010).

Later work by Ezeh and Chukwu (2011), who examined small scale mining and its effect on soil pollution, noted a strong association between the levels of soil pollution and proximity to mines. They established that mining exposed geological materials to intensive weathering and subsequent chemical and mechanical breakdown with the help of rainfall and runoff. The concentration of heavy metals in the soils of the study area was directly attributable to the mining lead, Zinc, Cadmium and copper ores.

The mining process and activities such as drilling, extraction, benefication, dewatering of the subject area; leaching from the waste rock piles and tailing dams cause changes in the water quality. Water contamination could also occur when the pollutants are directly introduced to the water bodies by the miners as observed by Siegel (2013) who recorded instances where artisanal miners in Burkina Faso washed the ore in water pits and used mercury to amalgamate the gold. This degraded water resources in the study area. In situations where mining involves sulphide bearing minerals, the potential pollution of water resources is a valid concern to government and host communities. This is more so because once the sulphide bearing rocks are exposed to water and oxygen, they undergo natural oxidation resulting in acidic discharge. The discharge then seeps through the waste rock piles, tailing dumps and country rocks, dissolving metals along its flow path, eventually finding its way to water bodies (Magombedze, 2006).

Mining affects water quality by increasing levels of suspended solids and decreasing the PH of the receiving surface water body. Odira *et al* (2012), claims that depending on scale, mining activities have potential to pollute water resources through the introduction of waste rock, tailings, silt and effluent discharge into surface water bodies. These pollutants contain a wide range of metal and chemical pollutants such as cyanide, cadmium and lead. Other studies have documented evidence to the effect that (Aigbedion and Iyayi, 2007), water pollution as a result of mining occurs when metals contained in the excavated rock come into contact with water. Mining also affects water bodies when seepage from tailings and waste rock impoundments come into contact with the water bodies.

Mining moreover, degrades water resources through the introduction of harmful bacteria that make mine water unsafe for domestic use by rural communities (Gyang and Ashano, 2010). An analysis of bulky water samples collected from a mining pit over a two year period confirmed presence of bacterial organisms including Bacillus Sp, Pseudomonas aeruginosa, Protes Sp, Escherichia coli, Chromobactarium Sp, Alkaligenes Sp, Shigela sp and Flavobactarium (Obiekezie, 2006). Merriam *et al* (2013) seemed to corroborate this position when they noted a positive interactive effect of mining on biological condition of a stream caused by flow augmentation from deep mines. They observed that an increase in surface mining caused streams to exceed chemical or biological standards.

The overall effect is the deterioration of water quality, which consequently leads to a reduction of aquatic life, increased livestock mortality, contamination of the food chain by way of heavy metals presence in fish and plant tissue which ultimately leads to gastric disorders and diarrhoeal diseases. Mining impacted water bodies further lead to ecosystem deterioration. Mining also discharges huge amounts of mine water to the environment and degrades the water quality by further lowering the water Ph of the affected area (Tiwary, 2001, Liakopoalos *et al*, 2010; Ochieng *et al*, 2010). In non-acidic mines, water quality shows high hardness which indeed reduces its utility in domestic purposes. To a large extent, the level and type of water contamination depends on the nature of mineralization, mining methods and processing chemicals employed in chemical extraction. There is evidence in literature that most critical changes however, occur as a result of leaching from stock piles and point discharges of mine drainage (Mestre, 2009; Nude *et al*, 2011).

However, the impact of mining on water resources is not universally accepted yet water impacts are among the most contentious aspects of mining projects (Bebbington and Williams, 2008). The ante-mining school of thought maintains that mining negatively impacts on quality and availability of water by causing a series of physical impacts including lateral instability of river channels (Kitetu, 1997; Magombedze, 2006; Dashwood, 2007; Gilbert, 2010; Bayram and Onsoy, 2014; Padmalal and Maya, 2014). Other scholars find no serious harmful impacts on the environment of the studied area associated with the extraction and quarrying methods (AlHarthi, 2001). In evaluating the impacts of quarrying of gypsum deposits on the environment, AlHarthi (2001) conducted field and laboratory tests of gypsum deposits at Maqna area in Saudi Arabia and found no harmful impacts of mining on water. This particular study though, was conducted with the sole objective of identifying the most effective method of quarrying and might not therefore; provide adequate and conclusive evidence of the impacts of mining on water.

Other researchers have adopted a middle ground; according to Zabowski *et al* (2001) the impacts of mining to watersheds are highly variable depending on the type of mining, processing and environmental factors. In a study of mining impacts on trace metal content of water, soil and stream sediments in the Hei river basin in China, it was established that the total concentration of calcium, lead and Zinc were high in some stream sediments and soil near the sites. High River PH and water flow rates appeared to contribute to limiting quantities of metals in the river water. Related studies (Ohimain, 2003; Akabzaa *et al*, 2007; Aremu *et al*, 2010) on surface, ground and abandoned pond water samples within a mining area catchment found out that streams in the study areas had higher trace and major ions loading than ground water. The microprobe results indicated that waste rocks and related mine spoil contained a variety of Iron, Calcium, Lead and Zinc and co- bearing sulphides that accounted for the augmented levels of these metals in drainage proximal to mining.

There is conclusive evidence however that the impacts on water resources are long lasting. Measurements of major and trace metal elements within tributaries of a river of West Virginia confirmed that mines reclaimed nearly two decades earlier continued to contribute significantly to water quality degradation in the watershed. Heavy metal pollutants generated by mining activities in the Jordanian desert 2000 years ago, continue to persist in modern environments and impact on plants, animals and man (Pyatt and Grattan, 2001; Lindberg *et al*, 2011).

Deleterious impacts of mining on water have as well been noted in other parts of the World. Younger and Wolkersdorf (2014) insist that mining can have significant impacts on the Natural water environment by disrupting existing hydrological pathways within the host strata, which has potential to disrupt ground water flow. Disposal of water pumped out during mining could also depress the water table around the dewatered zone. This consequently reduces the flow of streams and wetlands that are in hydraulic continuity with the affected ground water body. After mining, the flooding of the open pits or backfilling can also cause water quality deterioration when the backfilled material initially gets saturated (Younger and Wolkersdorfer 2014).

2.5.4 Impacts of the Gypsum Mining on Particulate Matter Concentration

Air quality refers to the composition of air in terms of how much pollution it contains. The deposition of pollutants in the air devalues its quality, particularly when the air contains gases, fumes, dust or odour in harmful amounts, to the detriment of health or comfort of humans and animals, or which could cause damage to plants and materials. To protect the public from injury, various National and International legislation has categorized clean air as a basic requirement of human health and wellbeing (WHO, 2005; RoK, 2010).

For people living or working near mining sites, air pollution emanating from mining activities continues to front a significant threat to health. The deposition of dust, especially particulate matter, Sulphur dioxide and Nitrogen dioxide reduces the quality of air and ultimately the quality of life for people, flora and fauna (Chaulya, 2004; Sharma and Siddiqui, 2010). Research links the major sources of air pollutants in mining regions to land clearing, removal of overburden, vehicular movement, excavation, loading and off-loading of ore minerals (Prusty, 2013).

Air deposition is one of the most used parameters of assessing the impacts of open cast mining on public health. In an assessment of dust generation due to open cast coal mining in India, Ghose and Majee (2000) analyzed dust deposition and noted a direct relationship between the acreage of land under open cast mining and the quantities of dust generated. By using emission factor data to quantify generation of dust, they observed that due to top soil removal, coal extraction accounted for 9.4Mt of dust per day. This significantly contributed to air pollution in the work zone and surrounding locations.

Literature is full of documentation associating extractive industries to negative air quality that eventually compromises public health in terms of higher rates of disease, physical injuries, and exposure to the air pollutants, noise and respiratory and cardiovascular system effects. The analysis by various scholars paints a persuasive observation of the harm to human health from exposure to dust and numerous toxins released into air and water by open cast mining (WBIFC, 2009; Subhrendu *et al*, 2010; Murray *et al*, 2011; Kinyua *et al*, 2011). However, Studies on the effect air pollution on human health are not conclusive because there are arguments for and against the extractive industry as a contributor to air pollution. In a study of the feasibility of constructing a community profile of exposure to industrial air pollution, Pless-Mulloli *et al* (2000) argued that children in open cast communities were exposed to small but significant amounts of Particulate Matter (Pm10) to which open cast was a measurable contributor.

To answer the question whether living near open cast coal mining sites affected acute and chronic respiratory health, Pless-Mulloli *et al* (2000) assessed 4,860 children aged between one to eleven years old from five socio-economically matched pairs of communities close to open cast and control sites. Exposure was assessed by concentrations of particulate matter (Pm10), and the researchers came to the conclusion that particulate matter (Pm10) was higher in open cast areas, and that the mines were a measurable contributor of Pm10 in the adjacent areas. Little association was found however between living near an open cast and an increased prevalence of respiratory illness and asthma severity (Pless-Mulloli *et al,* 2000).

Applying similar methodology, Olesugun *et al* (2009) seemed to give credence to the observations by Pless-Mulloli *et al* (2000) after evaluating the impact of granite quarrying on the health of workers and nearby residents in Abeokuta, Nigeria, and coming to the conclusion that psychological and health problems suffered by nearby residents included shock, nasal infection and asthma. A different position is advanced by Howel *et al* (2001) who compared general practitioner consultation rates of children living in communities close and away from open cast mines. He argued that four out of the five pairs of open cast and control communities had similar consultation rates for all conditions, and therefore concluded that there was no relationship between the open cast mine and health conditions. Davidson and Hawe (2012) however, assume a middle ground and caution that the diverse impacts of health of individuals can only be understood in the wider context of environmental and social changes occurring in the mining region.

To ensure uniformity in the application of research findings and adaptation to local conditions, the impacts of air pollution in open cast mining areas have previously been evaluated against acceptable pollution control standards. Most countries have their own levels of permitted exposure and various International organizations issue recommendations. The recommendations differ greatly and have been readjusted over time (Karlson, 2009). Chaulya (2003) used Indian air quality standards to assess the extent of air pollution in an open cast mining area. Through determining concentrations of suspended particulate matter, respirable particulate matter and sulphur dioxide in residential areas and mining areas, Chaulya (2003) confirmed that Particulate matter and respirable particulate matter concentrations exceeded the respective standards set in the Indian National ambient air quality standard. Using similar methodology, Chaulya (2004), observed that the 24 hour annual average concentrations of Particulate matter Pm10 exceeded the prescribed maximum of 250 $\mu g/m^3$ standard set in the Indian National Ambient Air Quality (N AAQ).

Besides national standards, levels of air contamination could be assessed using sociological data. In earlier studies, negative impacts of dust generation was assessed using sociological data, as demonstrated by Moffat and Pless-Mulloli (2003) in a study of health and environmental concerns of parents living near open cast coal mines in the United Kingdom. They characterized parental risk perceptions in relation to children's asthma status. The sociological data collected highlighted respondents recognition of the place specificity of exposure, though no link was found between children's asthma and exacerbation of the condition.

The studies by Howel *et al* (2001) and Pless-Mulloli *et al* (2000) do not however, factor the probability of the impacts of pollution spreading to the control communities over time and therefore, producing the same results. More recent studies point to additional evidence of negative health impacts. In a study focused on the coal mines of china, it was proved that while the coal industry employed about 4 percent of the Chinese labour force, it accounted for 45 percent of fatalities from industry owing to poor industrial health and safety (Wright, 2004). In a similar investigation aimed at determining whether coal mining in West Virginia was related to poor health status and chronic health conditions, Hendryx and Ahern (2008) established that as coal production increased, health status worsened, and rates of cardio pulmonary disease, lung disease, cardiovascular disease and kidney diseases increased. They concluded that among West Virginia adults, residential proximity to heavy coal production was associated with poor health.

The difference in results between Hendryx and Ahern (2008) and Pless-Mulloli *et al* (2000) may be explained by the differences in methodology adopted. While Pless-Mulloli *et al* (2000) monitored the concentrations of particulate matter (Pm10), collected daily health data by symptom diary, and abstracted general practitioner records, Hendryx and Ahern (2008) used telephone survey to obtain data on health and presence or absence of chronic diseases. For completeness and reliability, the current study chose to assess the concentrations of particulate matter through actual air sampling and measurements.

Research has also proved that the dust generated by opencast mining also indirectly affects human health through the food chain. The deposition of dust on pasture fodder leads to negative effects like reduction in milk production and increased fodder residuals (Jaarsveld, 2008). There is more evidence of harmful extractive industry impacts noted in soil samples collected from mining sites and households near mining sites (Zota *et al*, 2011; Pearce *et al*, 2012). The samples were analyzed for Lead, Zinc, Cadmium, Arsenic and Manganese. The results revealed more than normal concentration of Lead, Zinc, Cadmium and Arsenic. The dust generated by opencast gypsum mining also negatively impacts on livestock development.

This study sought to compare the concentrations of respirable Particulate Matter (Pm 2.5) against National Air Quality standards as set by WHO (2006) and the National Environmental Management Authority (NEMA) of Kenya. Just like in the Indian Case study the current study examined the influence of mining on air quality and by extension public health by evaluating the concentration of respirable dust generated by the Kajiado gypsum mining industry and comparing the same with the WHO (2006) and standards as set by NEMA.

2.5.5 The Intervening Policy Environment

Kopinski *et al* 2013 advise that the key to a beneficial extractive industry lies in a well defined mineral development policy with consistent legislation and regulations, well structured and capacitated institutions to administer the laws, codes of conduct with predictable enforcement practices. The enforcement practices must target both the environmental and social impacts of the extractive industry. The legislations must be drafted in such a way that they clearly indicate the authority of the government and conditions of accessing mineral lands, rights and obligations for environmental protection and restoration f mined areas. The foundational laws need also be clear on the procedures and entitlements in sharing of the fiscal and social benefits of mining (Petrora and Marinova, 2013).

2.5.5.1 The Institutional Framework

Institutions could be defined as a set of rules, written or informal, governing relationships among role occupants in organizations like the family, schools and other major areas of social life (Portes and Smith, 2010). In the extractive industry set up, institutions help government to define policy applicable to both mining and environmental protection. They also provide the fiscal and legal framework for administering the mineral rights and protecting the environment. Institutions as well help the government to regulate the health and safety conditions of the mines and in setting up a reliable geological infrastructure.

Experience from World Bank supported countries that successively implemented institutional reforms in the 1990s indicate that simple institutional structures established with careful assignation of functions and clear objectives contribute to a climate of public confidence and the transparency of administration of mining policies. A functional institutional structure typically accommodates a ministry or department that acts as the political head of the sector, provides leadership in policy making, mining promotion, and administration of mining and legal rights. The ministry or department should also be facilitated to supervise matters related to mining occupational health and safety (Zota *et al*, 2011).

Literature places a premium on well managed mining institutions. If institutions are supported by a good geological database, they have potential to positively influence the government's chances of entering into sustainable extractive agreements (OECD, 2008). In this context, institutions in land and revenue collection play a critical role since some negative social impacts emanate from a community perception; that mining companies unfairly occupy their land without sufficient compensation. Institutional weaknesses in the Mining sector have in the past led to protests, land use conflicts and low revenues to government. Sonter *et al* (2013) advises that for the industry to contribute to regional development, land management policies must be flexible and promote incentives to enable companies invest beyond compliance.

The place of good institutions in natural resource management, especially in conversion of natural resources has been elaborated in a number of studies. Bourgouin and Haarstad (2013), in an article entitled "from good governance to the contextual politics of extractive regime change' suggests that the notion of resource curse is inextricably linked to issues of good governance and would take certain types of institutional reforms to escape. They give an example of mining revenue management reforms as one institutional change that would unlock development potential.

To signify the importance of institutions in resource extraction, other scholars have equated the role of institutions to that of the immune system of a healthy human body by suggesting that in order to escape the natural resource curse, countries needed to strengthen their ‘immune’ framework system. This would involve strengthening the legal framework, improvement in transparency and accountability and making attempts to strengthen non resource sectors of the economy (Kopinski *et al*, 2013; Triscritti, 2013).

Institutions are useful tools in managing mining related disputes. According to Alba (2012), it is the responsibility of the state to accommodate and resolve conflicts in the extractive industry. Although this appears to suggest that institutional management is exclusively a responsibility of the state and completely ignores the role of non state actors such as traditional chiefs who derive their authority from customary law but still have strong influence on access and exploitation of mineral resources (Geenen and Claessens, 2013), more recent studies appreciate the contributions other stakeholders including host community leadership and mine management teams could make towards effective natural resource extraction governance (Hilson, 2002**a**).

Environmental and social economic impacts of the extractive industry activities are thus a function of the existing national institutional framework. While not a silver bullet, institutions supported by national and local level regulations play a crucial role in regulating the conduct of extractive industries (Upton, 2012; Armah *et al*, 2013; Simons and Macklin, 2014). In the absence of suitable legislation or where the legal provisions are not followed, indigenous communities resort to litigation and direct political activation against government and extracting companies (O’Faircheallaigh *et al*, 2008). This position was reinforced by Hilson (2002 **b**) when he examined the environmental impacts of small scale gold mining in Ghana, and came to the conclusion that, in order to achieve environmental improvement and prevent conflicts, it was necessary to design and implement industry specific management tools and strategies

In Kenya, before the year 2013 mining activities were regulated by the Department of Mines and Geology that was by then housed by the Ministry of Environment and Natural Resources. The Department of Mines and Geology was elevated to a fully fledged Ministry in May 2013 when President Uhuru Kenyatta formed his first Cabinet, in recognition of the crucial role that mining was expected to play in National development. The Ministry was fashioned with the express mandate of:

i. Carrying out mineral exploration and mining policy management,
ii. Carrying out an inventory of mineral resources in Kenya,
iii. Facilitating mining and mineral development in Kenya.

For functional efficiency, the Ministry was divided into five Directorates as shown in Fig. 5. They include the Directorate of Corporate affairs which is responsible for general administration and the Directorate of Geological surveys that is charged with mineral explorations and geological mapping and environmental engineering. Others are the Directorate of mineral management and regulations which is responsible for mine health, licensing, compliance and enforcement; the Directorate of resource surveys and remote sensing responsible for geo information, remote sensing, aerial and ground surveys and; Directorate of mineral promotion and value addition. The schematic arrangement is shown in Fig. 5

For efficient management and regulation of mining activities, the Ministry of Mining is expected to work closely with stakeholders in the extractive industry such as the Ministry of Water, Environment and Natural Resources, the National Land Commission and the National chamber of mines. The Mining Bill 2014 proposes to create a Minerals Rights Board (MRB) as a government lead agency in determination of mineral rights, licensing and related procedures. It also creates the Directorates of Mines and geology as technical arms of the ministry and the National mining Corporation as the investment arm of government in the mining sector.

Institutional Organogram

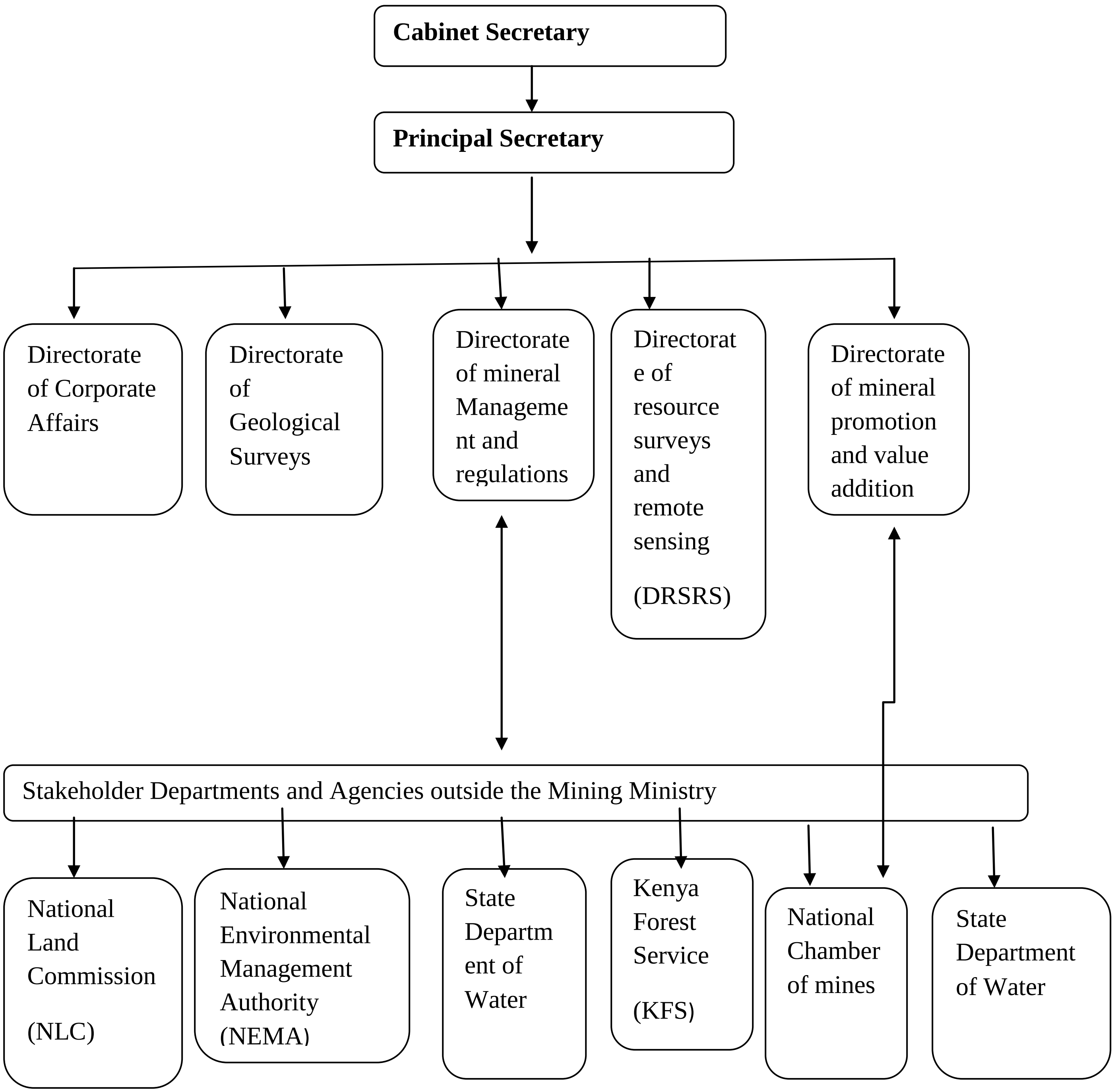

Figure 5: Existing Institutional Structure

2.5.5.2 The Constitution of Kenya (2010)

The Constitution of Kenya, 2010 (RoK, 2010) is the overarching legal instrument in environmental management in Kenya. The preamble statement of the constitution makes reference of the environment by stating that Kenyans respected the common heritage and were determined to sustain it for the benefit of the future generations, while Article 10 of the Constitution underscores sustainable development as a critical National value and principle of good governance.

The central nature of the environment in the lives of Kenyans is emphasized in Article 42 that bestows upon every person the right to a clean and healthy environment, which includes the right to have the environment protected for the benefit of the present and future generations particularly through measures anticipated in Article 69. Article 69 (1) (a) requires the state to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources. 69 (1) (f) and (h) require the state to ensure equitable sharing of the benefits accruing from natural resource exploitation. The enforcement of environmental rights by courts of law is protected by the constitution under article 70, while article 71 empowers parliament to make legislation to give effect to the provisions of the constitution on natural resources.

Chapter five of the Constitution of Kenya (2010) is devoted to the governance of the Environment and Natural Resources. However, given the current interest in minerals and the critical role that mining is expected to play in powering the Kenyan economy, the Constitution does not specifically draw attention to mining but merely lumps mineral exploitation together with the exploitation of other natural resources. This denies mining the requisite prominence to attract the budgetary and legislative resources it deserves. The role of the constitution in shaping the mining industry has been canvassed by Panagos and Grant (2013) who suggest that the Constitution of a country has a role to play in both moulding the legislations and influencing the attendant actions of local communities, the mining industry actors and the central government (Panagos and Grant, 2013).

2.5.5.3 The Mining Act, 2016

The most important legislation directly related to mining in Kenya is the Mining Act 2016 that repealed the Mining Act 1939, (CAP 306). The Act vests ownership of all minerals in the National Government in trust of the people of Kenya. The Act declares all mining and prospecting activities that do not conform to the Act as offenses. It provides for the registration and licensing of all mineral right holders and requires holders of prospecting rights to ensure their activities. Do not negatively affect the interests of other mineral holders, owners or occupiers of land over which the mineral right extends.

The Mining act 2016 further amend the Trading in Unwrought Metals Act (1933) and the Diamond Industry Protection Act (1949), in an attempt to give effect to Constitution of Kenya 2010, Articles 60, 62, 66, 69 and 71. The Act takes into account devolution, improves public participation in the issuance of various types of licenses and enhances the payment of royalties to local communities.

To streamline the management of mining operations, the Act creates a hierarchy of mining Boards and Institutions including the National Mining Corporation, a Mineral Board and the Minerals and Commodity Exchange. Clause 176 of the Bill prohibits the issuance of mining licenses unless the applicants have submitted and obtained approval for an Environmental Impact Assessment, a Social Heritage Assessment and an Environmental Management Plan. It also prescribes the compliance to the provisions of the water Act (2012) concerning the right to use water from any source, the Occupational Health and Safety Act (2007), concerning the health and safety of workers and miners. Clause 179 requires mining companies to ensure sustainable use of land through restoration of abandoned mines and quarries.

To facilitate community development, the Mining Act 2016 (2014) contains financial provisions for the sharing of revenues and royalties among National Government, County Governments and local communities, on a 70 % for National Government and 30% for county Governments basis. The National Government takes the bigger portion of mining revenues with the assumption that most of the revenues would be used to stimulate more mineral production at the county level through provision of infrastructural services and facilities. This however, puts county governments at a disadvantage in view of the fact that they would continue to receive 30% of the revenues without considering of the cumulative level of infrastructure development at the respective county over time. Subjecting the revenue sharing formula to review is not straightforward as it depends entirely on the wishes of politicians and the ruling class.

2.5.5.4 The Forest Management and Conservation Act 2015

This was assented to in September 2016 and is aimed at operationalizing Article 69 of the Constitution of Kenya 2010. The Act broadly classifies forests into three, namely public forests, Community forests and private forests. Public forests are controlled and regulated by the Kenya Forest Service that is empowered under Section 45 to regulate quarrying activities in gazzetted forests. To ensure sustainability in the utilization of forest resources, the Act does not allow quarrying in sections of forests that are home to endangered animal and plant species, have cultural importance or categorized as water catchment areas.

Conditions and criteria for issuance of licenses for utilization of forests include the preparation of Environmental Impact assessment reports. Section 34 of the Act empowers the Cabinet Secretary responsible for forest management to declare any areas of private or community forests that have environmental or biodiversity value as provisional forests for the sake of minimizing further destruction and allowing recovery.

2.5.5.5 The Physical Planning Act, 1996- Currently under Review

Another significant piece of legislation is the Physical Planning Act 1996 (CAP 286), of the laws of Kenya (RoK, 1996), which is the principal Act for land use planning in Kenya. The Act is administered by the Director of physical planning and county governments. It provides for the preparation of Environmental Impact Assessment reports in support of development applications and projects that are potentially injurious to the environment, including quarries. The physical planning act stipulates the procedure for effecting land use changes, as well as the classification of any alteration of the material use of land as development that would require approval of the county government. It provides a legal framework for evaluating the feasibility of development applications aimed at changing land use from Agricultural to quarrying. The proposal to repeal the act contains provisions that are meant to empower county governments to take a more active role in land management.

2.5.5.6 The Environmental Management and Coordination Act 2015 (EMCA)

The Environmental Management and Coordination Act (EMCA) 2015 revised the EMCA (1999) to provide a coordinating structure for implementation of the sectoral laws such as the forest conservation and management Act, the mining act and the Physical Planning. Under EMCA, the National Environmental Management Authority (NEMA) is empowered to craft regulations for the management of Natural resources. This enables NEMA to make regulations for mining, range land development, dust control and water safety among others (RoK, 2011). The regulations are aimed at guaranteeing an open space setting and rural character of pastoral lands and preserving agricultural fields for agricultural production. The regulations require mining companies to carry out Environmental Impact Assessment (EIA) studies and prepare after use plans to restore disused pits, within twelve months of depletion mines. The regulations in place require mining to be carried out using appropriate technology to increase efficiency, control dust and vibration to acceptable levels, and, discharge waste only at designated sites to minimize impacts (RoK, 2011). Of interest to this study is section 71 of the amended act that requires the Cabinet Secretary responsible for water to establish criteria and procedures for the measurement of water quality standards and recommend minimum water quality standards for different uses including drinking and further, make provisions for the control and regulation of water pollution. Since the Act was assented to at the end of 2015, the said standards are yet to be developed.

The most challenging aspect of the EMCA however, is its low enforcement capacity since EMCA 2015 draws support from various pieces of legislation. However, the legislations are domesticated and administered by different line ministries, which creates operational overlaps and conflicts likely to be exploited by mining companies. Some of the Acts are obsolete; particularly the Mining Act which came into effect seventy years ago and is currently before Parliament for review since it has not been sufficiently amended to address challenges posed by devolution and increased demand for minerals. The penalties proposed for noncompliance to the Physical Planning Act, the Forest management and Conservation Act and the Environmental Management and Coordination Act (EMCA) are too lenient to guarantee environmental sustainability in the mining sector.

2.5.5.7 The Water Act 2014

The water act 2014 was enacted with the specific purpose of giving effect to the provisions of the Constitution of Kenya 2010 on access to quality water (Article10, 43, 60 and 232). The Act aims to regulate, manage and develop water resources, water and sewerage services and related services to eventually improve water resources management in Kenya, following decades of institutional mismanagement. The act introduced radical reforms in the water sector such as the separation of water resource management from water supply and distribution management.

To ensure the provision of quality water services, the water Act 2014 provided for the regulation of water service through the creation of a water services regulatory authority responsible for the formulation and enforcement of the water standards, procedures and regulations. The Authority is responsible for collection and testing of water resources. Further, the Act disallows obstruction or pollution of water resources by throwing or conveying rubbish, dirt, refuse or effluent. It also disallows the adding of any other offensive things into or near water resources in such a manner as to cause pollution.

2.5.5.8 The Public health Act 2012 (Cap 242)

The Public health Act of 1986 was revised in 2012 with the sole objective of securing and maintaining public health. The Act lists various forms of nuisance that constitutes pollution including pollution of land, water bodies, air and public utilities such as roads and market places. The Public Health Act 2012 further defines polluted water bodies as water resources used by people for drinking, domestic purposes or in connection with any dairy, which in the opinion of a public health officer is injurious or dangerous to health.

The Public Health Act 2012 is operationalise through regulations that disallow discharge of injurious substances into the atmosphere, land or water bodies and expressly empowers public health officers to order remedial action against the authors of any such nuisance, and remove the nuisance within a specified amount of time. The Public health officers, by law have access to any land therefore, kept in such a manner or state as to constitute nuisance and cause any preventable disease, injury or danger to public health. This important provision is however difficult to implement without sufficient staff deployment at the rural areas where the mining activities take place.

2.5.5.9 Corporate Social Responsibility (CSR)

To enhance socio economic impacts in the extractive industry, mining companies apply the concept of Corporate Social Responsibility (Coronado and Fallon, 2010). Corporate Social

Responsibility (CSR) is born out of the idea that companies owe a duty to the wider communities in which they operate, especially in the mining sector. The concept of CSR is suitable in addressing social, environmental and economic issues associated with mining since companies are expected to negotiate economic, environmental and legal dimensions of CSR with Government.

Heikkinen *et al* (2013) equate CSR to a means of obtaining the social license to extract mineral resources in a given area. In one case study based in Finland, Heikkinen *et al* (2013) observed that the mining company maintained a newsletter through which it informed members of the local community about future employment opportunities and continued to participate in local community projects aimed at improving education, health and sports related activities. The mining company also continued to engage in continuous skills development in order to higher as many locals as possible. These led to environmental and social improvements at operations and within communities for the generation of economic benefits and social well being (Guerin, 2009; Colonado and Follon, 2010; Yakovleva and Vazquez-Brust, 2012 Pegg and Zabbey, 2013; Altine and Afonis, 2013; Lindsay, *et al* 2013).

Research has established the value of community based institutions in the extractive industry set, particularly in the context of public perception and expectations. This is important because public perception plays an important position in shaping the mining company business strategies and strategies of corporate social responsibility (Maconachie and Hilson, 2013; Bebbington *et al*, 2010; Bebbington and Burry, 2009). Lawson and Bentil (2014) also argue for continuous assessment of public perception right from exploration, during operation and mine in order to increase awareness among community members. Enlightened Community members supported by enthusiastic bureaucracy improve possibilities for more aggressive enforcement of environmental laws and consequently reduced pollution (Orihuela, 2014).

2.5.5.10 International Best Practices

Lindsay *et al* 2013 advise that mineral extraction and management woks well when based on internationally acceptable best practices. The best practices might appear expensive and prohibitive at the beginning but in the long term, produce long term gains for the industry. Best management practices fall under the following broad categories:

i. Open and effective communication with the local community and other interested parties. Under this, the authorities include citizens in the decision making process right from the zoning changes, the mine permit approval and in evaluating the environmental impact assessment reports. This allows the affected public an opportunity to influence the site location for the proposed mine. This approach has intensively been used in the United states, particularly in the state of Colorado where gypsum mining occurs using the same technology as the study area.

ii. Adapting risk analysis by taking into account environmental factors, engineering and land planning needs. Land use regulations are carefully applied at the time of mine selection and the local planning authorities determine the suitable land use both before and after mining. Environmental protection regulations related to traffic management, noise levels and aesthetic value disturbance are enforced.

iii. Maximizing efficiency through minimizing waste, improving mine design and management practices. This has been successfully applied in Canada, under the environmental mining council laws of British Colombia

iv. Substituting renewable for non renewable minerals and recycling

v. Returning the land to a desirable post mining form. This is achievable by use of performance bonds that guarantees the reclamation of the mined sites by giving the state authority to pursue reclamation costs from mining companies that fail to reclaim mined sites. The state also has the option of a reclamation bond, which is a financial warranty that equals the cost the state would incur to reclaim the site to a desirable state, should the mining operations fail to reclaim the site. This approach has successfully been employed in the state of Colorado in the United States of America (USDI, 2011a).

vi. Applying the precautionary principal, without unnecessarily relying on scientific evidence of destruction or environmental degradation. Australia has successfully applied the same through her mining industry, whenever threats to the environment or irreversible damage to the environment are noted (USDI, 2011a).

An equally influential area of policy is extractive agreements couched in the form of Impact and Benefit Agreements (IBAs). The IBAs are usually non disclosure contracts entered between the mining companies and the local area residents with little involvement of the government, in which the locals surrender their rights to the affected land in exchange economic and social benefits (Panagos and Grant, 2013). However, it is important to appreciate the fact that the IBAs work well in a situation where the local communities actually want the mineral extraction to take place. In many cases, local people do not want the mining projects to take place at all. The reliability of IBAs for managing mining area conflicts and uncertainties is therefore limited (Panagos and Grant, 2013).

These are meant to encourage investment in the extractive sector and guarantee reasonable government revenue from mining. They enable communities to obtain a greater share of resource rents through better informed negotiations with mining companies. Lahiri-Dutt (2011), claims that the relationship between mining companies and adjacent communities is generally mediated by agreements. The agreements need to include provisions for protecting the rights of the affected people and their representation in decision making organs related to mining (O'Faircheallaigh and Corbelt, 2005; Lange, 2011; Guerin, 2009; Okechukwu, 2013; Bradshaw and McElroy, 2014).

Literature has examples of cases where benefit agreements have been used to facilitate extractive industry regulation. In Canada, mining companies sign Impact and Benefit Agreements (IBAs) with the local land owners before mining projects commence. The IBAs vary in scope and substance but generally include contractual elements ranging from the sharing of profits, employment opportunities for the local Aboriginal residents and provisions relating to socio-cultural matters.

2.6 Theoretical Underpinnings

The natural resource sector is an important part of many African countries economies. If harnessed right, natural resources constitute enormous opportunities for development (Bond and Fajgenbaum, 2014). The impact of extractive industry on socio economic development of resource rich countries has been a subject of debate among policy planners and scholars alike (Ville and Wicken, 2013) within the context of the following theories.

2.6.1 The Resource Curse Theory

The resource curse concept was coined in mid 1990s in an effort to explain the perspective of an inverse relationship between resource abundance and socio economic growth in the affected countries. The resource curse, it was argued befalls a country when it continues to experience negative growth as a result of overdependence on mineral resource extraction and external market forces such as fluctuations in the price of primary commodities (Shoko and Mwita, 2015).

The curse has its roots in the abundance of natural resources that cause dysfunction in the country's economy, which eventually becomes difficult to manage, and results in resources being used inefficiently. The ensuing economic dysfunction yields to further decline in trade, increased revenue volatility and negative socio economic impacts (Arnonkitpanich, 2009; Nkongolo, 2013**).** The resource curse hypothesis proponents insist that the gains associated with resource abundance bring with them policy, social and economic challenges that lead to slower economic growth manifested through the following:

i. The Dutch disease, which refers to the de-industrialization of an economy as a result of the detection of a natural resource. This phenomena happened in Holland when the Country discovered and exploited oil from the North Sea but ended up with a strong

Dutch currency that made her exports uncompetitive and eventually caused a decline in the Dutch industrial sector;

ii. Rent seeking. As natural resources increase, the number of entrepreneurs engaged in rent seeking increases while that of entrepreneurs running productive firms decreases. Eventually, the drop in income as a result of this is higher than the increase from natural resources. The abundance of natural resources therefore leads to lower welfare (Ragna, 2002). The heavy dependence of natural resource tax revenues especially from multi-National companies in place of general taxation weakens the relationship between the government and its domestic tax constituency, thereby weakening national institutions;

iii. The state neglects of human capital development and fails to support the recruitment, support and investment in people through training, education, coaching, mentoring and internship of human resources;

iv. Decline in savings investment, as a result of overspending of resource incomes;

v. Income inequalities.

vi. Sluggishness in the face of plenty. With abundance of natural resources, striving to achieve the best in either public policy or private sector is muted by the easy wealth;

vii. Failure to establish or consolidate democracy.

The notion that natural resources oriented economies are bound to experience retarded development has however, been challenged by other scholars. The first challenge is based on the basic question of causality. Torvik (2009) argues that there is no evidence that resource abundance causes slow growth. The second is the identification of the dimensions in which resource rich *blessed* states differ from recourse rich *cursed* states. This became important with the realization that some resource rich countries experienced growth. Ville and Wicken (2013) argue that Australia and Norway have achieved modern levels of development as resource based economies, thus avoiding the resource curse through repeated diversification into new resource products and industries.

The third challenge on the resource curse theory is on policy implications. Torvik (2009) laments that if countries with natural recourses tend to follow a more inward-looking policy, and if such a policy reduces growth, it would be misleading to blame the bad growth on resource abundance. The problem is policy, not resources. The debate narrows down to the conclusion that the resource curse affects states that are highly dependent on a particular resource that is held in abundance at the expense of other economic sectors and a general absence of efficiency enhancing reforms, checks and balances in the constitution and enabling laws.

Kenya is not entirely dependent on minerals. The resource curse theory does not therefore provide a firm theoretical base for the current study. It is however possible that the enabling laws and policy do not provide sufficient checks and balances in the mining sector. The study relied on the resource curse theory only to the extent it provided light in the search of explanations on the intervening role of policy on the impacts of gypsum mining in Kajiado.

2.6.2 The Cost-Benefit Analysis Theory

The cost benefit analysis process is a project evaluation tool that involves the examination of decisions in terms of their costs and benefits (EU, 2014). It is a simple decision rule that consists of accepting only those undertakings that make a positive profit. In evaluating the contribution of a particular development project, planners are required to develop models that predict the total extent on the economy, of undertaking a particular project. This simply entails the comparison of the state of the economy with the project and without the project.

Mishan and Quah (2007) equated the relationship between a project and its impacts to the concept of policy, and argued that the cost benefit analysis depended on the ability of policy planners to make predictions and analyze impacts objectively. In reaction to policy, the cost benefit analysis theory rests on the premise that each production plan is compatible with at least one policy environment, and once the policy is specified, there is a unique production plan associated with each policy, which also reflects changes in social welfare. This attribute is useful in selecting welfare improving projects since only projects with positive impacts are acceptable.

The cost Benefit analysis tool has been widely used in valuation of environmental costs and benefits. It is also used to assess how much money people are willing to accept for an increased risk (EU, 2014). Individuals are observed for behaviour that is later used as a basis for valuing benefits. It is believed that some people accept work with an increased risk of injury or death while others are willing to spend resources to mitigate the risks. By attaching monetary value to both costs and benefits, it offers potential for comparing a wide range of programmes with both benefits and costs (UK, 2014, Kulman and Linderhof, 2014).

The current study could not adopt the Cost Benefit Analysis theory, safe for the procedures employed in project identification, impact analysis and the influence of policy on production plans adopted by mining companies. The scope of this study did not allow monetary valuation of the impacts, discounting and sensitivity analysis.

2.6.3 Sustainable Development Theory

Sustainable development has been defined differently by various scholars. To sustain means to maintain, keep in existence, keep going. This however, does not make sense to human development since society cannot be maintained in the same rate (Amonkitpanish, 2009). The human society is a complex and adaptive system embedded in the natural environment system, on which it depends for support. The human society and the environmental systems therefore co-evolve in a mutual interaction and the ability to evolve and change must be maintained if the systems are to remain viable and sustainable.

The most quoted definition, which leans more on economic aspects of development, equates sustainable development to development that meets the needs of the present generation without compromising the ability of the future generations to meet their own needs. A broader and more encompassing definition describes sustainable development as the kind of human activity that nourishes and perpetuates the historical fulfilment of the whole economy of life on earth (Ladd and Melaned, 2013). This necessitates taking into account of social sustainability, environmental sustainability and economic sustainability aspects of development since sustainable human societies will always have environmental, material, ecological, social, economic, legal, cultural, political and psychological dimensions that require attention (Werner *et al*, 2007).

The assertion by Ladd and Melaned (2013) is supported by Hopwood *et al* (2008) in describing sustainable development as development that maximizes the net benefits of economic development, subject to maintaining the services and quality of natural resources over time. They maintain that, for sustainable development to occur, local economies must, (i) utilise renewable resources at rates less than or equal to the natural rates of generation, (ii) generate wastes at rates less than or equal to the rates at which they could be absorbed by the assimilative capacity of the environment and; (iii) optimize the efficiency with which exhaustive resources are used, which is determined by among other things; the rate at which renewable resources can be substituted for exhaustible resources and by technological progress. In the context of extractive industries therefore, there is need to take care of the environmental costs associated with expenditure incurred by households and government in mitigating the effects of extraction on health and other forms of environmental damage.

This study adopted sustainable development as the underpinning theoretical principle upon which the study rests. It was chosen because it demonstrated appreciation of natural environmental limits, based on the understanding that as the human society evolve within the physical environment; development is constrained by the available space, pollutant absorption capacity, and capacity of soils, water bodies, atmosphere, soil fertility and climate (Ladd and Melaned, 2013). The assertion that sustainable development must adhere to natural limits provides a suitable foundation for assessing the sub systems pertaining to extractive industries on viability and support to the local socio-economic base. Aspects of the Cost Benefit theory that relate to environmental costs, hereby referred to as environmental impacts in relation to the benefits of extraction is also relevant and was incorporated to support the sustainable development theory. With the understanding that sustainable development is not possible in an environment of weak institutions (Torvik, 2009), qualities of the resource curse theory that relate to institutional management were also adopted.

2.7 Summary and Research Gap

Literature suggests that extractive industry could generate serious bio-physical and compromise socio-economic challenges. For instance, the cumulative effects of land dereliction and pollution loads on water resources are known to alter land use in the host communities (Ezeaku, 2012). Literature further confirmed that Mining contributed significantly to degradation of air quality through the deposition of particulate matter. Water quality depression with potential for generation of acid mine drainage (Kitetu, 1997; Dashwood, 2007; Gilbert, 2010; Bayram and Onsoy, 2014; Padmalal and Maya, 2014) was also reported.

In literature, there was however, no consensus on the nature and extent impacts specific to gypsum mining in Kenya since not much work had been done to assess the impacts. For instance, while one group of scholars maintained that gypsum mining negatively impacted on quality of water by causing a range of physical impacts (Tiwary, 2001; Liakopoalos *et al*, 2010), others found no relationship between gypsum mining and water quality (AlHarthi, 2001). Arguably, none of these studies provided a conclusive picture of the impacts of gypsum mining on the environment.

It is suggested that mining negatively impacts on fauna and flora and consequently disturbs the forest ecosystem around mining sites. As mining sites increase in size, they tend to eat into agricultural land thereby threatening production and livelihood systems (Gardiff and

Adriamanalina, 2007; Martinez *et al*, 2007). There was however limited cross sectional data on the impact of mining on fauna and flora in the Kenyan context. Little had been written about the changing livelihoods of households in gypsum mining neighborhoods in Kenya. The literature review certainly revealed knowledge gaps that needed to be addressed in order to make available detailed descriptions of effects of gypsum mining on livelihoods, landscape, water quality and particulate matter concentration.

2.8 Conceptual Framework

Grounded on the Sustainable Development theory and supported by aspects of the Cost Benefit Analysis and Resource Curse theories as discussed earlier, the conceptual framework attempts to elucidate the interactions between the independent and dependent variable. Dependent variables are defined as those variables which are measured or manipulated by the researcher to determine their relationship to an observed phenomenon, which constitutes the depended variable (Nyandemo, 2011). Independent variables on the other hand, are those that determine the phenomena we wish to explain (Gatara, 2010).

The study adopted gypsum mining activities as the independent variable and attempted to test their relationships and influence on dependent variables, represented by livelihood, landscape, water quality and particulate matter concentration. The independent variable activities such as overburden removal, preparation routes and auxiliary facilities, mining blasting and extraction and; initial processing and benefication are collectively referred to as mining operations and constitute the independent variable. The dependent variables on the other hand are those aspects the investigation that assume different scales depending on the intensity of mining operations.

These are represented by various parameters such as local procurement, infrastructure development, employment opportunities, tax revenues and land compensation payments. Parameters for water quality considered included PH, Total Hardness, Bacterial contamination and trace metal pollution. For landscape changes, the study focused on parameters such as destruction of habitats and biodiversity, land dereliction and land cover changes.

Air quality investigations revolved around air deposition (Pm $_{2.5}$) rates, respiratory effects and sound pollution. The study, in addition focused on the intervening influence of mining policy on the scales assumed by the dependent variables. A schematic presentation of the conceptual framework is presented in figure 6.

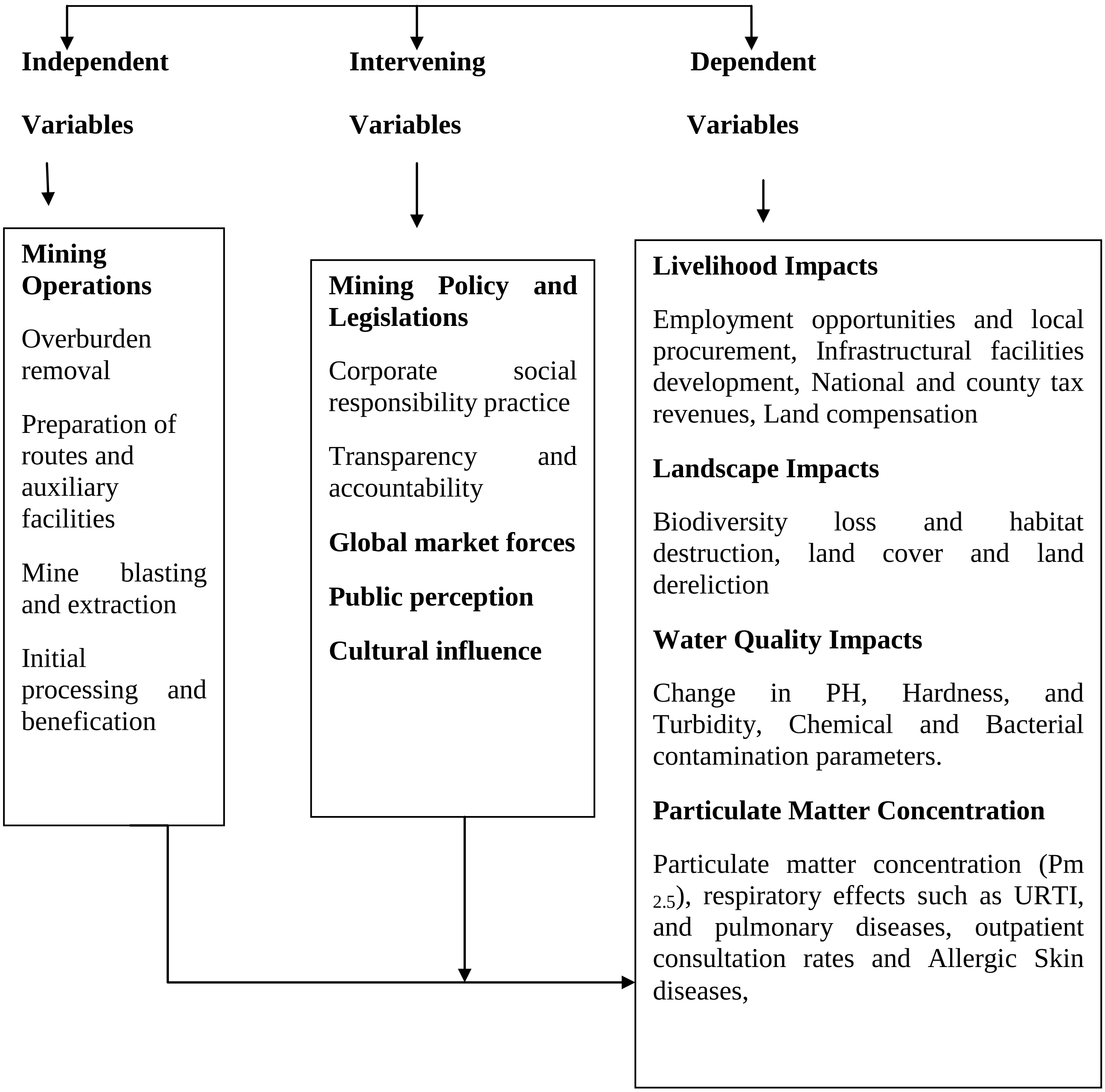

Figure 6: Conceptual Framework

CHAPTER THREE

3.0 METHODOLOGY AND MATERIALS

3.1 Introduction

The chapter deals with how and where the study was carried out. It covers research design, population, sample size and sampling procedure, data collection, data analysis and study assumptions.

3.1.1 Study Location

The study area was located in Kajiado County, Kajiado East Sub County. It covered Enkirigirri, Olturoto, Ilpolosat and Nkama locations. Enkirigirri, Olturoto and Ilpolosat locations are approximately 20 Km from the County Headquarters while Nkama location is nearly 50 Km from the Headquarters (Fig. 7). The study area is known for Gypsum extraction since the year 1968.

3.2 Study Design

Kothari and Garg (2014) define research design as the arrangement of conditions for the collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy and procedure. Good design provides a blueprint for the collection, measurement and analysis of data while minimizing bias and maximizing reliability (Burke and Onwuegbuzie, 2004). This study adopted the Mixed Method Research (MMR) design. MMR involves a systematic mixing of qualitative and quantitative data in a single investigation in order to allow more completeness and synergistic utilization of data than do separate qualitative and quantitative data collection and analysis. MMR also allows for validation of findings using both qualitative and quantitative sources and further provides an expanded understanding of the research problem (Buzeley, 2014).

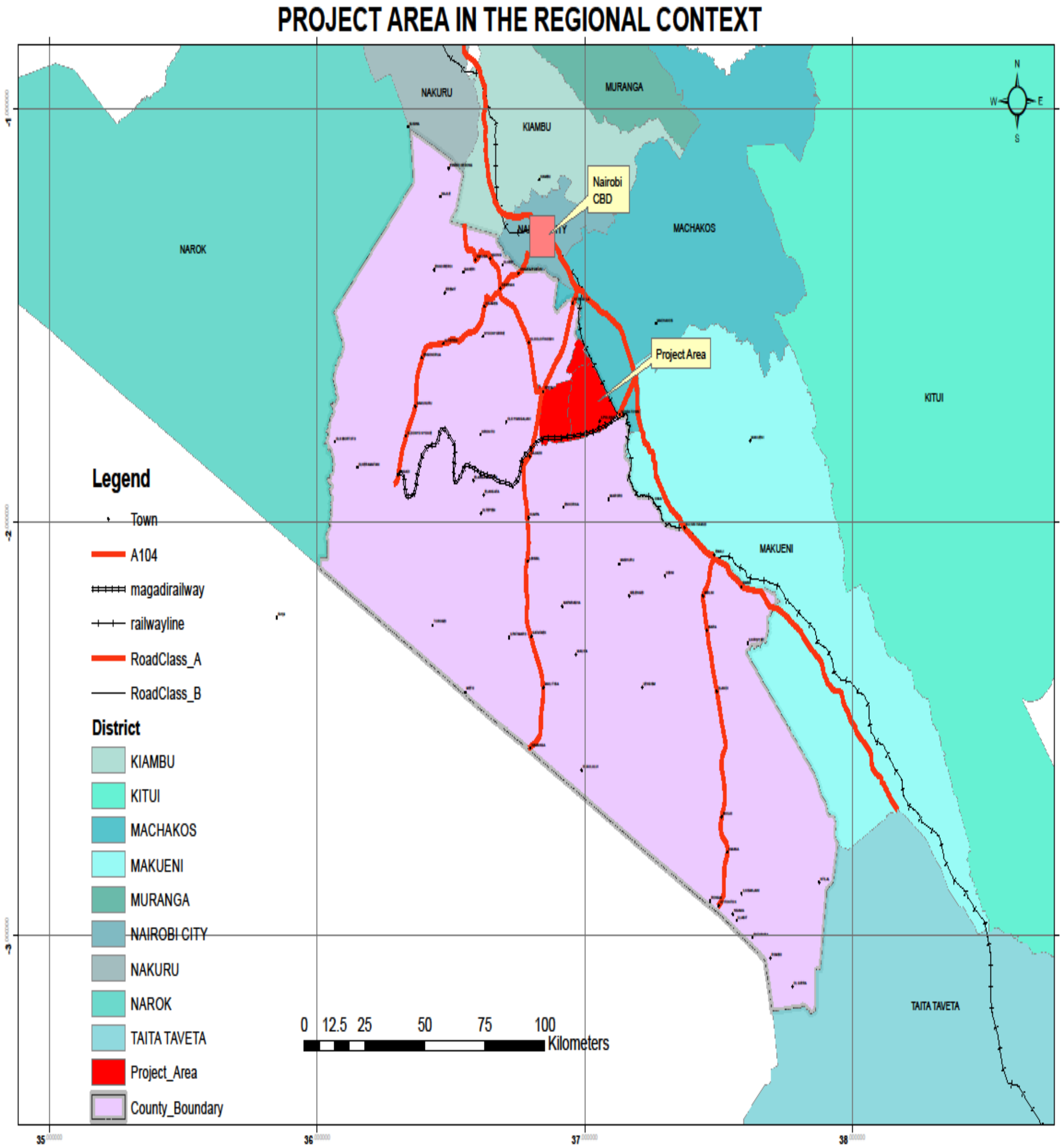

Figure 7: The Study area in Regional Context

3.2.1 Mixed Method Research Designs

MMR designs can be developed from two major types of mixed methods research, namely mixed model and mixed method. Mixed model mixes qualitative and quantitative approaches across the stages of the research while mixed method involves a qualitative phase and quantitative phase in an overall research study (Creswell, 2009). To construct a MMR depends on whether the researcher wants to exclusively employ qualitative or quantitative data and if the researcher intends to conduct the research phases concurrently or sequentially as explained below:

i) In sequential MMR, the phases of data collection and analysis for both qualitative and quantitative have to be integrated at some point in the study. For example, a researcher might choose to collect and analyse qualitative data so as to inform the collection and analysis of quantitative data. This is popularly known as sequential MMR, in which the two data sets may possibly be kept separate but connected in a sense that qualitative and quantitative research are connected between data analysis in the first phase of research and data collection of the second phase. The purpose for sequential data collection is to use quantitative data and results to interpret qualitative findings.

ii) Alternatively, the researcher could collect both data sets concurrently and integrate or merge the two data sets by transforming qualitative data into counts and comparing the same with descriptive quantitative data. If concurrent data collection and analysis of qualitative and quantitative data is adopted, the findings must be integrated at the discussion and conclusions stage.

iii) In yet another version of MMR, a researcher might choose not to connect nor integrate the data sets but simply embed one data set within a larger study where the embedded data set provides a supporting role in the study (Cathain *et al*, 2010).

According to Onwuegbuzie and Teddlie (2003), the rationale for the MMR is based 5 major considerations including:

i) Triangulation. This involves seeking convergence and corroboration of results from different methods and designs examining the same phenomenon
ii) Complementarily. This encompasses the seeking of elaboration of results or enhancement of results through illustration or clarification
iii) Initiation in the form of discoveries of paradoxes and contradictions that lead to the reframing of the research hypothesis
iv) Development. The investigator using MMR develops capacity to use the findings from one method to help inform the other method
v) Expansion. The investigator seeks to expand the depth of the research by using different methods for the various components of the investigation

This study adopted the concurrent triangulation strategy because it offered the advantage of collecting both data sets at the same time and allowed the researcher to gain different perspectives of data at different within the research process. The concurrent triangulation strategy allows data mixing at different stages including data collection, data analysis, conclusions or at all the three stages. In this study, mixing of qualitative and quantitative findings took place during discussion on findings and conclusions as suggested by Johnson (2014).

3.3 Data Collection Methods and Techniques

The study collected qualitative and quantitative data from both primary and secondary sources. Qualitative data was obtained from primary and secondary sources using various methods such as interviews, questionnaire study observation (Appendix II and III) informant discussions. The (Appendix IV) informant discussions targeted medical personnel heading the selected medical facilities, employees of mining companies and government departments at County level. Quantitative data was collected using a range of methods including sample analysis, satellite imagery analysis and outpatient data audits. This approach was adapted from Ahmad *et al* (2014) who in a study of the impacts of mining activities on various environmental attributes, obtained study data using both primary and secondary sources. In the Ahmad *et al* (2014) study, primary data was obtained through interviews, questionnaire study, sampling and experimentation. The methods used in data collection and analysis are summarised in Table 4.

Table 4: Data Collection and Analysis Methods

Objective	Data Collection Method	Data Analysis Method
To assess the impacts of gypsum mining on livelihoods in Kajiado County	Questionnaire study and key informant interviews for qualitative data	Correlation analysis, ANOVA, Cross tabulation, regression analysis
To investigate the impact of gypsum mining on landscape in Kajiado County	Satellite imagery, and Observation for quantitative data, Questionnaire study for qualitative data	Descriptive statistics on land cover, Cross tabulation, regression
To establish the impact of gypsum mining on water quality in Kajiado County	Questionnaire study for qualitative data, Outpatient consultation interviews, physical analysis for quantitative data	Descriptive statistics on water quality parameters, Regression and correlation for qualitative data
To examine the impact of gypsum mining on air quality in Kajiado County.	Questionnaire study for qualitative data, Outpatient consultation interviews, air sampling analysis for quantitative data	Descriptive statistics on Particulate matter readings and outpatient consultation rates, Regression and correlation for qualitative data

3.4 Study Population

Population refers to people or items with the characteristic one wishes to understand. This implies the entire group of individuals, objects or things that share common attributes or characteristics and may or may not be found within the same geographical location. The term population can also be used to refer to all items of any field of inquiry (Kothari and Garg, 2014). The population of interest to the study comprised of all households in Enkirigirri, Olturoto, Ilpolosat and Nkama locations which made up the gypsum mining area of Kajiado County. This study also included people working as miners in gypsum mining sites in the four locations while key informants such as government officials, medical personnel and managerial employees of mining companies were included. According to the 2009 census report, the four locations had a population of 1908 households. Household heads were included in the population of interest, and, for government officials, this study targeted heads of Government departments related to mining, environmental management, medical personnel, especially heads of facilities or health statistical units and administration officers. For mining company employees, the study targeted senior managers responsible for mine operations and corporate responsibilities.

3.4.1 Sample Size

Sample size is the number of respondents included in a survey. Noordzij *et al* (2010) define sample size as the number of experimental units included in a study. The size is restricted by cost, ethical and time considerations and determined by three factors: (i) the estimated preference of the variable of interest; in this case, awareness of physical and social economic impacts of gypsum mining in Kajiado County, (ii) the desired level of confidence and (iii) the acceptable margin of Error.

As recommended under MMR, parallel concurrent sampling was carried out to ensure separate qualitative and quantitative samples were drawn from the same population as suggested by Cathain *et al*, (2010). This facilitated the determination of specific qualitative and quantitative sample sizes. For qualitative data collection, the sample size was based on the number of households in the study area based on the 1999 census report. The 1999 census report indicated the number of households at 1908. The appropriate sample size was calculated using the following formula suggested by Nassiuma (2000); $n = \frac{NC^2}{C^2+(N-1)e^2}$

Where n= Sample size, N= Population, C= Coefficient of Variation, e = Standard error. Nassiuma (2000) advises that in most surveys, a coefficient of variation falling within the range of 21 % ≤ C ≤ 30% and the standard error in the range 2% ≤ e ≤ 5% is acceptable. The higher the coefficient of variation and standard error selected, the lower the variability in the sample. Since the population of interest (N) for this study was 1908 households, the sample was calculated as follows:

$$n = \frac{1908 \times 0.3^2}{0.3^2 + (1908 - 1)\ 0.03^2}$$

$$n = \frac{171.72}{1.8063}$$

n = 95

To obtain qualitative data based on Key informant interviews, the study recruited heads of government departments concerned with mining activities at the county level including the departments of Water, Range management, Education, Revenue collection, Physical planning and Environmental management. For the mining companies' staff, the research included the head of mine operations, the Community liaison officer and the environmental management officers. The study therefore included 17 interviews that targeted 4 medical personnel, 4 officials of the mining companies and 9 heads of government departments related to environmental management and revenue collection.

To obtain quantitative data on outpatient consultation rates the four medical facilities in the study area including the EAPC staff clinic, the Ilmukutani Health Centre, PCEA Health Centre and Isinya Health Center were included. The EAPC Staff clinic was chosen because it is located in the mine crushing site while PCEA is located about 2 Km outside the mining area. Ilmukutani is located 5 Km away while Isinya Health centre is located about 50 Km away from the Nkama mine crushing site. Two air sampling sites were selected, one each for the main mine crushing site and the village located next to the main mine crushing site at Nkama to enable an assessment of site to site variation of Pm 2.5 concentration and the health effects. For water quality assessment, borehole water was sampled from a borehole located about 5 Km from the mines while mine pond water was selected for sampling per location based on proximity to the mining sites

3.4.2 Sample Identification

Sample identification was done by proportional allocation. The 95 respondents were distributed proportionately among the 4 locations. According to the 2009 population census, Nkama and Olturoto Locations had 476 and 407 households respectively. Ilpolosat had 478 while Enkirigirri had 547 households. By proportional allocation, Nkama and Ilpolosat contribute 24 respondents each to the total sample size while Olturoto and Enkirigirri contribute 20 and 27 respectively. For key informant interviews, the research prioritized the heads of government and company departments included in the study population and in their absence, their deputies. Heads of EAPC clinic, PCEA health centre, Ilmukutani Health centre and Isinya Health Centre were included alongside the local administrators of the 4 locations of the study area. All heads of department related to environmental management were also targeted.

At the location level the population was further stratified to reflect the proportions of respondents working in the mines and those living in the neighboring villages, as determined by their respective contributions to the locational sample share. To distribute the proportion of respondents for villagers living near the mine, the researcher identified specific sites from where a left-hand random walk was taken to pick the desired sample size from household heads. To increase the chances of women participation, purposive random sampling was employed. The researcher attempted to sample female respondents from every other household in cases where the female respondents were not the house hold heads.

3.4.3 Data Collection Procedures

3.4.3.1 Reconnaissance Survey

The research benefited from a reconnaissance survey of the study area aimed at familiarizing with area and identifying all possible key informants. Using the Kenya Demographic and Health Survey (KDHS) data and the 1999 census report, the population was divided into 8 sub populations that were individually more homogenous than the total population, and then respondents were selected from each stratum to form a sample (Kafando *et al*, 2013).

3.4.3.2 Training of Research Assistants

Efficient data collection required well trained field assistants. This necessitated the recruitment and training of field assistants to assist the principal investigator in data collection. Three local field assistants were recruited, with preference being given to assistants with previous experience and knowledge of local language. The training on sample identification, propping and recording of response was done 3 days, after which the assistants were pilot tested to enhance their understanding of the study objectives and study instruments. This was anticipated to minimize bias and error during data collection.

3.4.3.3 Questionnaire Pre-testing

The study questionnaire was piloted after training of local field assistants, and the questionnaire thereafter amended accordingly. It was necessary to pilot test the study questionnaire as a way of assessing its suitability for the study and further confirm the reliability of the local assistants to ask the questions and record responses without much difficulty.

3.4.3.4 Respondent Invitations and sensitization

To facilitate data collection, the researcher sought the approval and support of the local administration and community leaders. Armed with the permit and authorization to collect data, the researcher visited the County Commissioner at Kajiado and sought his support, The County commissioner endorsed the researcher permit and requested the Sub County Commissioner and Locational Chiefs to inform the public about the pilot testing and data collection exercise. The investigator also prepared a short introductory letter concerning the study, which was circulated widely within the study area.

3.5 Sampling Frame

3.5.1 Secondary Data

Secondary quantitative data was obtained by reference to existing government documents such as public health records on outpatient consultation rates in the study area, aerial photographs and remote sensing imagery, which were used to reveal changes in landscape in the study area as proposed by Antwi (2009). Departmental reports of regulatory agencies were reviewed for evidence of cases of negative impacts in the past and the information obtained was used to corroborate the evidence adduced from the analysis of qualitative data.

3.5.2 Primary Data Collection

The collection of primary qualitative and quantitative data was carried out concurrently using a combination of methods including interviews, questionnaire study and sample analysis.

3.5.2.1 Interviews

These are structured face to face verbal communication between a researcher and the respondent. The researcher used an interview guide prepared for the purpose to collect qualitative data as suggested by Oluoch and Mwangi (2004). The incidence of different environmental impacts and the influence of national mining policy were assessed through interviews with key informants. The interviews were directed at technical experts in relevant government offices including Medical practitioners, environmental regulators and administrators. The key informants such as medical personnel were targeted in their capacities as experts, with a belief that they would be able to articulate the salient issues concerning mining in the study area and provide responses in areas that could not be measured by questionnaire study.

3.5.2.2 Questionnaire Study

A questionnaire is an orderly listing of questions that one would like to put to would-be respondents to solicit a particular type of information concerning variables of interest (Gatara, 2010). The researcher prepared and structures a questionnaire to meet data collection needs.

The current research adopted use of questionnaires because of their inherent advantages including the possibility of modification and adaptation during the research process (Kasomo, 2007; Kilonzo, 2014).

The prevalence of different environmental impacts was assessed through administration of questionnaires on sample of 95 local residents and mine workers, selected using simple random sampling and stratified random sampling. Questionnaires were used to obtain data from the villagers living near mining sites and respondents working in the mines. Residents were requested to share their experiences regarding mining and impacts related to mining prevalent in the study area.

3.5.2.3 Sample Analyzes

To obtain quantitative data, sample analyzes were taken on key impact areas including satellite imagery, air and water quality to assess the nature and extent of pollutants. This provided quantitative data on levels and types of pollutants related to gypsum mining in the study area which were later analyzed based on the WHO (2006) and NEMA standards and sensitivities as earlier suggested by Annegarn (2015).

3.6 Samples Collection

Samples collection for the bio-physical impacts analysis were designed in such a way that samples of the actual contaminant concentrations were collected accurately and consistently to reflect the concentrations of dust and water pollutants at the place and time of sampling. The number of samples collected included 25 water samples that were collected from three mine ponds and a borehole using the APHA protocol. Air sampling was done for 19 days spread over a six month period. Sampling data records were designed to include the date, time and location of sample collection.

3.6.1 Study Tools and Equipment

Quantitative data was collected using geo-physical measurements carried out as specified in the APHA protocol. Noise level was evaluated using CIRRUS Noise level meter Model CR: 832 C and particulate matter monitoring was conducted using a UCB particle monitor, version 8.0 (December 2010 model).

3.6.2 Water Quality Analysis

To quantify the effect of mine operations on water quality, surface water and groundwater investigations were carried out. Water sampling was carried out at selected sites within the study area. The sampling sites included mine pond water and borehole water which was used as control sample. The borehole water included in the study was located 5 Km outside the mining area in an agricultural farm. Water samplings were carried out from each site every month and samples taken to the Kenya Water Institute and the Department of Mines laboratories for analysis. The water quality analysis was based on the APHA protocol, 22nd edition that require water samples for drinking and waste water to be assessed for metal and other pollutant concentrations, focusing on indicators such as turbidity, electrical conductivity, PH, suspended sediment concentration and water hardness. The Chemical levels in sampled water were compared to WHO (2006) and NEMA water quality regulations standards to establish if the water was safe for domestic and drinking uses.

3.6.3 Air Quality Sampling and Analysis

To assess air quality impacts, Ambient Air Quality Monitors (AAQM) were placed at the mines at breathing level (1.5 – 3 m above ground). Suspended particulate matter (Pm2.5) was measured at the mine site and neighbouring village by running the air sampler in the study area for 24 hours every day for 19 days spread over a period of 6 months (Ahamad *et al*, 2014). The figures generated were compared with WHO (2005) and national standards recommended by the National Environment Management Authority (NEMA).

During this study, Particulate matter of mass concentration with aerodynamic diameter of less than 2.5 micrometers (Pm2.5) was assessed using the portable University of California Berkeley (UCB) air sampler, mounted on carefully selected sites at breathing height as recommended by Thurston *et al* (2011). The use of the UCB was adopted owing to support on efficacy of automatic samplers by Bada *et al* (2013) that produced consistent and reliable results. The monitor launch was preceded with a zeroing moment when the monitor was placed in a Ziploc bag for 30 minutes with minimum disturbance to ensure accurate readings. The logging value was set at 1 minute, so that the monitor recorded only one value per minute, for the 24 hour monitoring period.

The research also reviewed medical records related to outpatient consultation rates in medical facilities near the mining sites for respiratory and cardiovascular disorders. The need for respiratory and cardiovascular investigation was informed by evidence in literature (Andreas *et al* 2004) that exposure to Pm 2.5 had short term and long term health effects such as coughing, sneezing, runny nose, skin conditions and cardiovascular disorders. Andreas *et al* (2004) warn that increase in Pm 2.5 concentration often led to an increase in respiratory and cardiovascular admissions and outpatient consultation rates. It was therefore important to assess the impact of gypsum mining using similar parameters. The four medical facilities in the study area including Isinya Health Centre, the EAPC staff clinic, the PCEA and Ilmukutani Health Centres were incorporated.

3.6.4 Noise Level Analysis

The study attempted to measure noise from vehicles, bulldozers, excavators and noise from the crushing plant. The noise levels were measured at the mining site during working hours, with a 5 minute interval between the readings as advised by Ahamad *et al* (2014). The sampling sites included the mine site loading and offloading zones, the mine crushing site and the conveyor belt area. These were selected to give an indication of the noise levels coming from the transportation vehicles and mine crushing plant. For safety reasons, the readings were taken at a radius of 5 Meters from the subject noise generators such as haulage vehicles, conveyor belt and crushing plant. The readings were analyzed to determine the minimum, maximum, average noise levels which were ultimately compared with the standards prescribed by NEMA.

3.7 Instrument Validation

According to Streubert and Carpenter (2011), validity refers to whether the findings of a study are true and certain. The findings are true in the sense that they accurately reflect the situation, and certain in the sense that they are supported by the evidence. Nyandemo (2011) affirms this assertion by defining validity as the representation of the results internally and externally.

To ensure face validity, items of the questionnaire were constructed with consideration of the requirement of each objective and the questionnaire subjected to peer and expert review. After the actual survey, the questionnaires were subjected to a careful data cleaning process that included identifying incorrect entries and answers, missing frequencies and errors due to entry.

3.7.1 Reliability

Validity of instruments also depends on reliability of the same. Mugenda and Mugenda (2003) define reliability as the measure of the degree to which instruments yield consistent results or data after repeated trials. According to Robson (2002), threats to reliability may be as a result of participant error, observer error and instrument error. To ensure reliability in the current study, the study employed the test and re- test method of estimating reliability. Two sets of questionnaires were administered to 5 respondents in a space of seven days and the relationship between scores of the same administrations estimated using cronbach's alpha. Cronbach's alpha is an index of reliability associated with the variation accounted for by the true score of the underlying construct. It ranges from 0 to 1 and; the higher the score the more reliable the generated score is. Tavakol and Dennick (2011) have indicated 0.7 to be an acceptable reliability coefficient but lower thresholds are sometimes used in literature (Jusper, 2010). The current study had a cronbach's coefficient of 0.714 which was considered acceptable.

3.8 Data Analysis Methods

3.8.1 Qualitative Data Analysis Methods

The questionnaires used in qualitative data collection were checked for data inconsistencies and coded to enable the transformation of text data to numerical for ease of analysis using the SPSS software. The questionnaires were analysed using descriptive and inferential statistics such as ANOVA, Correlation, and Regression and cross tabulation. The Tests of association were used for categorical data whereas correlation analysis was used for describing relationships between continuous variables. Initial exploratory analysis using a scatter plot were undertaken for continuous data variables to see the kind of relationships that existed among them before detailed correlation analysis were undertaken.

For the purpose of testing for relationships between variables in the livelihood impacts (such as local employment, procurement), tests of association and correlation analysis were used, while for the analysis of association between and among categorical data (such as the relationship between schooling levels and contentment with the impacts of gypsum mining) the Chi-square test of association was used. Frequency counts for each observation and their respective percentage observations were used to identify the variables used in the association and to summarize each with their applicable descriptive statistics. Awinda and Kitetu (2012) used similar analysis techniques to assess the impacts of irrigational water use by small holder farmers in Gem Rae irrigation scheme, Kenya; and presented the study findings in frequencies (Awinda and Kitetu, 2012)

For tests of association, the study assumed the data to follow a chi-square probability distribution and for which the Pearson's chi-square test was used for the various categorical variables. In particular, this test was used to determine whether respiratory effects and working in the gypsum mines (as determined by the distance to the mine crushing site) occur together, which may indicate a common cause, or whether they were independent, that is, that their appearance in the sample respondents may be a matter of chance.

3.8.2. Quantitative Data Analysis

Quantitative data in particular data for the values obtained from measuring sample results for noise, water quality, and air quality, a normal probability distribution was assumed and hypothesis tests was calculated based on two-tailed tests. P-values were calculated from the sample and these were compared with the alpha levels. In correlation analysis, the data was continuous so that each variable was summarized with a measure of centrality and a measure of dispersion, such as the mean and standard deviation. These descriptive statistics were presented and used for primary comparisons. The correlation coefficient that was used was the Pearson's product-moment correlation coefficient which assessed the relationship between two approximately normally distributed continuous variables. A correlation matrix was generated and significant correlations flagged at the 0.05 level. The assumptions in this study are that data points from each study participant, when considered together, are more or less normally distributed.

The water specimen samples were analyzed using the APHA protocol (APHA, 99 22^{nd} edition) and results presented in descriptive and inferential statistics including frequencies and percentages, mean, median, minimum and maximum measurements of various parameters. The results were assessed for severity in relation to the NEMA and WHO standards. Specifically, the results for water quality, noise pollution level, and air quality were used to assess equivalence at baseline with WHO (2006) set standards. Horizontal and site to site variations were tested to see if they were statistically significant. The alpha level was set at 0.05 and compared with the P-value in determining whether the results obtained from the study area were statistically significant or not.

3.9 Ethical Considerations

The central aim of ethical considerations in research is to ensure that participants in research are protected from harm that might result from their involvement in the research. Ethics also promote the aims of research such as the contribution to knowledge, truth and avoidance of error. In the current research, the investigator sought approval to conduct the research from the National Commission for Science Innovation and Technology (NCSIT) in keeping with the requirements of the laws of Kenya. During the survey, participants were completely briefed on the nature and purpose of study while inappropriate inducements to participate in the study were avoided. The study attempted to achieve voluntary participation, informed consent, confidentiality and anonymity of respondents.

3.10 Study Assumptions

This study is premised on the following assumptions:

i) That the respondents included in the study will answer the questions in an honest and open manner

ii) That the participant recruitment criteria is suitable and therefore, assures that the participants have all similarly experienced the mining impacts

iii) That participant, especially key informants have a sincere interest in participating in the study and do not have any other motive in the assessment such as obtaining higher public rating

iv) That the County residents who make a living from gypsum mining invest the benefits to improve their livelihoods

v) That the County Government and National institutions responsible for mining provide an enabling policy environment to facilitate widespread multiplier effects of infrastructure development in the mining areas

CHAPTER FOUR

4.0 RESULTS ON DATA ANALYSIS, INTERPRETATION AND DISCUSSION

4.1 Introduction

This chapter presents data analysis, study findings and discussion. This study was conducted with the main objective of assessing environmental impacts of extractive industries, with particular emphasis on gypsum mining in Kajiado County. Qualitative and quantitative data was collected using questionnaires, interview schedules, administrative data reviews and sample analysis. In testing the study hypotheses, measures of central tendency and dispersion were used. The information collected and analyzed included general demographics, impacts of gypsum mining on livelihoods, landscape, water quality and air quality.

Assorted methods were employed to analyze data, with the qualitative data being coded, ranked and arranged in broad themes, to enable analysis by quantitative techniques. Quantitative data was analyzed using SPSS data analysis techniques to explain descriptive and inferential statistics while qualitative data was arranged per specific themes. The analysis, interpretation and discussion of the findings were done according to the themes of the study objectives. The chapter begins with presentation of qualitative data, specifically on questionnaire study rate of return and the demographic uniqueness of the respondents. The results of the correlations and the regression analysis are also presented. An analysis of the quantitative data is also presented before the two data sets are merged under the discussion and conclusions section of the chapter.

4.2 Qualitative Data Demographics

4.2.1 Response Rates

The response rates of questionnaires for the mine workers and villagers are presented in Table 5. The total number of questionnaires distributed to the mine workers and villagers were 22 and 73, respectively. A total of 22 and 73 questionnaires were returned and usable, representing 100% for the mine workers and villagers, respectively. A combined rate of return of 100% was obtained from all the questionnaires. This indicates a reasonable representation of the sample and of the entire population. According to Mugenda and Mugenda (2003), a response rate of 50% is adequate, while 60% is considered good and 70% and above is regarded as excellent. The current study response rate of 100% was therefore excellent and acceptable.

Table 5: Distribution and Rates of Questionnaire Return

Respondents	No. of Distributed Questionnaires	Returned No. of questionnaires	%ge Rate
Mine workers	22	22	100%
Villagers	73	73	100%
Total	**95**	**95**	**100%**

Source: Research findings 2016

From Table 5, the results indicate that the research obtained high questionnaire response rate. This was attributed to the methods used in data collection. Since the research was conducted in a rural pastoralist setting where rates of literacy are low, the study questionnaire was administered by the researcher and three research assistants. This helped to obtain immediate response and collection of the study questionnaire. To present sample characteristics, frequency distributions were used to demonstrate variations of respondents based on gender, marital status, education levels, work place designation, and average years worked and average hours worked in the mines per week. Frequencies and Percentages were used to demonstrate the characteristics of the respondents.

4.2.2 Demographic Features.

Demographic information, also known as research participant characteristics, provides valuable data concerning research participants for determining whether the respondents are a representative sample of the target population for generalization purposes. Demographics also help create a larger picture about each respondent and the household in which they live. In addition, demographic information describes some of the outcomes that are a basis for analysis in other sections of this study (Gjonca and Calderwood, 2004). Demographic information also performs a moderating function on dependent variables. In this study, demographic characteristics analyzed were either categorical or continuous. Categorical data included gender, education levels and designation while continuous data included the years and hours worked.

Table 6: Respondents Gender Distribution

Gender of the respondents	Frequency	Percent	Valid Percent	Cumulative Percent
Male	56	58.9	58.9	58.9
Female	39	41.1	41.1	100.0
Total	**95**	**100.0**	**100.0**	

Source: Research Data, 2016

Understanding gender perspectives in the current study was important in interpreting the results. Zelezny *et al* (2000) inform that there are gender based differences in how resources are used and how environmental problems are perceived within a community because women tend to be more environmentally concerned than men. Table 6 indicates that male participants comprised 59% while the female participants comprised 41% of the study respondents. Among respondents who worked in the mining sites, female mine workers comprised 32% while male mine workers made up 68%. For respondents in the villagers living near mining site category, 56% were male and 43% female.

This implies that there were more male respondents for the study than the females. This is consistent with other regarding the participation of women in studies. One such study by Langowitz and Minniti (2007) where stratified a representative sample of 2000 individuals per country in 17 countries, found out that the level of female involvement in mining activities tended to be significantly lower than that of men (Langowitz and Minniti, 2007).

Table 7: Marital Status Distribution of Respondents

Marital Status	Frequency	Percent	Valid Percent	Cumulative Percent
Single	11	11.6	11.6	11.6
Married	60	63.2	63.2	74.7
Separated/Divorced	1	1.1	1.1	75.8
Widowed	23	24.2	24.2	100.0
Total	**95**	**100.0**	**100.0**	

Source: Research Data, 2016

Table 7 shows that married respondents dominated the study with 60 (63%). The widowed respondents followed with 23 (24%), the singles with 11 (12%) and separated or divorced 1 (1%). The findings are consistent with Maliganya and Renatus (2013) who in the study of large scale mining activities in Tanzania observed that majority of those engaged in mining activities were married and only 5% of the respondents were divorced. Maliganya and Renatus (2013) ascribed this to the fact that villagers in rural communities valued marriage because of the social capital opportunities marriage provided.

Table 8: Respondent Educational Levels

Education Levels	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
No formal education	30	31.6	31.6	31.6
Primary Education	32	33.7	33.7	65.3
Secondary school(not completed)	10	10.5	10.5	75.8
Secondary school(completed)	15	15.8	15.8	91.6
Tertiary or other College	6	6.3	6.3	97.9
University	2	2.1	2.1	100.0
Total	**73**	**100.0**	**100.0**	

Source: Research Data, 2016

From Table 8 on education levels, the study established that respondents with no formal education constituted 30 (32%), those with primary education 32 (34%), those with Secondary education though not completed were 10 (11%), secondary education and completed 15 (16%), tertiary or other College were 6 (6%) while only 2 (2%) had university education. This indicates that majority of the respondents (75.8%) had basic level of education and only 8% had obtained college or university education. Apparently, those with higher levels of education engaged in activities outside the extractive industry. Education levels of respondents were critical to this study because of apparent influence on responses. Nyamu (2014), studied factors influencing the adoption of Information Communication Technology (ICT) among small enterprises in Nairobi and came to the assertion that the academic qualifications of the respondents facilitated their ability to correctly offer relevant information regarding the matter under investigation.

Table 9: Respondent Employment Categories

Main occupation	Frequency	Percent	Valid Percent	Cumulative Percent
Unemployed	25	26.3	26.3	26.3
Self-employed	38	40.0	40.0	66.3
Government employee	3	3.0	3.0	69.3
Casual labourer(not in mines)	8	8.4	8.4	77.7
Casual labourer(mining & loading)	16	16.8	16.8	94.5
Supervisor/Managerial	1	1.1	1.1	95.6
Machine Operator	1	1.1	1.1	96.7
Mechanic	1	1.1	1.1	97.8
Watchman	1	1.1	1.1	98.9
Lab Assistant	1	1.1	1.1	100.0
Total	**95**	**100.0**	**100.0**	

Source: Research findings, 2016

The results from Table 9 on occupation of the respondents indicates that the unemployed were 25 (26%) while 38 (40%) were engaged in self-employment. Government employees consisted of 3 (3%), casual labourers not engaged in the mines make up 8 (8%) while those casual labourer in mining & loading make up 16 (17%). The supervisor/managers (1), machine operators (1), mechanic (1), lab assistant (1) and watchman (1) represented 1% of the study respectively. The results agree with Maliganya and Renatus (2013) who in a similar study reported that the most prevalent modes of employment in the study area were livestock farming, petty trade and public service, with majority of those involved in petty trade being women.

Research has demonstrated the value of occupation as a driver of environmental attitudes (Baptiste and Nordenstam, 2009). Rural community members engaged in farming and pastoralism tend to have the highest levels of environmental concerns while casual labourers and semi skilled villagers who lack personal resources for the development of the environment have low levels of concern. Those that directly engage in extractive industry activities also have high levels of concern for the safety of the environment (Baptiste and Nordenstam, 2009).

Table 10: Distance to Mines

Distance	Frequency	Percent
1Km to 2km	27	37.0
2km to 3km	19	26.0
4km to 5km	18	24.6
6km to 7km	6	8.2
8km to 9km	1	1.4
10km to 11km	2	2.7
Total	**73**	**100.0**

Source: Research Data, 2016

Table 10 demonstrates how far the mines are located in relation to the villagers. The findings revealed that majority 27 (37%) of the respondents who lived in the villages near the mining sites, were within a distance of 1 Km to 2Km from the mine sites. Those in the 2 to 3km category were 19 (26%), 4 to 5km 18 (24.6%), 6 to 7km 6 (8.2%), 8 to 9km 1 (1.4%) while those in the 10 to 11km represent 2 (2.7%). Research on proximity based attitudes towards natural resource extraction has proved that villagers who resided close to environmental areas had higher levels of environmental beliefs, concerns and therefore, greater support for policies that support and protect the subject resources than those villagers residing further away from the resources (Baptiste and Nordenstam, 2009).

Table 11: Average Duration (Hours) Worked at the Mines

HOURS	Frequency	Percent
21hrs to 40hrs	5	22.7
41hrs to 60hrs	17	77.3
Total	**22**	**100.0**

Source: Research Data, 2016

Table 11 shows the average number of hours worked by respondents in the mines. Mine workers who worked for duration of between 21 to 40 hours was indicated by 5 (22.7%) of the mine workers while 41 to 60 hrs was indicated by 17 (77.3%). Majority of mine workers therefore, worked between 41 to 60 hrs per week.

Table 12: Number of Years Worked at the Mines

Year	Frequency	Percent
1yr to 5yrs	6	27.3
6yrs to 10yrs	10	45.4
11yrs to 15yrs	6	27.3
Total	**22**	**100.0**

Source: Research Data, 2016

As indicated in Table 12, the mine workers with the most experience and therefore most exposed to the impacts of gypsum mining comprised of those who had served for 6 to 10 years 10 (45.4 %) while the 1 to 5 years and 11 to 15 years categories had an equal 6 (27.3%) representation. This shows that a majority of the mine workers was in the experienced category, from 6 to 10 years and with time moved to other income generating activities since a decline is shown to emanate as years progressed. The length of time worked in the mines is used as an indicator of risk of exposure (Table 13). The study assumed individuals or groups to be at risk of exposure because they are exposed to higher concentrations of factors of susceptibility such as age, pre-existing medical conditions, gender and environmental factors. It was considered important to understand the levels of exposure and therefore risk because of the need to take into account such information in assessing and managing the air quality impacts.

Table 13: Average Number of Workers per Mine

Employees	Frequency	Percent
1 to 50 employees	5	22.7
51 to 100 employees	4	18.2
101 to 150 employees	2	9.1
151 to 200 employees	11	50
Total	**22**	**100.0**

Source: Research Data, 2016

Results in Table 13 show the average numbers of employees at a given mine when operating at full capacity. The majority of the respondents indicated at full capacity with 151 to 200 employees representing 11 (50%), 101 to 150 employees representing 2 (9.2%), 51 to 100 employees representing 4 (18.2%) and 1 to 50 employees representing 5 (22.7%).

4.3: Study Findings on Environmental Impacts

The findings of the study are discussed per objectives, the relevant hypothesis and responses obtained from respondents.

4.3.1 Impact of Gypsum Mining on Livelihoods.

In the first objective, the study sought to assess the impact of gypsum mining on livelihoods of respondents in Kajiado County. The qualitative data investigation used questionnaire and interviews to collect perceptions of the respondents. This was achieved by asking the respondents to react to questions and statements structured in a Likert format to describe their livelihood conditions in relation to gypsum mining. The researcher prepared a Likert scale and computed a total score for each respondent. These together with other items were each rated on a 5-point Likert scale ranging from: 1 = not important (NI) to 5 = very important (VI). The results are summarized in Table 14.

Table 14: Perceived Impacts of Gypsum Mining on Livelihoods

Importance of gypsum mining	**NI Freq (%)**	**MI Freq (%)**	**FI Freq (%)**	**I Freq (%)**	**VI Freq (%)**	χ^2	**p-value**
Physical Infra. Devt.	6(6.3)	19(20)	25(26.3)	26(27.4)	19(20)	13.368	.010
Social Infra. Devt.	11(11.6)	17(17.9)	27(28.4)	18(18.9)	22(23.2)	7.474	.113
Land compensation	45(47.4)	6(6.3)	12(12.6)	11(11.6)	18(18.9)	52.022	.000
Educational bursaries	20(21.1)	31(32.6)	14(14.7)	10(10.5)	20(21.1)	13.263	.010
County revenues	3(3.2)	13(13.7)	16(16.8)	31(32.6)	32(33.7)	32.316	.000
Cultural values	34(35.8)	25(26.3)	15(15.8)	15(15.8)	6(6.3)	24.316	.000
Communal relations	13(13.7)	27(28.4)	34(35.8)	15(15.8)	6(6.3)	26.842	.000
Dusty pasture	43(45.3)	9(9.5)	17(17.9)	3(3.2)	22(23.2)	50.225	.000
Local procurement	9(9.5)	61(64.2)	16(16.8)	8(8.4)	1(1.1)	122.000	.000
Local Employment	21(22.1)	69(72.6)	2(2.1)	2(2.1)	1(1.1)	179.263	.000
Local trade	8(8)	6(6.3)	27(28)	14(14)	40(42)	43.158	8(8)

The results in Table 14 demonstrate that the respondents ranked very important (χ^2 =43, P ≤ 0.001) that the extractive industry had supported local trade opportunities thereby providing county residents with occasion to acquire financial capital and secure their livelihoods. This is consistent with Amankwah (2013 where in a study of the impact of illegal mining on water for domestic and irrigation purposes, came to the conclusion that mining provided opportunities for miners and their families to make a living out of mining activities and had the potential to improve livelihoods and the standards of living.

Other respondents ranked important (χ^2 =13, P $\leq$ 0.010) that mining had supported physical infrastructure (such as roads). Infrastructure development was an important aspect of physical capital which had encouraged secondary economic activities in the study area, as previously outlined by Adjei (2007). Mining had led to the development of social infrastructure such as schools (Fig. 8), hospitals and water projects, which contributed to the enhancement of human capital. These were ranked fairly important (χ^2=7, P $\leq$ 0.113). This was acknowledged during key informant discussions where it was revealed that the mining company spent an average of 1 million shillings annually on educational scholarships for needy pupils, employed teachers and constructed classrooms. The mining company developed and operated six community water supply boreholes and maintained the roads leading to the borehole sites.

The findings show that the respondents least valued benefits from compensation for land acquired by mining business ranking not important (χ^2 =52, P$\leq$0.001), implying that the land compensation was considered insufficient. Indeed, one land owner had resorted to levying a fee on all vehicles using a section of the road that traversed his private land located near the Kibini mine. To enforce compliance, the land owner had owner employed local youth to throw stones at vehicles whose drivers were not willing to pay the illegal fees.

Figure 8: Tuition Block at Elerai near Kibini Mine

The opportunities for formal education and literacy programs for community (provision of scholarships/bursaries) had been provided ranked minor important (χ^2 =13, P $\leq$ 0.001). This indicates that the gypsum mining activities had not contributed to the human capital development in the study area and did not therefore support the local community in taking up non natural resources based livelihood opportunities. Respondents rated mining contribution to the County revenue in form of direct payments, royalty payments and community trust funds as important (χ^2 = 32, P $\leq$ 0.001). This is consistent with a report by Galay (2008) who also came to the conclusion that gypsum mining contributed to revenue generation through income tax, earnings from royalties, surface rent and supported foreign exchange earnings.

On the aspect of mining supporting community cultural values and heritage activities, the respondents ranked not important (χ^2 =24, P $\leq$ 0.001), a connotation that the gypsum mining activities did not contribute to building of social capital in the host community. The findings however, show that respondents rated income from local procurement opportunities for fellow members of the community as very important (χ^2 = 122, P $\leq$ 0.001). This was seen as very important because it enabled households to improve resiliency against unexpected livelihood losses due to external shocks such as drought. This is in agreement with Zarsky and Stanley (2013) who in the study of whether extractive industries brought sustainable development in Guatemala observed that the earnings from wages and procurement constituted important sources of income for the local population.

Zarsky and Stanley (2013) claimed that the payments made to government in form of royalties and taxes were necessary as compensation for the loss of non-renewable resources extraction and for the contamination of the environment. As long as the payments were shared with municipal governments and local communities, they contributed to sustainable development of the mine regions. Zarsky and Stanley (2013) came to the conclusion that wages and procurement services involving purchase of materials, equipment and supplies constituted a potent way of injecting income into the local economy and build local linkages with other sectors of the economy. These also were seen as a mechanism of sharing revenues from mining operations.

However, the respondents indicated little importance to the dust effects on crop and pasture (χ^2 = 50, P $\leq$ 0.001). The finding on the effect of dust on pasture is indeed inconsistent with Galay (2008), who used a similar study methodology and came to the finding that dust was a major cause of concern to livestock farmers living near the Khothagpa mine. He observed that respondents suspected that the dust generated by the gypsum mine operations such as blasting, loading and haulage was transported by air and settled on fodder crops and pasture. This made the pasture and fodder crops unpalatable for their animals besides being a hindrance to horticultural development. The difference in the responses regarding the contribution of dust to study area livelihoods could be attributed to low awareness levels in terms of the relationship between dusty pastures and low milk production and subsequently low injection of earnings to the local pastoral economy.

Further, the verdict that mining activity had fairly facilitated linkages between the local community, government and other sectors at the county and national level (χ^2 =2 6, P $\leq$ 0.001) was consistent with earlier claims by Elizondo (2015), who insisted that the contribution of the gypsum mining industry to livelihood development could be measured by the extent of its integration in the local economy vide forward and backward linkages. In the backward linkages, the gypsum mining industry should be able to demonstrate the scale at which it acquires materials and inputs from the local production sector, while in the forward linkages the mining industry must be assessed on the extent to which its products serve as inputs of local industries (Elizondo, 2015)

On the other hand, the respondents positively indicated that employment opportunities for the local community (χ^2 = 179, P ≤ 0.001) was very important, same with the impact of mining on business support infrastructure development (χ^2 = 82, P ≤ 0.001). These means that employment was an important element in the mining areas in Kajiado County since it had the strongest association to the significance of gypsum mining while input to development of social infrastructure such as schools and hospitals indicated the least association to the significance. Key informant interviews revealed that local villagers comprised 60% of the gypsum mining workforce, distributed in all cadres. The value and ranking of gypsum mining in employment generation finding is consistent with literature. Galay (2008) investigated the socio-economic impacts of gypsum mining and recognized both formal and informal employment positions as the greatest needs of communities living near mining sites. The people employed in the mines as drivers, machine operators and servicemen formed majorly of the employees recruited from community members. Employment creation had a multiplier effect on community welfare since the mine employees were also the main customers of local business enterprises (Galay, 2008).

From the findings, there is high prospect that mining was an important contributor to local development and other aspects in the social economic activities of Kajiado County residents. Similar results were previously obtained by Hilson *et al* (2013) who observed that the extraction of Gold in hitherto impoverished Northern Ghana injected considerable wealth into the study area households and helped to secure food security and alleviate financial hardships. The earnings from the Artisanal mining led to the expansion of the local economy, curbed migration and significantly supported local enterprise development.

4.3.2: Impact of Gypsum Mining on Landscape

In the second objective, the study sought to investigate the impact of gypsum mining on the landscape in Kajiado County. Qualitative data was collected using key informant discussions and a questionnaire study. In analyzing the questionnaire, the researcher prepared a Likert scale and computed a total score for each respondent. These together with other items were rated on a 5-point Likert scale ranging from: 1 = very positive (VP) to 5 = very negative (VN). The questionnaire study findings were triangulated by observation and interview. The results are summarised in Table 15

Table 15: Perceived Impacts of Gypsum Mining on Landscape

Impact areas	NI Freq (%)	MI Freq (%)	FI Freq (%)	I Freq (%)	VI Freq (%)	χ^2	p-value
Overall land cover/use	30(31.6)	60(63.2)	3(3.2)	2(2.1)	-	95.021	.000
On vegetation/Habitat	3 (3.2)	4(4.2)	2(2.1)	8(8.4)	78(82.1)	230.105	.000
Physical appearance	3(3.2)	2 (2.1)	3(3.2)	7(7.4)	79 (83.2)	241.745	.000
Accumulation of dust	43(45.3)	9(9.5)	17(17.9)	3(3.2)	22(23.2)	50.225	.000
Environmental management funds	44(46.3)	27(28.4)	16(16.8)	44.2)	4(4.2)	60.421	.000

Source: Research data, 2015

The results in Table 15 suggest that the respondents indicated as minor importance (χ^2 = 95 P ≤ 0.001) to the overall contribution of gypsum mining to the county landscape. The assistance given by gypsum mining enterprises to environmental management programmes was indicated as not important (χ^2 = 60, P ≤ 0.001). The impact of gypsum mining on landscape by destruction of vegetation and habitats was indicated as very important issue of concern (χ^2 = 230, P $\leq$ 0.001). The contribution of gypsum mining to the general physical appearance of land in the study area was also indicated as important (χ^2 = 241, P $\leq$ 0.001), and therefore, had the strongest association to the significance of gypsum mining while the accumulation of dust or crops and pasture that degraded the aesthetic features of the landscape had the least association (χ^2 = 50, P $\leq$ 0.001).

The results are consistent with literature on the impact of Gypsum mining on landscape, particularly in relation to open cast mining. Different scholars observed that open cast mining resulted in huge landscape scars, which further reduced the land under traditional land uses (Al-Harthi, 2001; Herzog *et al*, 2001). In the study of the environmental impacts of irrigation water use by small holder farmers in Gem Rae irrigation scheme, Awinda and Kitetu established that loss of biodiversity was statistically significant (Awinda and Kitetu, 2012).

The findings also agree with those of a study carried out by Mergulhao *et al* (2010) in a semi arid environment in Brazil, using similar methodology. Mergulhao *et al* (2010) observed that plant diversity was lower in the impacted areas, with a difference of up to 69% in comparison with native areas. They established that gypsum mining reduced plant diversity in the study area as a consequence of intensive soil disturbance. They established that some plants that depended on soil for mycorrhization were reduced or totally eliminated. The gypsum tailings areas were the most affected as a result of the waste rock and overburden deposits that covered the native plants (Mergulhao *et al* 2010). This position is equally supported by Lahiri-Dutt *et al,* (2014) who established that as much as mining provided villagers in the mining area with opportunities to improve their livelihoods, it also degraded the natural environment.

4.3.2.1 Quantitative Data on Landscape Impacts

In order to inspect the physical extent of the impacts of mining activities on landscape over time, the research analyzed satellite imagery. Satellite imagery data are valuable tools for determining temporally changes like forest clearing as well as gradual long term changes like precipitation decline. Setiawan and Yoshino (2012), believe that simultaneous analysis on land surface attributes by remote sensing is the best way to examine environmental changes, as long as the change detection methods allow identifying a change within long term data sets and seasonal variations. The basic premise in using remote sensing data for change detection is that changes in land cover result in radiance values, large enough in respect to radiance changes caused by other factors. Analysis of land cover and land use changes using satellite imagery is therefore efficient in natural resource assessment and monitoring (Musa and Jiya, 2011).

Forkuo and Frimpong (2012) define change detection as the process that measures how attributes of a given area have changed over time. It can also be equated to the determination of when land cover at a given location has been converted from one type to another and is therefore, an important tool for evaluating trends in the interaction between people and the environment (Boriah *et al*, 2008; Prakasam, 2010; Afify, 2011). The change detection process involves comparing aerial photographs or satellite imagery of the subject area, taken at different times. It seeks to know the pattern of landscape changes, the process involved and the human response to landscape changes. This provides the most accurate means of measuring the extent and pattern of changes in landscape conditions overtime (Forkuo and Frimpong, 2012). The change detection method was selected for the current study because of its effectiveness in demonstrating environmental changes within less time, at low cost and better accuracy.

According to Kilonzo (2014), landscape changes are often a result of anthropogenic pressure and climatic variability. Anthropogenic factors include deforestation, land degradation and human related green house gas emissions. For accurate change detection, care should be taken to ensure the images consistence of remote sensed data. This is possible if data is captured using the same sensor or instrument, same resolution and same spatial extent at anniversary or near anniversary dates.

To prepare the images for analysis, the different bands were layer stacked using Erdas imagine software. Since the images covered an area larger than the study area, it was necessary to delimit the image by clipping out the area of interest through extracting the shapefiles of the study area Locations including Nkama, Enkirigirri, Ilpolosat and Olturoto. In order to align the images to the Kenya Grid Coordinates, the shapefiles data re-projected to the Universal Transverse Mercator- World Global System 1984, zone 37 North (UTM WGS). Using the Erdas software, the clipped shapefiles were used to subset the three images and obtain the area of interest. The images were then stretched by rescaling the image histogram to increase the contrast of the colour combination. During stretching, the contrast of the original bands was also increased. Multi–temporal set of remote sensing data covering the study area was procured from the Regional Centre for Mapping and Resource Development (RCMRD), Nairobi. The data set included remote Sensing images for the years 1984, 1995 and 2014, high resolution photographs and the digital image processing software (ERDAS). The images had a path of 8168 and row of 061. Images were procured and examined for change detection using the ERDAS IMAGINE, ENVI and ArcGIS software.

4.3.2.2 Supervised Image Classification

Digital image classification is the process whereby a human operator instructs the computer to perform an interpretation according to certain conditions, defined by the human operator (Kerle *et al*, 2004; Afify, 2011; Rawat and Kumar, 2015). Image classification is suitable for landscape studies because it enables the investigator to generate various land cover data sets based on supervised or unsupervised classification of the multi spectral satellite data. The classification based on different spectral characteristics of different materials on the earth's surface has been used in different projects by the Food and Agriculture (FAO) to produce data sets such as the Pan-African land cover data set for the African region, while in Europe it has been used to generate a firsthand inventory of land cover (Kerle *et al*, 2004). Chen *et a*l (2003) advise that for accurate image classification, the investigator must ensure that the training samples are representative of all possible changes in the study area.

Image classification as a technique of change detection has both advantages and disadvantages. Kilonzo (2014), cautions that the advantages of image classification include atmospheric and environmental impact reduction, possibility of attaining complete matrices of change and ability to minimize the effect of using multi-sensor images. The disadvantages include the requirement for complete and accurate training data and the final accuracy being dependent upon the classification accuracy of the individual images (Hussain *et al*, 2013).

In the present study, the image was classified, taking into account five land uses of interest, namely mining ponds/quarry pits, bare ground, woody plants and bush and grasses. The classification was done using the supervised classification algorithm. During the supervised classification, high resolution images and familiarity with the site were used to identify pixels that represented patterns and objects of interest. Having visited the mining sites, the investigator knew the attributes that described the five classes of interest and the algorithm to use. Training samples were selected to enable the computer identify pixels with similar spectral characteristics. After the training samples were identified, classification of the images was carried out using the maximum likelihood algorithm. The Maximum likelihood decision rule was adopted for classification because it is the most commonly used algorithm (Kerle *et al,* 2004; Nori *et a*l 2008; Xie *et al*, 2008; Fichera, 2012).

4.3.2.3. Accuracy Assessment for Classified Images

Since image classification is based on samples of the classes, actual quality should be checked and quantified after classification. In the current study, this was done by sampling of a number of elements and comparing the classification result and the true World class elements. The true World class elements were obtained from field observations and high resolution photographs. The researcher created the regions of interest for the satellite images after which a confusion matrix was performed on both the supervised classified image and the true world class elements. The accuracy assessment reports for the three images were generated as shown in Table 16

Table 16: Accuracy Assessment for Classified Images

Year	Classified Image	Overall accuracy (%)	Kappa (%)	Coefficient
1984	Landsat L4-5TM	85.7	76.6	
1995	Landsat L4-5TM	94.9	92.5	
2014	Landsat L8-TM	99.0	99.0	

Source: Research data, 2016

The accuracy assessment results concur with Setiawan and Yoshino (2012), who used similar methodology and validated the change detection using actual land use change. They obtained an overall accuracy of 76.1%. The research established that the study area which provides environmental services such as pasture, water and forestry to the residents of Kajiado had been affected by human activities including mining. It was detected that as a consequence of gypsum mining, the area occupied by both mine ponds and quarry pits had increased from 398 acres in 1984 to 1344 acres in 2014. Consequently, the area under bare ground increased by 1788 Acres over the same period as shown in Fig. 10. The increase in waste land acreage is attributable to the primary benefication process that includes the spreading out of gypsum ore for sun drying before crushing. The gypsum tailings that are sometimes deposited near the disused mine pits do also give an indication of bare ground in the remote sensed data. It was as well noted that the area under bushes and grasses decreased by 19,853 acres (16%). This could be attributed to land clearance to set up mine infrastructure such as roads, staff housing, mine drying fields and tailings deposits (Fig. 11 and Table 17) and climatic changes (Kilonzo, 2014). Over the same period, the area under woody plants declined by 12,882 acres (65%).

The research observations are in agreement with community perceptions noted during the qualitative data analysis, where the Kajiado residents associated gypsum mining with the overall appearance of the landscape (χ^2 = 241, P $\leq$ 0.001). The results are also consistent with Musa and Jiya (2011) observations, where remote sensing data was used in an assessment of the mining impacts on vegetation cover at the Jos plateau of Nigeria and revealed a continuous reduction in vegetation cover in the study area, due to intensive mining activities and subsequent soil erosion. In the Musa and Jiya (2011) study, it was concluded that mining had led to loss of vegetation cover and denied both micro and macro-organisms their natural habitats. The loss of vegetation due to mining further led to soil erosion and loss of pasture for livestock. In the current study, loss of vegetation was attributed to deforestation by the immigrant population as a result of mine expansion and other anthropogenic factors. The most used method of quantifying land cover change results is to tabulate the totals for each land use cover type and examine the trends over the study period (Nori *et al* 2008; Wang *et al* 2009). The changes as detected by the remote sensed data analysis for the current study are demonstrated in Table 17 and Fig. 10.

Fig. 9 elucidates that as the area under mining increased, the acreage under woody plants, bushes and grasses decreased. Taking 1984 as the base year, it is evident that by the year 1995, the area under mining declined by close to 100 (37%) acres while, the acreage under bushes and grasses increased by 8344 acres (7%). By 2014 however, the area under mining had increased by more than 300%, leading to a decline in acreage under bush and grasses by 16%. This demonstrated an inverse relationship between mining and pasture availability in the study area (Fig. 9, 10, 11 and 13).

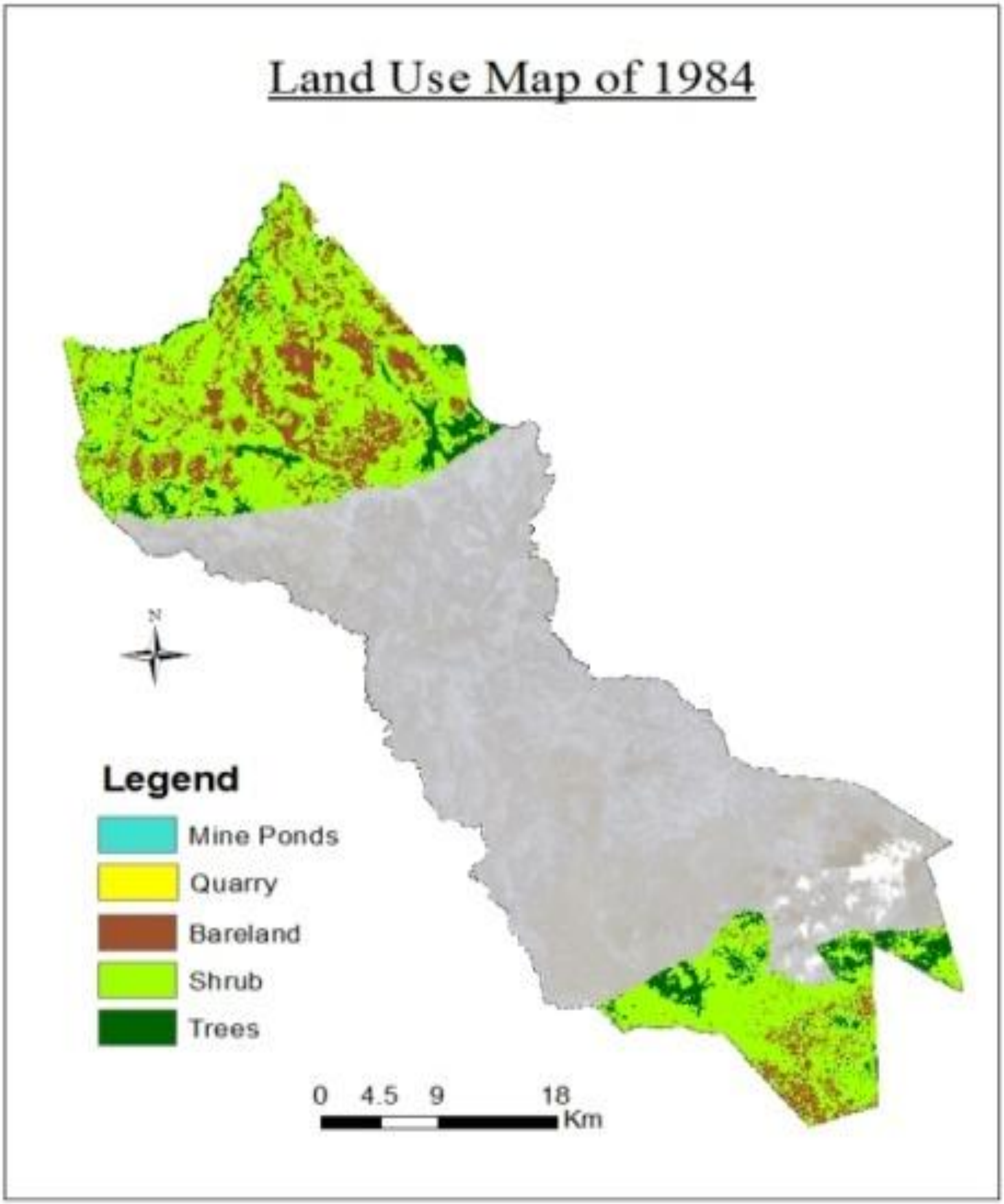

Figure 9: Land Cover 1984

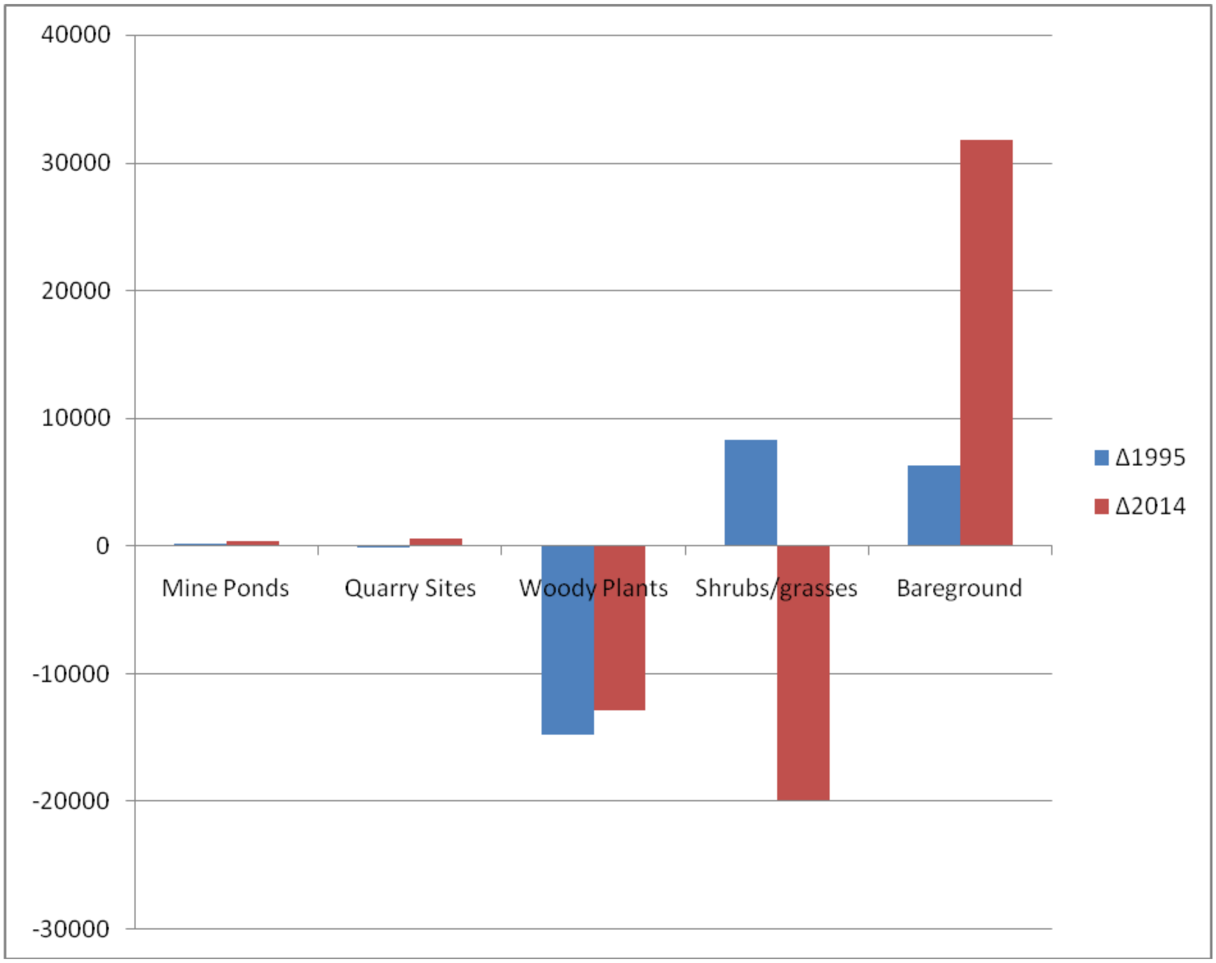

Figure 10: Land cover Changes (Acres) 1984 to 2014

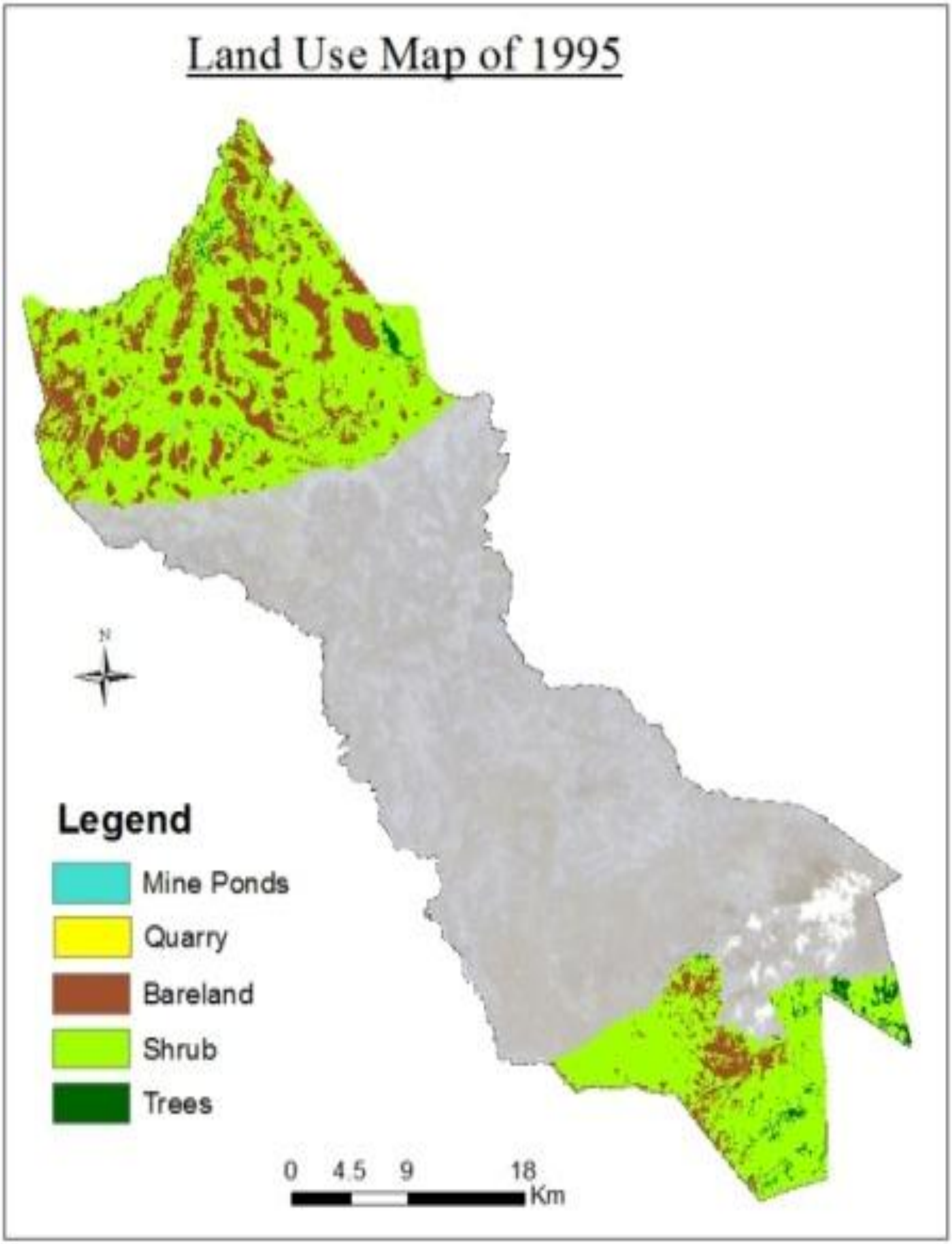

Figure 11: Land Cover 1995

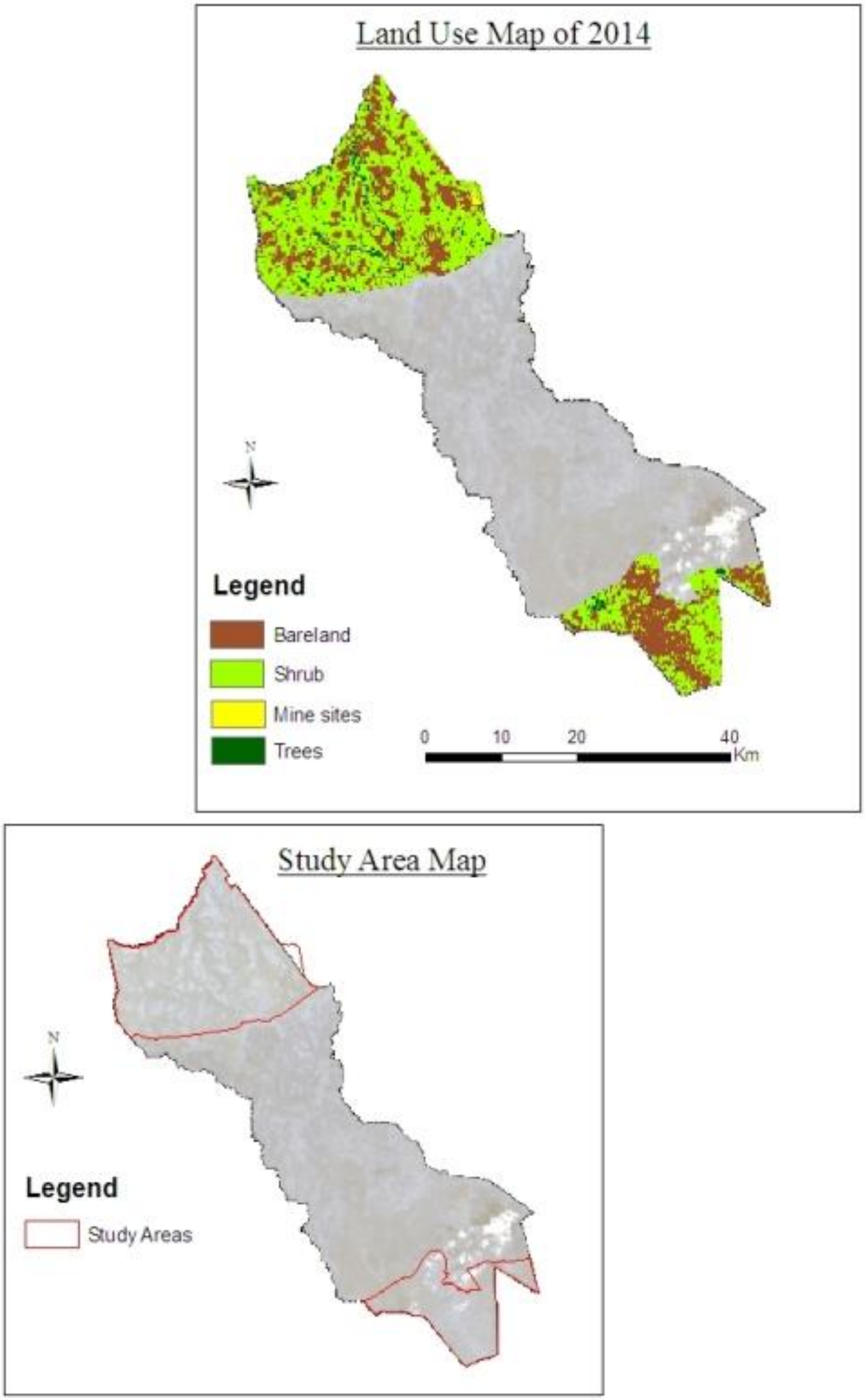

Figure 12: Land Cover 2014

Previous research by the Department of Remote Sensing and Resource Surveys established that the dominant vegetation types in the study included open grassland, bushed grassland and wooded grassland. This study established that the main mine site at Kibini is located in an area dominated by wooded grass land while the Enkirigirri and Olturoto areas are under open grassland. The Ilpolosat site is under bushed grassland. The study confirmed loss of woody plants and herbaceous plants as a consequence of open cast gypsum mining. Woody plants such as *Pennisetum mezianum, Cynodon dactylon, Digitaria melanjiana, Digitaria scalanun, Aristida adoensi, Becium ovatum, chroris roxburgiana, Acaia species* and *Balanitis* species are affected at Enkirigirri (Fig. 13)

Consequently, the base for livelihoods supporting systems affecting Kajiado residents is probably destroyed since the herbaceous and woody plant roots that are believed to be a source of traditional medicine and pasture for livestock for the pastoralist community are lost (Table 17). Further, it is probable that the destroyed vegetation cover contributed to climate change since are known to absorb and store carbon in the trees and soil but when destroyed release the same into the atmosphere as carbon dioxide and other green house gases (Dunham *et al* 2008).

Table 17: Landscape Changes from 1984 to 2014

Land Cover	Area 1984 (Acres)	Area 1995 (Acres)	Area 2014 (Acres)	Change 1984 - 1995	Change 1984 - 2014	%ge Change
Mine Pond	74	230	449	156	375	0.2
Bare Land	35976	42314	67764	6338	31789	17.5
Mine/quarry	324	203	895	-121	572	0.3
Trees	19540	4822	6658	-14718	-12882	7
Shrub	125608	133951	105755	8344	-19853	11
Total	**181521**	**181521**	**181521**	**-**	**-**	

Source: Research Data 2016

Figure 13: Abandoned Mine Pit in the Study Area

In the Bushed grasslands of Ilpolosat, the intensification of Acacia Mellifera, Acacia Nubica, *Balanitis Aegyptica* and *Acacia Tortilis* was *compromised* while herbecious plants such as *Digitaria melanjiana, Pennisetum stramenium* and *Eragrostis papposa* were negatively impacted. At the Kibini mine, the destroyed plant species included *Acacia tortilis, Lippia Javanica, Grewia tenax, Acacia mellifera* and *Commiphora Africana*. Non-woody plants affected include *Chloris roxburghiana, Justicia exigua, Penicum maximum, Themeda triandra and Eragrotis papposa.*

The destruction of pasture affects livestock development while woodland and shrubs reduction compromises wildlife habitat is corroborated by qualitative analysis where the Kajiado residents attributed the destruction of vegetation and wildlife habitats to gypsum mining (χ^2 = 230, P ≤ 0.001). This increases possibilities of human-wildlife conflicts. The field observations by the researcher also revealed the presence in the study area deep abandoned mine pits that exposed the residents, livestock and wildlife to accidents. Since the study area falls within a wildlife dispersal area, the loss of pasture also limits the free movement of wildlife such as Wildebeest, common Zebra, Impala, Gazelles, Ostrich and Warthogs that are common in the study area owing to proximity to the Nairobi National Park - Amboseli National Park migration corridor.

The damage of forest cover could lead to more soil erosion and sandstorms that would contribute to poor public health, global warming and emergence of environmental diseases such as malaria. However, the questionnaire study and key informant discussions indicate little importance to the accumulation of dust on pasture (χ^2 = 50, P ≤ 0.001). The destruction of trees exposes the study area households to the risk of diminished fuel wood sources.

These findings are in agreement with Prakasam (2010) who employed satellite imagery to study land cover changes in a biodiversity rich area in India (Kodaikanal taluk) over a 40 year period. Using image classification and validation by ground-truthing, Prakasam (2010) established a reduction of area under forestry by 36% and a near commensurate increase in area under agriculture and urban development. He concluded that forestry land was taken up by human activities in the form of agriculture and urban development which effectively led to deterioration of ecosystems and loss of biodiversity .Growth of the Agricultural sector also negatively impacted on water resources through contamination from Agricultural chemicals and fertilizers.

The current study findings are also in agreement with Fichera (2012), who used the land cover classification and change detection analysis method to assess the impact of urbanization on landscape and concluded that anthropogenic factors had considerably modified land cover of the study area, with significant land conversions. Fichera (2012) observed that during the five decades under study, one land use had increased nearly five times, from 1.6% of the study area to 9.1%, at the expense of other land uses. The land cover and conversion have also been previously confirmed by Kitetu (2014), who in an ecological assessment of potential impacts of river bed sand harvesting to riparian ecosystems in Kenya, concluded that mining caused damage to habitats of animals and bottom fauna especially insects and mollusks populations. Mining moreover, negatively affected some plants found in semi- arid ecosystems including bacteria, fungi and algae. These resulted in loss of genetic materials an d bio-diversity (Musa and Jiya, 2011; Kitetu, 2014).

4.3.3: Impact of Gypsum Mining on Quality of Water in Study Area

The third objective sought to establish the impact of gypsum mining on the quality of water in the study area. Following the questionnaire study, the investigator prepared a Likert scale and computed a total score for each respondent. These, together with other items were each rated on a 5-point Likert scale ranging from: 1 = little important (LI) to 5 = extremely important (EI) and the results summarised in Table 18

Table 18: Perceived Impacts of Gypsum Mining on Water Quality

	LI Freq (%)	**SI** Freq (%)	**NI** Freq (%)	**I** Freq (%)	**EI** Freq (%)	χ^2	p-value
Negatively affects quality of surface water	33(34.7)	28(29.5)	16(16.8)	8(8.4)	8(8.4)	28.344	.000
contaminates water sources	40(42.1)	12(12.6)	16(16.8)	5(5.3)	20(21.1)	37.376	.000
Might affect ground water table	14 (14.7)	53(55.8)	15(15.8)	8(8.4)	82.06)	43.158	.000

Source: Research Data, 2016

The results in Table 18 show that the respondents attached little importance to gypsum mining as a contributor to water availability in the study area (χ^2 = 32, P $\leq$ 0.001). The respondents further indicated little importance to the contribution of gypsum mining to water quality effects (χ^2 = 33, P $\leq$ 0.001). The likely effect of gypsum mining on the water table was the most significant since it showed the strongest association (χ^2 = 33, P $\leq$ 0.001), attributed to the belief that the mine pits allowed more water to percolate to the ground and therefore, raise the water table.

Discussions with key informants revealed the association of gypsum mining with the water availability as a result of potential perforation and rapture of shallow ground water aquifers. Respondents indicated as somewhat important the effect of gypsum mining on ground water table (χ^2 = 43, P $\leq$ 0.001) while little importance (χ^2 = 37, P $\leq$ 0.001) was attached to negative effects of gypsum on water quality.

The results are consistent with Al-Harthi (2001), who used a similar protocol to intensively evaluate gypsum extraction and its effects on water quality at Maqna. He sampled water at the gypsum mining sites and carried out laboratory and *in situ* analysis of the samples and came to the conclusion that there were no harmful effects on the environment of the study area, associated with the extraction of gypsum mining.

4.3.3.1: Quantitative Analysis Water Quality

To appraise the impacts of mining on water quality, sample analysis and direct observation was carried out as suggested by the APHA water quality protocol (1999, 22nd edition). Water samples were collected from surface (Fig 14) and ground water bodies in the study area including, mine ponds and boreholes, for chemical and bacteriological assessment.

A total of 25 water samples were collected from different water body settings in the study area, in the following distribution: 5 borehole water samples and 20 mine pond water samples taken from different points and depths in the ponds (Fig. 14). Water samples were collected preserved and stored using procedures similar to those specified in the APHA 1999 (22nd edition) protocol and recommended by Ahmad *et al* (2014). The samples were collected using plastic bottles that were rinsed three times using the water that was to be sampled before the actual samples were taken. The analyses were performed at the Kenya Water Institute laboratories, and followed standard methods. For trace metals analysis, the samples were analysed at the Kenya Department of Mines and Geology laboratory. The results are demonstrated in Tables 19 and 20.

Figure 14: Gypsum Mine Pond water in Study Area

The results tabulated in Tables 19 and 20 signify inconsequential variations in the concentrations of trace metal pollutants in ground water samples. For instance, the ground water samples indicated less contamination, with only traces of nitrates and copper being detected.

Table 19 : Water Quality Parameters for Ground water

Parameter	Units	Mean	Median	Min.	Max	WHO Value	NEMA Val.
PH	pH Units	8.3 ± 0.156	8.240	7.97	8.7	6.5 – 8.5	6.5 – 8.5
Turbidity	N.T.U	0.3 ± 0.029	.270	.260	.38	5	-
Conductivity	□S/cm	1138 ± 3.1	1135	1133	1146	NS	-
Total Hardness	mg/L caCO3	933 ±3.86	931	925	942	300	-
Nitrates	mg/L NO3	1.74 ± 0.278	1.47	1.3	2.45	10	10
TSS	mg/L	0	0	0	0	NS	1200
Total Coli	/100 ml	0	0	0	0	03	-
E- Coli	/100 ml	0	0	0	0	Nil	Nil
Zinc	Zn mg/L	0	0	0	0	3	1.5
Cadmium	Cd mg/L	0	0	0	0	.003	0.01
Lead	Pb mg/L	0	0	0	0	.01	0.05
Copper	Cu mg/L	.020 ±0.005	.030	.01	.03	2	0.05

Source: Research Data 2015

The concentrations of nitrates in the ground water samples ranged from 1.3 to 2.45 mg/L. while, copper concentration ranged from 0.01 to 0 .03 mg/L. These were safely below the WHO guide values of 10 mg/L and 2 mg/L respectively. The investigation also revealed a mean concentration level of Zinc at 0.0333 Zn mg/L, which was well below the WHO guide value of 3 mg/L. The assessment did not either reveal any detectable levels of other heavy metals such as Cadmium and Lead. This is consistent with the study findings by Udiba *et al* (2013), who used similar methodology in analyzing the impact of mining activities on ground water quality at the Ureta mine in Nigeria and came to the conclusion that the concentration of Zinc in the mine water was below the WHO (2006).

The results are in agreement with the observations by Gyang and Ashano (2010) who adopted the same parameters in an analysis of the effects of mining on water quality. In their study of the impacts of mining on waters of the Jos plateau in Nigeria, they affirmed that the chemical concentration levels for Copper (0.05 mg/l), Zinc (0.03mg/l), Lead (0.00). Nitrates (0.00 - 10 mg/l) and PH (6.63 – 7.99) were below the WHO guide values. They also recorded total hardness at 61.25 which was below the WHO guide value. However, they noticed above normal levels for turbidity (478.79 NTU) which was attributed to the use of pond water for domestic purposes and watering of livestock which was always allowed to walk right into the water ponds to drink (Gyang and Ashano, 2010). The low concentration of chemical pollutants could partly be explained by the sample water PH. Water PH is a measure of how acidic or base the water is and is therefore, an important indicator of water that is changing chemically. The PH determines solubility and biological availability of chemical constituents such as nutrients and heavy metals. The degree to which heavy metals are soluble therefore, depends on the PH.

The findings further agree with the outcome made by Margutti (2009), where water chemistry characterization techniques were used to examine the impact of gypsum mining on ground water sources and it was established that gypsum quarrying activities seemed not to affect ground water quality. This findings are also consistent with the conclusions by Al-Harthi (2001) who observed that ground water at the Maqna area was free of contamination by the gypsum extraction processes, safe for the high concentration of soluble salts. This study also revealed that unlike the ground water samples, surface water sources proximal to the gypsum mines were more contaminated as shown in Table 20.

Table 20: Water Quality Parameters for Surface water

Parameter	Units	Mean	Median	Min.	Max.	WHO Value	NEMA Value
PH	pH Units	8 ± 0.08	8.010	7.400	8.660	6.5 – 8.5	6.5 – 8.5
Turbidity	N.T.U	80.10 ± 0.57	121.5	1.380	156	5	-
Conductivity	S/cm	28203 ±3664	27422	2429	48830	NS	-
Total Hardness	mg/L caCO3	1102 ± 24.29	1124	952	1252	300	-
Nitrates	mg/L NO3	10.12 ± 0.41	10.3	6.800	12.7	10	10
TSS	mg/L	878 ± 189.25	598.5	100	2370	NS	1200
Total Coli forms	per/100 ml	555 ± 167.93	180	75	2400	03	-
E-Coli	Per/100 ml	47.8 ± 10.16	30	7	150	Nil	Nil
Zinc	Zn mg/L	0.033 ± 0.01	.015	.01	.002	3	1.5
Cadmium	Cd mg/L	0	0	0	0	.003	0.01
Lead	Pb mg/L	0	0	0	0	.01	0.05
Copper	Cu mg/L	.024 ± 0.02	.015	.01	.03	2	0.05

Source: Research Data 2016

4.3.3.2: Nitrates Concentration

In investigating the nitrate concentration in the samples, the palintest method was used employing an ELE International photometer, Serial number 41833. Test tubes were rinsed with distilled water and the nitratest tube was filled with sample water to the 20 ml mark. One level spoonful of nitratest powder and one nitratest tablet were added into the sample. The screw cap was replaced and the test tube shaken for one minute. The tube was allowed to stand for one minute and inverted to aid flocculation. The screw cap was removed and the sample decanted to a 10 ml test tube. One nitricol tablet was added and the mixture, crushed and the sample allowed to stand for 10 minutes to facilitate full colour development. Using a photometer at wavelength

570 nm and a nitrates calibration chart, a reading was taken. To ensure reliability, triplicate readings were taken precisely at the lapse of 10 minutes and an average calculated for each sample. The mean nitrates concentration for surface water was 10.1 mg/L, ranging from 6.8 mg/L to 12.7 mg/L. In some samples, the concentration of nitrates in surface water was above the WHO (2006) and EMCA (2006) guide values of a maximum of 10 mg/L.

The findings on nitrates concentration concur with those by Margutti (2009), who associated the presence of nitrates in the water samples with the blasting material usage and came to the conclusion that gypsum quarrying had insignificant impacts on ground water quality. The findings for surface water bodies however, are a departure from the Al-Harthi (2001) verdict. This could be explained by the mere fact that Al-Harthi (2001) investigated the mining activities in an area that was devoid of surface water bodies and generally desolate. The absence of water, trees, pasture and therefore, the attendant anthropogenic activities including farming, industrial and settlement makes the two study areas incomparable.

The current study area accommodates human settlements in close proximity to the gypsum mining sites. The surface water bodies that are also important sources of water for domestic use and livestock farming are prone to contamination with animal droppings resulting from runoff. The questionnaire study results indicated the possibility of storm water polluted by gypsum tailings further polluting surface water bodies was confirmed by the laboratory assessment. This is in agreement with Galay (2008), who in an examination of socio-economic impacts of gypsum mining at the Kothagpa mine observed that while there was no evidence of negative water impacts resulting from the mining activities, there was a relationship between the poorly stored gypsum tailings and mud waste that were dumped near the mine pits, that eventually got deposited in the surface water bodies by runoff and wind erosion.

4.3.3.3: Water PH Analysis

To determine the water PH in the samples, the PH meter was calibrated using freshly prepared buffer solutions (4 and 7) and rinsing the electrode with distilled water as suggested by Ladwani *et al* (2013). The electrode was then immersed in the sample water and readings taken. Three readings were taken for each sample and an average figure adopted as the validated result. The meter reading indicated a mean PH reading of 8.3 and 8 for ground water and surface water respectively. These were within the WHO recommended guide values of 6.5 to 8.5 and do not therefore, facilitate the dissolution and seepage of heavy metals (WHO, 2006; EMCA, 2006).

4.3.3.4: Water Turbidity

The study also examined water usability and palatability parameters including turbidity and total hardness. Turbidity in drinking water is caused by the presence of suspended and dissolved matter, such as clay, silt, organic matter, plankton and other microscopic organisms. The particulate matter may be present from source as a consequence of deposition of sediments in the water system and as a result of run-off from mining pits and tailings (WHO, 2005).

Turbidity of the samples was measured using an ELE Paqualab Turbid Meter, Serial Number T891105. The turbid meter was calibrated to zero by placing the Off/On knob at the off position, and turning it on. Using the Zero function, the meter was adjusted to read Zero. The Standardization functionality was also used to attain a reading of 205. The sample water was then placed in the measuring cells and three readings were taken for each sample. A validated average figure was recorded. It was revealed that while ground water turbidity was 0.3 Nephelometric Turbidity Units (N.T.U) with a minimum of 0.26 and a maximum value of 0.38, surface water samples had a mean value of 80.1, with a minimum of 1.38 and maximum of 156. The mean turbidity value for surface water was 16 times the recommended WHO value of 5 N.T.U (WHO, 2006). Among the effects of high turbidity is the inefficiency in the water treatment process. WHO (2006) warns that for water treatment to be effective, the turbidity of the water being treated must be less than one because higher levels of turbidity protects micro-organisms from the effect of disinfection.

4.3.3.5: Total Hardness

This study also examined the total hardness of the sample water. The sample water total hardness was investigated using EthyleneDiamineteTra-Acetic acid (EDTA) and its sodium salts method. For each sample, 50 ml of sample water was put in the conical flask and by use of a pipette; 1 ml of the total hardness buffer solution was added. One spatula of the total hardness indicator was added to the sample before titration using the 0.01N EDTA. The titration was stopped at the point when a colour change from pink to blue was noted. A titre range reading was taken for each titration and the result multiplied by 20 to arrive at the total hardness. Three titre range readings were taken for each sample and their arithmetic average adopted as the validated hardness result (Fig. 15). The research established that the total hardness limit for ground water had a mean value of 933 while for surface water samples the mean total hardness was 1102. Both water sources therefore, indicated higher than the WHO (2006) guide value of 300 $caCO_3$/L.

WHO (2006) suggests that hardness is caused by calcium and magnesium deposition and is indicated by the precipitation of soap scum and the need to use soap to achieve cleaning. Concentrations of between 100 to 300 mg/L, and in some instances 500 mg/L are acceptable (WHO, 2006) since there is no evidence in literature on effects of water hardness on mortality (Lake *et al*, 2009). Hardness, otherwise known as the capacity of water to react with soap, is believed to be a constraint to water utilization by poor families since hard water takes considerably more soap to lather. Research links water hardness (Fig. 15) to dissolved polyvalent metallic ions, predominantly calcium and magnesium from sedimentary rocks, seepage and run-off (WHO, 2003). Although there is no evidence that hard water causes any adverse effects on human health, it is confirmed that water with hardness of above 200 mg/L could increase soap consumption and therefore, reduces the ability of the study area residents to utlise the surface water for domestic purposes.

The quantitative analysis findings are consistent with the observation by Akabzaa *et al* (2007), who in an investigation of the impacts of mining activities on water resources in the vicinity of Obuasi mine, observed elevated levels of trace metals in samples collected from surface water and came to the conclusion that such concentrations were most likely derived locally from the water–mineralized rock interaction. The findings also agree with Nganje *et al* (2010) who employed similar protocol to assess the impacts of mine water drainage on water quality in a river proximal to the mines and established that the turbidity, electrical conductivity and total water hardness exceeded the WHO (2006) standard guide values. The elevated concentrations of trace metals were suspected to be products of the dissolved host minerals.

Figure 15: Water Hardness Analysis Underway

4.3.3.6 : Bacteriological Analysis

To ascertain if the water samples were free from dangerous bacterial and other pathogens, bacteriological analysis was carried out based on a common group of bacteria found in the human gut called Coliform. The research used multiple tube fermentation technique where sample water was exposed to MacConkey broth, a nutrient specific to Coliform and allowed the Coliform to multiply and indicate presence by colour change and evolution of gas. The bacteriological analysis revealed that Coliform concentrations in surface water samples were many times higher than those observed in ground water samples. The concentration of Total Coli forms and faecal Coli forms was undetectable in the ground water but high in the surface water samples. The mean total Coli form concentration in the surface water samples was 555/ 100 ml, with a minimum of 75 and maximum of 2400. This is several times higher than the recommended maximum of 3. The mean concentration of faecal coli form in the surface water samples was 47.8. Compared to the WHO (2006) requirement of zero presence of faecal coli form, the concentration of this parameter in the samples was significantly high.

The detection of significant bacterial pollution in water demonstrates the potential effect of bacteriological contaminants on the health of the local population, and is in agreement with Odira *et al* (2012), who in evaluating the effect of climate change and anthropogenic activities at Tudor claimed that the water contaminants could have a devastating effect on the local population. Research has also proven that the presence of Escherichia Coli (E.Coli) in parts of the body other than the intestinal flora of humans and animals where it causes no harm can cause serious diseases such as Urinary Tract Infections (UTI), diarrhea and meningitis.

Diverse strains of coli are known to cause severe diarrhea in children aged below 5 years, and occurs commonly in developing countries with the affected children presenting with malnutrition, weight loss and growth retardation. The implicit contamination of water resources at the study area is prone to further compromise accessibility to safe drinking water by increasing the cost of water treatment for household consumption, because of the presence of pollutants (Afroz, *et al* 2014). Presence of coli in the surface water samples provides evidence of recent faecal pollution resulting from contamination from run-off containing cattle and human excreta and therefore, confirms the influence of anthropogenic activities near the water bodies.

The investigator also visited health facilities in the vicinity of the mining sites and conducted key informant discussions with medical personnel. Administrative data on outpatient consultation rates was also reviewed. The examination yielded information on the most prevalent diseases in the study area, which were then ranked depending on the number of outpatient consultation per month. The outpatient consultation rates at Isinya Health Centre in the Months of October 2015 and January 2016 are shown in Table 21.

4.3.3.7: Health Effects Particulate Matter Concentration

Table 21 shows that waterborne diseases related outpatient consultation rates in the study area. These include diarrhoea, dysentery, typhoid fever and intestinal worms accounted for 20.3% of the under 5 year old cases reported at the health centre while the older population (over 5 year olds) in the same category accounted for 18%.

There is no significant difference in the outpatient consultation rates for children aged below 5 years and the rest of the population ($p \leq 0.206$). The bulk of outpatient consultations constituted respiratory diseases such as pneumonia, URTI, asthma and tonsillitis. During the dry season (September/October 2015), respiratory diseases accounted for 58% for the under 5 year olds consultation and 42% for the over 5 year olds. During the wet season (December/January, 2016) the respiratory diseases accounted for 55% of the consultations while the same accounted for 36% for the over 5. There was therefore a slight decline in the number of respiratory diseases during the rainy season. The bacteriological analysis results were thus reinforced by the medical examination results and consistent with Obiekezie (2006) finding, where in the analysis of bulky water samples collected from mine pits, it was confirmed to contain bacterial organisms E.coli.

Table 21: Outpatient Consultation Rate at Isinya health Centre

Disease	Under 5 Oct 2015	Over 5 Oct 2015	Under 5 Jan 2016	Over 5 Jan 2016
Diarrhoea	201	176	278	149
Dysentery (Bloody Diarrhoea)	0	12	3	4
Tuberculosis	0	3	0	41
Poliomyelitis	9	0	0	0
Fevers	6	0	1	5
Malaria	5	10	10	46
Urinary Tract Infections	4	0	4	168
Bilharzias'	0	16	0	0
Typhoid fever	0	8	0	3
Intestinal Worms	2	115	4	5
Eye Infections	24	3	22	24
ear Infections	5	24	5	8
URTI	284	11	543	354
Asthma	0	11	1	13
Tonsillitis	21	656	10	75
Pneumonia	36	10	22	45
Other disorders of the respiratory system	237	48	10	75
Skin disorders	34	20	102	106
Brucellosis	1	2	0	9
Cardiovascular conditions	0	5	0	5
All other diseases	131	600	46	407
TOTAL	**1000**	**1730**	**1061**	**1542**

The results are further supported by Amankwah (2013) who confirmed that mining polluted water bodies with mud and trace metals to the extent that the communities living near the mining sites could not rely on the polluted waters for domestic and drinking water supply needs. In the words of Amankwah (2013) and Fink *et al* (2011), the water bodies near mining sites were so unsafe that they escalated disease outbreaks in the affected communities.

4.3.4.: Impact of gypsum mining on air quality

The fourth objective sought to examine the impact of gypsum mining on the concentration Pm 2.5 in Kajiado. Qualitative data for this objective was obtained from interviews and questionnaire study where the research sought to identify respondent association of air quality place specificity of the impacts of air pollution. The researcher prepared a Likert scale and computed a total score for each respondent. These together with other items were rated on a 5-point Likert scale ranging from: 1 = little important (LI) to 5 = extremely important (EI) and the results summarised in Table 22. The results in Table 22 imply that the respondents posted upper respiratory concerns as being extremely important (χ^2 = 44, P ≤ 0.001) to their general wellbeing. Allergic skin conditions associated with gypsum mining were also indicated as extremely important (χ^2 = 241, P≤0.001) while cardio vascular infections as a consequence of mining was ranked of little importance (χ^2 = 44, P ≤ 0.001). Eye infections and loss of hearing were indicated at little importance (χ^2 = 37, P≤ 0.001) and (χ^2 = 28, P ≤ 0.001) respectively. Allergic skin conditions therefore, showed the strongest association (χ^2 = 241, P ≤ 0.001) and portray the respondents clear understanding of the link between gypsum mining and public health conditions in the study area (Table 22).

Table 22: Summary of Perceived Air Quality Impacts

Public Health Impacts	LI Freq (%)	SI Freq (%)	NI Freq (%)	I Freq (%)	EI Freq (%)	χ^2	p-value
Dust caused URTI	29(30.5)	15(15.8)	3(3.2)	9(9.5)	38(40)	44.298	.000
Cardiovascular infections	43(45.3)	9(9.5)	17(17.9)	3(3.2)	22(23.2)	50.255	.000
Dust generated caused Eye infections	40(42.1)	12(12.6)	16(16.8)	5(5,3)	20(21.1)	37.376	.000
Allergic skin conditions	3(3.2)	2(2.1)	3(3.2)	7(7.4)	79(83.2)	241.745	.000
loss of hearing	36(37.9)	20(21.1)	20(21.1)	5(5.3)	12(12.6)	28.774	.000

Source: Research Data, 2016

The findings are consistent with the study conclusions made by Moffat and Pless-Mulloli (2003) and Olesugun *et al* (2009) in which respondents recognized place specificity of exposure to pollutants and indicated nasal infections and asthma as most common conditions suffered by residents of villages near mining sites. The findings are further supported by Hendryx and Ahern (2008), who in a study aimed at finding out if coal mining was related to incidences of poor health in villages near the coal mines, concluded that residential proximity was associated with poor health.

4.3.4.1: Quantitative Examination of Particulate Matter (Pm 2.5) Concentration

To triangulate the qualitative data findings, the researcher conducted sample analysis of particulate matter (Pm 2.5) in the open cast mine site and a neighbouring village located about 2 KM away from the Nkama mining site. A similar approach was used by Ahmad *et a*l (2014) to examine the impact of mining on air quality, in which sampling equipment were placed in the mining site and in a local residential area. The sites were so selected on the assumption that mining activities generated large scale ramification that affected the health of both workers in the industry and local residents living in the neighbouring villages (Ahmad *et al*, 2014).

Particulate matter investigation was considered necessary because it is an important component of air pollution, having both long term and short term effects on human health because many toxic elements are concentrated at this particle size fraction. Using UCB air particle monitor (version 8), the research obtained 24 hour Pm 2.5 data for the two sites for 19 days over a period of 6 months. The UCB monitors were fitted with 9 volt batteries before the monitors were launched and placed at sampling points located 1.5 meters above ground level, as shown in figure 16

Data was downloaded every 24 hours and summarised as indicated in Table 23. Tables 24 and 25 indicate the air sampling results for the gypsum crushing area and the control site located about 2 Km from the crushing site, at the Kibini gypsum mine during the dry and wet seasons. Since the study area is located in a rural wildlife dominated area, it was not possible to install air samplers outside the built environment for safety and security reasons. The mean 24 hour Pm 2.5 concentrations ranged from minimum of 132 $\mu g/m^3$ to a maximum of 1312 $\mu g/m^3$, and a daily mean of 570 $\mu g/m^{3.}$. At the control site, the Pm 2.5 had a mean of 88 $\mu g/m^{3,}$ and ranged from a minimum of 26.4 $\mu g/M^3$ to a maximum of 573 $\mu g/m^3$. The Pm2.5 concentration was much higher at the mine crushing site as compared with the control site.

The site to site variations were statistically significant between the mine crushing site and the neighbouring village site in a two tailed t- test, P ($T \leq t = 0.003$) and indicated a rapid decrease in Pm 2.5 concentrations as you moved out of the crushing area towards the neighbouring village site. During the rainy season, the site to site variation was more pronounced, with the Pm 2.5 concentration dropping more rapidly from a 24 hour mean of 1675±769 µg/m^3 at the crushing site to 59 ± 33 µg/m^3 at the control site.

It is probable that while the concentration remained high at the point of generation, precipitation significantly reduced the PM 2.5 concentration in areas further from the crushing point as suggested by Bada *et al* (2013), who in an investigation of air quality at a quarry site in Nigeria, came to the conclusion that the concentration of Pm 2.5 decreased significantly ($P < 0.05$) with distance from the mine crushing site to the residential areas. Similar results had previously been reported in literature (Hendryx and Ahern, 2008; Olesugun *et al* (2009); Chaulya, 2004; Pless-Mulloli, *et al*, 2000) that, particulate matter concentrations tended to be higher in open cast areas than in surrounding villages and that mining was a major contributor to the particulate matter concentrations.

The findings are consistent with Bada *et al* (2013), who in an investigation of air quality at a quarry site in Nigeria, came to the conclusion that the concentration of $Pm_{2.5}$ decreased significantly ($P < 0.05$) with distance from the mine crushing site to the residential areas. The study also noted variations between day time Pm 2.5 concentrations at the mine crushing site and at the village site. At the village site, the mean daytime concentration was 74 µg/m^3, with a low of 27 µg/m^3 and a high of 403 µg/m^3, while at the mine crushing site, the mean Pm 2.5

concentration was 760 µg/m^3 with a low of 178 µg/m^3 and a high of 1700 µg/m^3. It is probable that daytime Pm 2.5 concentrations remain high because of high daytime temperatures and reduce significantly during the night when the temperature is low as shown in Fig. 17

Figure 16: Air Sampler Positioning at Breathing Position

Table 23: Air Sample Analysis Results for Crushing Site and Control(Dry Season)

Mine Crushing Site				Control Site (Homestead)		
Sample	**mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
1	132 ± 7	13	3946	573 ± 13	270	2354
2	332 ± 8	153	5340	71 ± 0.3	68	188
3	1444 ± 11	1246	6538	26 ± 0.1	26	107
4	524 ± 5	452	4015	30 ± 0.3	28	156
5	1075 ± 30	273	6205	40 ± 1.6	39	152
6	1036 ± 28	381	7729	46 ± 0.5	41	259
7	1119 ± 37	302	8137	29 ± 0.4	27	396
8	613 ± 13	350	4798	45 ± 0.3	42	286
9	150 ± 2	58	699	46 ± 0.1	44	151
10	147 ± 5	752	679	53 ± 0.1	51	120
11	323 ± 2	176	998	59 ± 6.5	49	8938
12	158 ± 2	58	637	46 ± 0.1	42	278
13	401 ± 5	345	1452	45 ± 0.1	40	270
14	533 ± 5	452	2983	46 ± 0.5	41	276

Source: Research Data 2016

Table 24: Air Sample Analysis Results for Crushing Site and Control (Wet Season)

Mine Crushing Site				Control Site (Homestead)		
Sample	mean	Min	Max	Mean	Min	Max
1	337 ± 2.8	293	1918	12.4 ± 0.7	9.4	144
2	840 ± 10.3	619	5412	188 ± 0.5	182	463
3	136 ± 6.8	75	3620	24 ± 0.3	21	184
4	3737 ± 49	2433	14,003	42 ± 2.5	19	706
5	3327 ± 50	2171	11,126	27 ± 0.5	22.3	240

Source: Research Data 2016

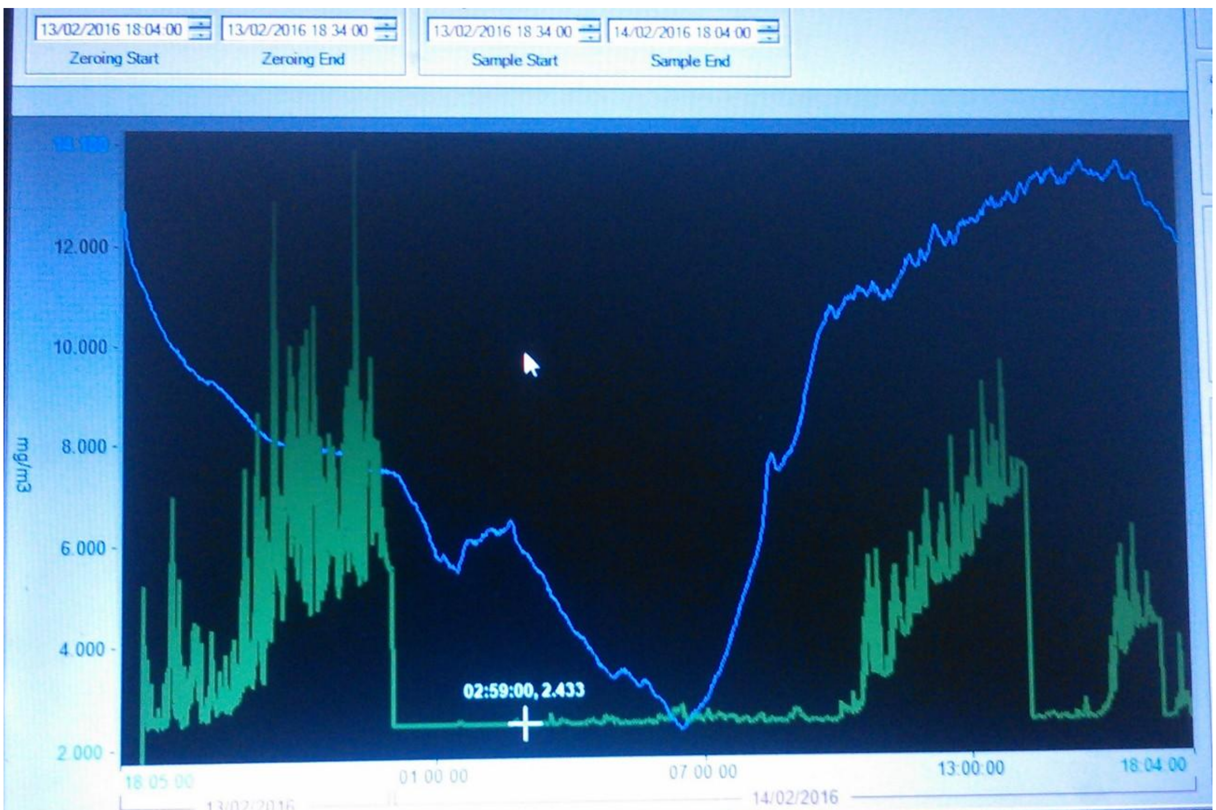

Figure 17: Pm 2.5 Concentration in Relation o Temperature

Fig. 17 indicates actual Pm 2.5 concentration at the mine crushing site in January 2016. It shows that the Pm 2.5 concentrations as shown in green vary with temperature, attaining pick Pm 2.5 concentration in the afternoon when the sun is overhead and late afternoon. The lowest temperatures, as shown in blue, usually occur between 2.00 am and 7.00 am correspond with the lowest Pm 2.5 concentrations. The observed variability of Pm 2.5 concentration with temperatures could be explained by the possible increased oxidation rates of sulfates at higher temperatures. This is consistent with Amos *et al* (2010). Site to site day time variations were statistically significant in a two tailed t- test, P ($T \leq t = 0.002$). The site to site variations findings are also in agreement with a study by Kinney *et al* (2012), who in the study of traffic impacts of Pm 2.5 on air quality in Nairobi, observed that the Pm 2.5 concentrations decreased rapidly as you moved away from the potential source of generation.

A comparable result had previously been reported in literature (Hendryx and Ahern, 2008; Olesugun *et al,* 2009 ; Chaulya, 2004; Pless- Mulloli, *et al,* 2000) that, particulate matter concentrations tended to be higher in open cast areas than in surrounding villages and that mining was a major contributor to the particulate matter concentrations. The 24 hour daily Pm 2.5 (g/m^3) concentration findings over 14 sampling days, for the two sampling sites are illustrated in Fig. 18.

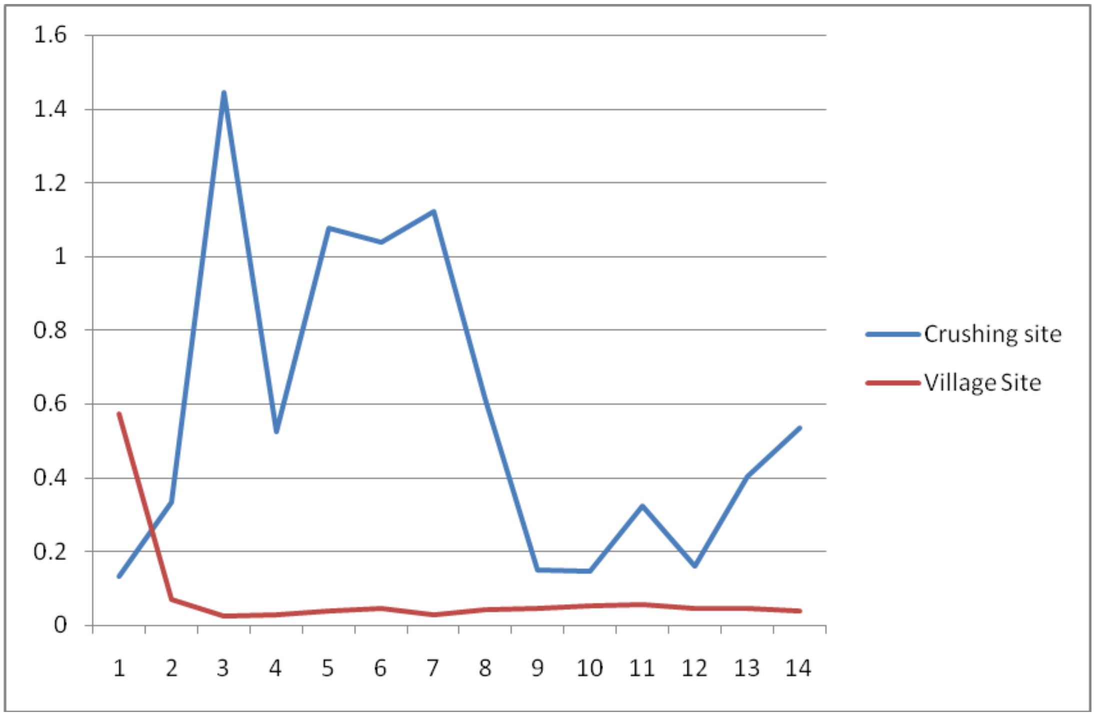

Figure 18: Mean 24 Hour PM 2.5 Concentrations for the Crushing and Control Sites

The WHO guide figure for Pm 2.5 concentration is given as 25 µg/m^3 (WHO, 2005). For comparison purposes, WHO (2005) requires 24 hour data collected over a 6 month period. The current study mean Pm 2.5 concentration is clearly above the recommended WHO guide value of 25 µg/m^3 and therefore exposes the Kajiado county residents to public health impacts particularly respiratory and cardiovascular diseases. This finding was confirmed in the qualitative analysis section where the respondents associated gypsum mining to dust pollution and consequent allergic skin and eye conditions. This findings are consistent with Kinney *et al*, (2012) that used a protocol similar to the one adopted in the current study to assess particulate matter concentration and came to the conclusion that particulate concentration above the WHO (2005) air quality standards resulted in public health effects. Karlson (2009) however, advises that for realistic analysis of the impact of particulate matter, it is advisable to evaluate the impact of Pm 2.5 concentration against acceptable pollution control standards.

The current study therefore, compared the study findings with the NEMA air quality guidelines (RoK, 2006) that allow a mean annual average tolerance concentration of 35 $\mu g/m^3$ and a 24 hour average of 75 $\mu g/m^3$. The current study observed Pm 2.5 concentrations that were consistently higher than the NEMA recommended rate of 75 $\mu g/m^3$ at the mine crushing site and the surrounding village except during the rainy season when the village sampling site posted a mean 24 hour reading of 58 $\mu g/m^3$. The guidelines recommend regular monitoring of Pm 2.5 concentrations wherever 2 consecutive Pm. 2.5 assessment readings exceed the regulation guidelines, and that the 24 hour average may not be exceeded more than 3 times in a year. It is an offense under the NEMA regulations for any person to cause the emissions that would exceed the Pm 2.5 levels indicated.

The qualitative and quantitative analyzes agree with Bada *et al* (2013) who used similar methodology to examine the quality of air near a quarry site and recorded significantly higher Pm 2.5 ($P < 0.05$) at the mine crushing site and loading section, while the least ($P < .05$) Pm 2.5 values were recorded at the neighbouring village. The Pm2.5 concentration decreased with increase in distance from the crushing site (Bada *et al*, 2013). An earlier study by Sharma and Siddiqui (2010), had used the same protocol to assess the air quality of an open cast area in India and obtained results comparable to the current study.

Sharma and Siddiqui (2010) noticed that peak particulate matter concentrations (945 μg/m^3) were recorded at the mine crushing site and the least (36 μg/m^3) recorded at the control site. They also established significant site-wise dust concentration variations (Sharma and Siddiqui, 2010). In the Chaulya (2004) study, site-wise variations were also reported, with maximum concentrations being noticed at the emission locations and a gradual diminishing of the dust concentration with increase of distance from the emission sources. Earlier studies also documented particulate matter concentrations that were higher than the recommended WHO (2006) guide values (Chaulya, 2004; Sharma and Siddiqui, 2010).

4.3.4.2: Outpatient Consultation Records

This study examined outpatient consultation records at health facilities located near the Nkama mine. The records examined included under 5 year old children and the rest of the population, aged above 5 years. The examination findings are summarised in Table 25. The medical records examination in relation to the health effects of particulate matter concentration investigations focused on 3 medical facilities within the vicinity of the Kibini mine namely the Ilmukutani dispensary, The PCEA dispensary and the East Africa Portland Cement (EAPC) Staff clinic. The Ilmukutani dispensary is located about 4 Km from the mine site while the PCEA dispensary is located 2 Km from the mine site. The health facilities outside the mine site were selected because the research purposed to investigate if there was any horizontal variation in particulate matter concentration and therefore, health effects among the sites (Kinney *et al* 2012)

As shown in Tables 25 and 26, most outpatient consultations in the study area, within the vicinity of the mine were on Upper Respiratory Tract Infections (URTI) which comprised of Bronchitis, pneumonia, coughing and nasal congestion. Other conditions recorded were Skin Infections that presented with wounds, rushes and lesions; Eye Infections and Abdominal diseases. Malaria, Typhoid fever and Urinary Tract Infections were also recorded. It is in addition indicated that in the month of September 2015, 401 outpatients visited the three medical facilities for medical attention.

Table 25 reveals that 187 (47%) of the outpatient consultations were diagnosed as URTI cases, 32 (8%) as skin disorder complaints and 30 (7.5%) as eye infections. The number of cases reported varied per medical facility. At the EAPC staff clinic, 42 (62%) of the outpatients sought URTI treatment while at the PCEA dispensary 89 (74%) sought URTI related treatment.

Table 25: Outpatient Consultation Rates per Health Centre (Dry Season)

Disease	Under 5 Ilmukutani	Under 5 PCEA	Under 5 EAPC	Over 5 Ilmukutani	over 5 PCEA	Over 5 EAPC
Diarrhoea	8	7	0	6	13	8
Dysentery	6	0	0	5	0	0
Malaria	10	3	0	10	0	0
UTI	2	3	0	22	3	7
Typhoid fever	2	0	0	8	0	0
Eye Infections	11	4	0	3	4	8
ear Infections	5	1	1	8	8	2
URTI	19	13	5	19	89	42
Skin disorders	11	8	0	10	3	0
Brucellosis	0	0	0	5	0	0
Total	**74**	**39**	**6**	**96**	**119**	**67**

Source: Research Data 2016

Variations were noted in consultation rates for outpatients aged less than 5 years old and those aged above 5 years. Out of the 119 patients aged below 5 years, 37 (31%) sought treatment for URTI, 19 (16%) for skin infections and 15 (13%) for eye infections. In the outpatients aged 5 years and above proportion, 282 patients visited the health facilities out of which 150 (53%) sought treatment for URTI, 18 (6.4 %) ear infections, 15 (5.3%) eye infections and 13 (4.6%) skin infections. Upper respiratory tract infections seem to affect the older population more than it does children aged below 5 years.

Table 26: Outpatient Consultation Rates per Health Centre (Wet Season)

Disease	**Under 5 cases Ilmukutani**	**Under 5 cases PCEA**	**Over 5 Ilmukutani**	**Over 5 PCEA**
Diarrhoea	6	4	5	7
Dysentery	6	0	3	0
Malaria	14	0	14	1
UTI	2	0	9	3
Typhoid fever	2	0	5	0
Eye Infections	5	0	8	2
ear Infections	3	0	6	1
URTI	12	14	14	17
Skin disorders	5	2	15	4
Brucellosis	0	1	25	0
Pneumonia	3	0	5	3
Joint pains	0	0	42	0
Total	**58**	**21**	**151**	**38**

Source: Research Data, 2016

There were also variations in consultation rates in the dry season and the rainy season (Table 26). The study observed that in January 2016 (Rainy season associated with the *elnino* phenomena), 79 children aged below 5 and 189 members of the community aged above 5 years visited the health facilities. The number of children aged under 5 seeking treatment for URTI marginally increased from 30% in the dry season to 33% while those aged above years decreased from 150 (53%) in the dry season to only 31(16%) in the rainy season. This is attributable to reduction of concentration of particulate matter in the atmosphere because of the heavy rains, which consequently reduced the public health risk as suggested by Amos *et al* (2010). Employing correlation between particulate matter (Pm 2.5) and meteorological variables in the united states of America, Amos *et al* (2010) came to the conclusion that Pm 2.5 concentrations depended on meteorological conditions in that the concentration of volatile concentrations increased with increase in temperature as a consequence of increased oxidation while for less volatile increase in temperature resulted in reduced concentration because of change from particle phase to gas phase. Amos *et al* (2010) further suggested that increase in precipitation led to a reduction in all Pm 2.5 components as a result of scavenging.

Those aged below 5 complaining of skin infections declined from 19 (16%) to 7 (8%) while those 5 years and older increased from 13 (5%) to 19 (16%). Water borne diseases such as typhoid fever, diarrhoea and dysentery among children aged below 5 increased from 23 (19%) to 18 (29%) while for those above 5 years it remained constant at 20 (11%). There was however, no statistically significant variation among the health facilities for the over 5 consultation rates and morbidity ($F(2, 27)$ 0.2214, $P < 0.8026$). This could be explained by the fact that inhalable particulate matter could remain in the atmosphere for days and weeks and subjected to long range trans-boundary transport in air, subsequently having the same health effects in the study area and neighbouring villages (Pless-Mulloli *et al*, 2001; Atuegbu, 2011; WHO, 2013).

In this study, key informant interviews revealed the presence of confounding factors on the effect of particulate matter on health effects of the study area residents. This included wind speed, indoor pollution associated with the traditional Maasai housing and the construction of residential houses very close to livestock sheds which subjected the residents to breathing far rich air that might contribute to upper respiratory diseases. Another confounding factor is the cultural practice whereby the study area residents sat on the ground including dusty grass, which possibly exposed them to more dust than people who sat on chairs. To control for the influence of confounding factors, the research stratified the respondents into two categories including those that work in the in the mines and are housed in modern company maintained house and the other strata comprising those who live in the village near the mines. The different strata yielded different results in terms of outpatient consultations, with those working in the mines being more affected.

The particulate matter sampling and medical consultations analysis results imply that people who spent long hours near the mines were of particular interest regarding the negative impacts associated with Pm 2.5 concentrations. During Key informant discussions with medical personnel at the EAPC staff clinic, it was reported that majority of those who sought medical attention at the facility were members of staff working either as machine operators or haulage drivers. The respondents perceptions analysed in qualitative section corroborate the finding that people living or working close to the mine site suffered adverse health effects such as sneezing, eye and skin allergies. The findings also agree with previous research by Orihuela (2014) while studying the governance regimes in smelting enterprises in Chile and Peru reported that in mining, the people directly affected by contamination were commonly those benefited by the polluting industry. The findings also agree with Ahmad *et al* (2014) who in an examination of health impacts arising from mining related particulate matter concentration, observed that 73% of respondents complained of eye irritations, 38% complained of suffocation, 37% chest pain and 21% suffered from sneezing.

The results further agree with Erdiaw-Kwasie, *et al (*2014), who used similar methodology and came to the conclusion that among the mining communities of Prostea in Ghana, the most prevalent diseases included respiratory diseases such as tuberculosis, asthma, common cold and catarrah whose source could be traced to dust deposition associated with mining activities in the study area. In the Erdiaw-Kwasie *et al (*2014) study, the other diseases attributable to mining in the study area included malaria arising from the mosquito breeding grounds made available by the abandoned mine pits and diarrheal diseases.

The suspected association of respiratory diseases with mining was previously theorized by Pope and Dockery (2006) who argued that long term exposure to elevated Pm 2.5 concentrations had potential to increase mortality from heart and lung diseases. In an attempt to understand the impact of particulate matter on human health, they noted evidence of Pm 2.5 related cardiovascular health effects and therefore, concluded that poor health resulting from asthma, URTI, Chronic cough were linked to air contamination. This line of thought was supported by Lepeule *et al* (2012) who investigated the association between Pm 2.5 concentrations and mortality and came to the conclusion that each increase of Pm 2.5 by 10 $\mu g/M^3$, was associated with an adjusted risk lung cancer mortality.

More recent literature too supports the existence of association between high concentrations of particulate matter and poor health conditions of people who spend substantial number of hours in areas of high particulate matter concentration. For example, the Air Quality Expert Group (AQEG) (2012), warn that since particulate matter, especially Pm 2.5 had the capacity to penetrate deeply into the human respiratory system, it had acute effects including increase in new hospital admissions, premature deaths of the old and the sick because of diseases of the respiratory and cardiovascular systems. Pm 2.5 is also known to worsen preexisting asthma conditions and increase the general feeling of unwellness which further leads to low activity and productivity (AQEG, 2012, Bada *et al* 2013).

The assertion about the health impacts of Pm 2.5 is further supported by WHO (2013), in a report of the health effects of Pm 2.5 maintains that it included inhalable particles that were small enough to penetrate the thoracic region of the respiratory system, thereby resulting in respiratory and cardiovascular morbidity (WHO, 2013). The long term exposure to Pm 2.5 was associated with an increase in the long term risk of cardiopulmonary mortality by between 6% to 13%, for every increase of 10 $\mu g/M^3$ of Pm 2.5.

4.3.4.3. Noise Level Measurements

To corroborate the study questionnaire findings on noise pollution impacts, the researcher carried out noise level measurements at the mining site. The specific areas and equipment targeted were the haulage trucks, the mine crusher, conveyor belt and the mine pit blasting area. Mine blasting is usually done at night to minimize its effect on public safety. Because of security reasons, it was therefore, not possible to sample the noise levels at the blasting point. The study however, obtained noise level measurements using sound level meter model : Cirruss CR: 832 C, serial number 022271FC, manufactured in 2012 and installed with deaf defier software. The noise meter was fitted with an MK: 216 microphone and an MV: 200 D caliber amplifier. Because the measurements were meant to be taken in the open area, a wind shield was placed around the microphone to reduce the influence of air turbulence. The sound meter employed had the capacity to measure and store overall sound values, noise history during each measurement. It also had the capacity to accumulate the total sound energy over the measurement period and calculate an average reading in Decibels. The average, maximum and peak values were calculated and the results compared with the standards prescribed by NEMA. Ahmad *et al* (2014) used a similar protocol to obtain noise pollution levels which were later compared with the standards prescribed by the Central Pollution Control Board of India. The field measurement results are shown in Table 27

Table 27: Noise Level Sampling Results

Sample	**Run Time**	L_{eq}	L_{max}	L_{Peak}
1	4.59	84.4	100.6	116.1
2	4.59	70.1	88.8	105.2
3	4.59	54.3	71.4	90.2

Source: Research Data 2016

Table 27 displays the noise meter readings for three samples taken at the mine crushing site that also houses staff residential buildings and a health facility, during peak working hours when haulage vehicles, the conveyor belt and the crushing machines were all running. The Sound meter was set to take one readings every 5 minutes within a range of 40: 110. The L_{eq}. indicated in the table refers to a decibel weighting equivalent to continuous sound pressure level during a period of time. L_{max} and L_{Peak} refer to maximum sound pressure level and peak sound pressure level respectively. From Table 27, it is evident that the average noise level was 81.4 dB, with highest peak of 116.1 dB. This is in agreement with the questionnaire analysis result where respondents attached little importance to loss of hearing as a consequence of gypsum mining noise levels

The meter readings were compared with the prescribed standard noise levels permissible by NEMA for mines and quarries. The NEMA (RoK, 2009) standards prescribe a maximum of 109 dB for buildings used as health centres, schools or residential areas located within the mining environment. The study average reading of 84.1 dB was lower than the NEMA maximum and therefore assumed to be tolerable.

The noise pollution findings are however, inconsistent with Kisku *et al* (2002) who used similar protocol to evaluate the impact of bauxite mining noise pollution levels on the health of mine workers and that of people living within the proximity of the bauxite mine. They investigated the various sources of noise including haulage trucks and mining equipment and compared the results to the local environmental regulator, the Central Pollution Control Board (CPCB). The

Kisku *et al* (2002) study came to the conclusion that mining equipment noise levels were much higher than the corresponding CPCB prescribed levels.

The differences in the study findings can be explained by the fact that while gypsum mining was undertaken in an open cast environment, the bauxite mine investigated occurred underground. Sengogut (2007), who considered occupational noise in mines and its control in the Western Lignite Corporation (WLC) sites in turkey, argued that occupational noise in underground mines tended to be unbearable due to the reverberant nature of the narrow mining spaces. In the Turkey study, Sengogut (2007) noted that both surface and sub surface mining noise measurements revealed undesirable noise levels (83 – 90 dB), which was above the nationally acceptable noise standard value of 87dB. Sengogut (2007) advises that although noise levels from open cast and underground mining were similar in intensity, the noise impacts were less significant in open cast mines because the noise emitted from the equipment easily spread hemi-spherically in the free sound fields.

4.4 The Intervening Policy Environment

In assessing the environmental impacts of gypsum mining, the influence of the intervening variables was important as a guide to policy initiatives. The researcher purposed to investigate the prevailing role of policy on the scale adopted by the environmental impacts of gypsum mining. A Likert scale was prepared and a total score for each respondent prepared. These together with other items were each rated on a 5- point Likert scale ranging from: 1 = Strongly Agree to 5 = Strongly Disagree and the results summarised below in Table 28

The results in Table 28, point to concurrence by the respondents that Gypsum mining in their area is well regulated (χ^2 = 42, P $\leq$ 0.001). More so the respondents agreed that the environmental impacts of gypsum mining in their area had been well addressed by the government authorities (χ^2 = 38, P $\leq$ 0.001). However, the respondents were unsure on enforcement of health issues being well taken care of by the government (χ^2= 38, P $\leq$ 0.001). The respondents were also uncertain on the mining policy being followed in guiding the mining in this area (χ^2 = 64, P $\leq$ 0.001), just as being equally uncertain on being adequately represented in decision making in regards to sharing and benefitting from natural resources in their county (χ^2= 24, P $\leq$ 0.001). The respondents' agreed to there being sufficient information and education to help deal with the health and environmental risks of mining (χ^2= 15, P $\leq$ 0.001).

Table 28: The Intervening Policy Environment

Mining policy & regulation	SA	A	U	D	SD	χ^2	P-value
Gypsum is well regulated	5(5.3)	39(41.1)	28(29.5)	12(12.6)	10(10.5)	42.915	.000
The environmental effects have been well addressed	7(7.4)	32(33.7)	35(36.8)	10(10.5)	10(10.5)	38.872	.000
Enforcement of health issues is well addressed by government	2(2.1)	21(22.1)	39(41.1)	13(13.7)	20(21)	38.421	.000
The mining policy has been enforced	3(3.2)	18(18.9)	48(50.5)	11(11.6)	13(13.7)	64.366	.000
I am adequately represented in decision making	5(5.3)	14(14.7)	32(33.7)	17(17.9)	27(28.4)	24.105	.000
There is sufficient information and education on risks of mining	5(5.3)	26(27.4)	25(26.3)	17(17.9)	22(23.2)	15.474	.000

Source: Research Data, 2016

The findings are in agreement with those of Panagos and Grant (2013) who examined the impact of constitutional change in Canada on aboriginal mining rights and made the observation that Aborigines' affected by various mining projects did not just want a fair share of the mining resources, but also strived for participation in the management of the resources. Like the Aborigines, the Maasai in the current study area expressed desire to share in the power to make decisions about the fate of their land and the resources it supported. In the words of Panagos and Grant (2013), the mining area residents wanted to be partners in the gypsum resource management. The wish of the Maasai of Kajiado County to participate in the management of gypsum extraction is not unreasonable because as it is aimed at guaranteeing sustainability of resource extraction. Sustainable development requires stronger governance institutions that facilitate accountability and transparency through inclusive and responsive participation of all stakeholders.

4.5 Inferential Statistics

Inferential statistics is the process of using descriptive statistics to estimate population parameters and draw conclusions about the population. It makes inferences about the population using data drawn from the population and reach conclusions that extend beyond the immediate data. It employs hypotheses testing, common tests such as t-tests, ANOVA tests and regression analyzes to confirm or reject study claims.

4.5.1 Correlation Analysis

In this section, the results for specific research hypothesis are presented using Pearson's correlation test. To investigate the relationships among the constructs a Zero-order correlation table was generated where the correlation coefficient measures the degree to which changes in the value of one variable approximate change in the value of another variable. Pearson correlations were run to ascertain the relationships between the study variables. The analysis was based on the premise that a positive correlation indicates the extent to which those variables increase or decrease in parallel while a negative correlation indicates the degree to which one variable increases as the other decreases.

The correlation summary presented in Table 29 indicates a moderate but significant relationship within the variables. From the correlation results, it was established that mining had significant positive effect on livelihood in the Kajiado County($r = 0.346$, $\alpha = 0.001$). This shows that there is a positive socio-economic impact on the county residents connected with gypsum mining activities.

Regarding the impact of gypsum mining on landscape, the study had set out to explore whether mining activities had any effect on the county landscape. The correlation results indicated a negative insignificant relationship ($r = -0.099$, $\alpha = 0.340$). This implies that as the area under mining increased, landscape aspects such as bio-diversity, vegetation cover, habitats and aesthetic beauty deteriorated. Overburden removal and dumping of gypsum waste (Fig. 19 and Fig. 20) were identified as the most common form of bio-diversity destruction.

Concerning water, the study aimed to establish whether mining activities had any impact on water quality parameters in Kajiado County. The correlation results indicated a non significant relationship ($r = .098$, $\alpha = 0.347$). Finally, the study also sought to determine whether the gypsum mining activities had any significant impact on the air quality in Kajiado County. The correlation results show a significant effect on air quality ($r = 0.545$, $\alpha = 0.001$), with gypsum mining explain 54.5% of the air quality impacts.

Table 29: Correlation Analysis Results

		Livelihood	Landscape	Water Quality	Pm 2.5	Mining
Livelihood	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	95				
Landscape	Pearson Correlation	-.288**	1			
	Sig. (2-tailed)	.005				
	N	95	95			
Water quality	Pearson Correlation	.342	.411	1		
	Sig. (2-tailed)	.034	.010			
	N	95	95	95		
Pm 2.5	Pearson Correlation	-.218*	.262*	.223	1	
	Sig. (2-tailed)	.001	.340	.347	.001	
	N	95	95	95	95	
Mining	Pearson Correlation	.346**	-.099	.098	.545	1
	Sig. (2-tailed)	.001	.340	.347	.001	.001
	N	95	95	95	95	95

**Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Research Data, 2016

Figure 19: Gypsum Tailings Dumping in the Study Area

Figure 20: Benched Deep Open Cast Activities in the Study Area

4.5.2 Cross Tabulation

Cross tabulation results indicated the respondents agreed that mining had an important (64) influence the livelihoods of Kajiado residents. It established mining having importance and being a positive measure (40) (Table 30).

Table 30: Cross Tabulation of Effect of Mining on Livelihood

		Effects of Mining On Livelihood					Total
		LI	SI	NS	I	EI	
Mining	Very Positive	0	0	0	1	0	1
	Positive	14	0	0	32	4	40
	Not Important	3	4	1	14	8	30
	Negative	1	3	1	16	1	22
	Very Negative	0	1	0	1	0	2

Source: Research Data 2016

Cross tabulation results as shown in Table 31, also indicated that Landscape aspects had very negative (64) influence on the resident's though mining had positive (59) attributes to the residents.

Table 31: Cross Tabulation Results on Effects Gypsum Mining on Landscape

		Effects of Mining On Landscape					Total
		VP	P	NS	N	VN	
Mining	Very Positive	3	0	0	0	0	3
	Positive	42	8	1	0	8	59
	Not Important	18	0	1	1	8	28
	Negative	1	0	0	1	1	3
	Very Negative	64	8	2	2	17	93

Source: Research Data 2016

Cross tabulation results for landscape as indicated in Table 32 revealed that majority of the residents strongly agreed (64) mining had an effect on water though they stated it not being an important factor (42)

Table 32: Cross Tabulation Results on Effect of Mining on Water Quality

		Effects of Mining On Water Quality					Total
		SA	**A**	**N**	**D**	**SD**	
	Very Positive	1	0	0	0	0	1
	Positive	13	3	0	0	3	19
Mining	**Not Important**	30	3	0	1	8	42
	Negative	10	1	2	1	6	20
	Very Negative	10	1	0	0	0	11
Total		64	8	2	2	17	93

Source: Research Data 2016

Table 33 demonstrates confirmation by cross tabulation that the residents placed little importance on their public health (64) and further stated that mining was not an important factor (41) to air quality.

Table 33: Cross Tabulation Results for Impact of Gypsum Mining PM 2.5

		Effects of Mining On Pm 2.5					Total
		LI	**SI**	**NS**	**I**	**EI**	
	Very Positive	1	0	0	0	0	1
	Positive	14	4	0	1	5	24
Mining	**Not Important**	29	2	1	1	8	41
	Negative	11	2	1	0	3	17
	Very Negative	9	0	0	0	1	10
Total		64	8	2	2	17	93

Source: Research Data 2016

4.5.3 Regression Analysis

Regression analysis was used to create the line of best fit, visualize the general trend in the dataset and make predictions about dependent variables from the independent variable. Regression is normally used when research is intended to predict the value of a dependent variable given the value of an independent variable. Regression analysis was therefore, used to determine how the independent variable influenced the dependent variable and demonstrated the extent to which the independent variable affected the dependent variable. It also gave an indication of the factors that is more significant, as shown in Table 34

Table 34: Regression Analysis Results

Model	R	R Squared	Adjusted R Square	Std of Error Estimate
1	0.720^{α}	0.518	0.514	0.54947

a. Predictor : (constant) mining industry activities
b. Predictor: livelihood, landscape, water quality and air quality
Source: Research Data, 2016

The square value of $r^2 = .518$ indicates that when all the variables are combined, the multiple linear regression model could explain for approximately 52% of the variation resulting from mining industry in Kajiado County.

Table 35: ANOVA Table

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	3.279	3	1.093	5.447	$.002^{b}$
1	Residual	18.258	91	.201		
	Total	**21.537**	**94**			

a. Independent Variable: mining industry
b. Dependent Variable: Livelihood, landscape, water quality and Particulate matter
Source: Research Data, 2016

The Anova results shown in Table 35 indicate an overall significance of 0.002. The overall relationships between the dependent and independent variables will be of the most importance in a linear regression model. A negative value implies that the expected value on the dependent variable will be less than zero when all independent/predictor variables are set to zero.

Table 36: Multiple Linear Regression Results

	Unstandardized Coefficients		**Standardized coefficients**	**t**	**Sig**	**Collinearity statistics'**	
	B	**Std Error**	**Beta**			**Tolerance**	**VIF**
(Dependent)	.241	.147		1.644	.104		
Livelihood	.401	.109	.375	3.679	.000	.895	1.117
Landscape	-.041	.104	-.041	-.396	.693	.876	1.142
Water quality	.203	.108	.190	1.878	.064	.909	1.100
Air quality	500	.101	.450	3.411	.001	0.888	1.126

a. Independent variable: Gypsum mining operations

The findings in table 36 demonstrate significance on livelihood aspects (p = 0.000) in the gypsum mining in Kajiado county and little or no significance in the landscape aspect's (p = 0.693). The findings further showed significance in the water quality impacts (p= 0.064). The study also found significance in the issues of air quality (p = 0.001). From the data in the above table the established regression equation was: Y = 0.241 + 0.375 X1 + -0.41 X2 + 0.190 X3 + 0.450 X4 ε.

From the above regression equation it was revealed that, if we were to hold mining activities at zero, the impacts on livelihood, landscape, water quality and air quality be at 0.241. A unit increase in mining would therefore lead to increase in livelihoods by a factor of 0.401; a unit increase in mining would lead to decrease in landscape characteristics by a factor of -0.041 while a unit increase in mining activities would lead to increase in impacts on water quality by a factor of 0.203. Finally, a unit increase in mining activities is expected to result in air quality impacts escalation by a factor of 0.500.

The VIF value for all the independent variables were lesser than 10, and the tolerance was also less than 0.1, implying that the questions in the questionnaire were not closely related. Therefore, there was no concern over multi collinearity. This led to the conclusion that mining activities impacted on livelihoods, landscape, water quality and air quality in Kajiado County. The dependent variable which was most important in the mining operations was also determined. This was obtained by the beta value where upon the results in Table 36 identified the effects of mining on air quality as the most significant variable of the study followed by livelihood then by water quality and landscape lastly in that order. The beta value for these variables 0.450, 0.375, 0.190 and -0.041 indicate that the dependent variables would change by a corresponding number of standard deviation when the respective independent variable altered by one standard deviation.

4.6 Hypotheses Testing

Hypothesis testing enables research to make probability statements about population parameters. In this section therefore, the specific objectives of the research are reviewed, hypotheses tested and implications explained.

4.6.1 Specific objectives

Ho_1: Gypsum mining has no significant impact on the livelihoods of residents of Kajiado County

Regression results showed that the livelihoods factors were significantly influenced by mining operations (β = 0.375; p value = 0.000 and t value 3.679) and thus the null hypothesis was rejected. This implies that mining positively impacted on livelihoods assets, and that the inclusion of physical and social infrastructure, support for social cultural values and heritage were quite significant catalysts in the expansion of livelihoods associated with gypsum mining operations in Kajiado County.

Ho_2: Gypsum mining has no significant impact on the landscape in Kajiado County.

Regression results showed that mining operations did not significantly impact on the landscape (β = -0.41; p value = 0.693 and t- value = -0.396) and thus the null hypothesis was not rejected. The implication of this is that the respondents did not recognize the potential and actual destruction of vegetation, bio-diversity and land dereliction as undesirable impacts of gypsum mining. Measures should therefore, be put in place to raise awareness levels on environmental impacts against the short term benefits of gypsum mining. Ignoring the negative impacts would compromise the livelihood assets of the residents.

Ho_3: Gypsum mining has no significant impact on water quality in Kajiado County.

Regression results showed that the water quality parameters were significantly influenced by mining operations (β =0 .190; p value = 0.064 and t- value = -1.878) and thus the null hypothesis failed to be rejected. The implication of this is that the quality of water ought to be safeguarded by mining companies to sustain the interests of the residents of Kajiado County within NEMA and WHO (2006) standards. Ignoring these factors will lead to high waterborne consultation rates in the study area and possible negative relations between the residents and the mining industry stakeholders.

H_{04}: There is no significant impact of gypsum mining on air quality in Kajiado County.

The regression results showed that mining operations significantly influenced air quality factors ($\beta = 0.450$; p value = 0.001 and t- value = 3.411) and thus the null hypothesis was rejected. The implication of this is that the Kajiado County residents viewed mining activities as a contributor to air pollution through respirable dust deposition that consequently led to undesirable health effects and poor health particularly allergic skin conditions, eye infections and upper respiratory tract infections.

4.7 Study Limitations

The study encountered a few limitations relating to access to data, recollections of events by participants and feelings such as:

i) Lack of satellite imagery in relation to the date of commencement of mining activities. Mining activities commenced in 1956 but the earliest satellite image available was developed in 1984. This led to an examination of the landscape impacts for only 30 years instead of the earlier planned 30 year cross sectional study. To minimize the effect of lack of imagery, the study corroborated key informant recollections on the status of vegetation and pasture with topographical maps prepared in 1972. The influence of this limitation on the overall research findings is therefore insignificant

ii) Fluency in local language. The study was conducted in a rural pastoral setting where literacy levels are low. Since the study also involved the assessment of perceived impacts of gypsum mining, the questionnaire study was conducted with the help of an interpreter because the researcher was not fluent in *Maasai.* The researcher therefore relied on the understanding and interpretation of the interpreter and presents possible loss of information. To reduce the influence of this, the researcher asked some of the questions of the study to key informants including heads of government departments responsible for environmental management. Loss of information during interpretation was therefore, kept to the minimum.

iii) Low retrieval of administrative data in county government offices. The research relied on administrative data on outpatient consultation rates. From key informant discussions, it emerged that by the time of commencement of mining activities, there was only one medical facility that was located outside the study area. Visits to the said facility (Kajiado District Hospital) did not yield any data dating back to 1956. The study therefore, relied on the perceptions of respondents that associated URTI diseases to the mining activities and the medical personnel who singled out those that work in the mine crushing area as the most affected since they formed majority of those that sought treatment for URTI. This however points to the need for further research to determine if there are other factors contributing to the present outpatient consultation trends.

iv) The researcher was unable to carry out soil sampling and analysis for soil pollution and toxicity. This was made difficult due to the nature and benefication of gypsum adopted by the mining companies that necessitated spreading out of gypsum ore in the open fields adjacent to the mining pits. The ore covered and possibly altered huge tracts of land around the mines. As an alternative, the research investigated the concentration of trace metals in the water bodies in the study area with the understanding that it the gypsum ore contained trace metals, they would be washed down and deposited in the water bodies by runoff. The results obtained suffice and the overall research findings are not therefore significantly affected.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This Chapter presents a summary of findings, conclusions, and recommendations arising out of the research results in chapter four and suggests areas for further research. The conclusions made are based on the integration of the qualitative and quantitative statistics. The overall objective of this study was to assess the environmental impact of gypsum mining in Kajiado County. More specifically, the study sought to assess the impact of gypsum mining on livelihoods, landscape, water quality and Particulate matter concentration. The study generated a number of findings, most of which are in agreement with existing literature and previous research findings.

5.2 Summary of Findings

i) The first objective of this study was to assess the impact of gypsum mining on livelihood in Kajiado County. To determine the extent of gypsum mining on livelihood, a Likert scale of measuring attitudes was used with importance rating. In Table 14, it is demonstrated that Kajiado residents place very high importance on opportunities and capacities afforded by gypsum mining through the enhancement of their assets and by extension their livelihoods. Employment is an important element in the mining areas in Kajiado County since it had the strongest association to the importance of gypsum mining while earnings from their lands indicated the least association to the importance.

ii) Infrastructure (such as roads) which according to key informants had encouraged secondary economic activities, was also rated very important alongside the development of social infrastructure (such as schools, hospitals and water projects) which benefitted out community members. Compensation, for land acquired by mining businesses was not considered as an important aspect of their livelihood alongside the opportunities for formal education and literacy programs for community (scholarships/bursaries) which had been provided ranked minor important. Subsequent analysis found significant association ($r = 0.346$, $\alpha = 0.001$). This shows that there is a significant and positive relationship existing between the gypsum mining industry and the County residents. The null hypothesis was thus rejected and the alternate hypothesis accepted.

iii) The second objective sought to investigate the impact of gypsum mining on the landscape in Kajiado County. Qualitative data revealed that the impact of gypsum mining on landscape was mainly felt in terms of the destroyed vegetation cover and the general aesthetic appearance of the county landscape. The impact on landscape by destruction of vegetation and habitats was indicated as a very important issue of concern ($\chi^2 = 230$, $P \leq 0.001$), while the contribution general physical appearance of land was indicated as important ($\chi^2 = 241$, $P \leq 0.001$). The County residents were least worried about the accumulation of gypsum mining associated dust on pasture ($\chi^2 = 50$, $P \leq 0.001$) and the general contribution of mining to the County landscape. Regression results showed that the landscape factors were not significantly influenced by mining operations $\beta = -0.41$; p value = 0.693 and t value = -0.396 and thus the null hypothesis was not rejected.

iv) The third objective sought to establish the impact of gypsum mining on the quality of water in Kajiado. Qualitative results revealed that the county residents attach little importance to gypsum mining as a contributor to the quality of water. The County residents however, associated changes of the water table to mining activities, chiefly as a result of improved percolation and ground recharge owing to the many mining pits doting the landscape (Fig.13). Regression results showed that the water quality factors were not significantly influenced by mining operations, $\beta = 0.190$; p value = 0.064 and t value = -1.878. Quantitative analysis revealed elevated bacterial concentrations which led to high waterborne consultation rates in the County. However, the bacterial contamination was an indirect result of the human activities in the vicinity of the mining sites, especially runoff and poor sanitation practices. The null hypothesis was thus rejected.

v) The fourth objective sought to examine the impact of gypsum mining on particulate matter (Pm 2.5) concentration. The County residents were mainly concerned with contribution of gypsum blasting and crushing to air pollution as evidenced by outpatient consultations on allergic skin reactions, upper respiratory tract infections and cardiovascular infections. Analysis of air samples indicated elevated particulate matter concentrations above the WHO (2005) guide values while key informant interviews and out-patient record perusal revealed high respiratory effects associated with gypsum mining dust. Regression results show that mining operations significantly impacted on air quality factors, $\beta = 0.450$; p value = 0.001 and t- value = 3.411 and thus, the null hypothesis was rejected.

5.3 Conclusions

From the findings of objective one, it was revealed that mining positively impacted on the livelihoods of Kajiado County residents. Scrutiny of satellite imagery however, established significant destruction of fauna and flora owing to open cast mining operations in the study area. These threaten the livelihood assets and environmental sustainability. The loss of bio-diversity could lead to unavailability of Wildlife and birds breeding grounds and subsequently lower earnings from Wildlife and Tourism related activities. The accompanying loss of trees and pasture also has the potential to disrupt the local pastoralist economy.

Based on key informant interviews and respondents perceptions revealed from the questionnaire study, it was also concluded that the extractive industry in Kajiado made an important contribution towards living standards and economic prospects of the County. Provision of employment opportunities being the resolving factor on livelihoods of the county residents was significant and important. It is thus, vital that measures are taken to establish a well regulated mining regime that would sustainably guarantee the livelihoods of the study area residents through improved land compensation, contributions to educational development through the provision of scholarship and bursaries and support to development of cultural heritage activities.

The study also observed positive outcomes to the livelihoods of some of the households of the study area. As a consequence of gypsum mining, some households noted improved earnings associated with local trade, procurement and employment opportunities. These reduced household vulnerability to external shocks such as drought and effectively ensured livelihood sustainability.

The study however, observed some negative impacts on livelihoods of some households in the study area. As the area under gypsum mining expanded, the households lost valuable pasture land. This affected livestock development because the land compensation earnings were not commensurate with the anticipated earnings from livestock farming and therefore, probably brought the household financial position to a worse situation than before mining. This led to frustration hence the regular confrontations witnessed between the gypsum mining companies and the study area residents. It can further be concluded that Kajiado residents desired to be involved in the regulation and management of gypsum mining activities with a view to protecting the population from adverse impacts and guaranteeing the flow of livelihood supporting benefits.

As regards to objective two, it was concluded that landscape was not an important aspect to the residents of Kajiado County. Environmental importance had been sidelined for commercial benefits accruing from mining related activities. It is worth noting that the loss of woody plants and pasture due to top soil removal, trampling by heavy machines and haulage potentially contributed to climate change due to possible release of carbon dioxide and other green house gases into the atmosphere. Trampling of pasture by haulage vehicles resulted in further degradation while dust deposition on grass lowered the livestock carrying capacity of the study area.

Since gypsum mining was majorly done through open cast mining, it resulted in land dereliction that devalued the scenery of the natural landscape and exposed the study area residents to accidents. Human and livestock deaths and injuries resulting from in abandoned mine pits compromised livelihoods of the Kajiado County residents.

From the results on objective two, it was apparent that the study area residents were least concerned with the impacts of gypsum mining on landscape, particularly land dereliction. This could be explained by the low awareness levels of local environmental destruction. A global view such as the one afforded by imagery analysis however points to significant land degradation and loss of bio-diversity.

From the findings of objective three, prevalence of waterborne diseases associated with mining indicates reduced participation in livelihood activities by the affected Kajiado residents as a result of the consequent hospital visits. Financial resources spent on the treatment of the waterborne diseases by the affected households unnecessarily increase the households' budget and diverts household resources away from productive livelihood activities. Measures have to be put in place to safeguard the water quality and availability to the residents. The elevated bacterial concentration levels are more of an indirect impact of gypsum mining on water resources than a direct one. The anthropogenic activities associated with Gypsum mining coupled with poor hygienic and sanitation standards lead to water pollution.

It can also be concluded that there is need for awareness creation to the study area households to embrace safe water treatment practices so as to control the effects of some of the waterborne diseases. The more vulnerable groups such as children aged under 5 years should be targeted for prevention of diarrheal diseases through home based sanitation programmes.

From the findings of objective four, it is probable that mining activities released respirable air pollutants (particulate matter) to the environment. Air pollutants such as Pm 2.5 were detected at elevated levels above the WHO (2005) guide value. Highest Pm 2.5 concentrations observed at the mine crushing site compared to the nearby villages. This was attributed the fact that dust from the crushing plant was pressurized and therefore, spread further away from the crushing plant. The respirable pollutants are seen to significantly influence aspects pertaining to the health and safety of Kajiado County residents.

5.4 Study Recommendations

Objective number one found out that gypsum mining had a very important influence on the livelihood of Kajiado residents. It is therefore, recommended that:

i. The extractive industry be better regulated to empower county residents through development opportunities and benefit sharing agreements to further advance residents' participation in gypsum mining and related economic activities designed to improve living standards in the County.

ii. Gypsum mining and the extractive industry in general could benefit from more elaborate recognition in the Constitution and support through budgeting at National and county level. This calls for a constitutional amendment to give mining specific reference and roles as per the expectations of Kenyans, instead of grouping mining together with all other natural resources.

iii. Enactment of County level legislations to regulate conservation and the participation of County residents and communities in the extractive industry and guarantee the flow of benefits to the individual land owners, communities and the County Government of Kajiado.

iv. The study recommends enhancement of physical capital through the expansion of infrastructural facilities such as electricity, water, rural roads and health facilities. These together with improved scholarship opportunities, could broaden the range of livelihood alternatives available to the households in the study area.

v. To enhance the role of infrastructure, particularly the livelihoods supporting county road network, the study recommends use of less dusty road construction materials such as murram, limestone and rocks. This is necessary so as to protect the roads regularly used by haulage trucks around Isinya where road maintenance is poor. This would also reduce the amount of dust generated by the haulage trucks and significantly reduce the health effects of particulate matter deposition.

Objective two established that, landscape aspects had very little importance on the current experiences of the Kajiado residents. It was evident that environmental protection regulations had not been implemented to discourage land derelictions. It is thus, recommended that:

i) While it is not possible to completely protect the study area from the negative effects of gypsum mining, it is important to consider the possibility of land rehabilitation and re-vegetation after a period of gypsum mining. The reforestation must be carefully carried out, preferably using species of trees that existed before mining. This would ensure the integrity of the restored habitats and compatibility with the study area wildlife diversity.

ii) For logistical and scientific support, the study recommends the setting up of a floating fund to be managed by the National government to facilitate the rehabilitation of dynamically changed mining landscape.

iii) It is recommended further that the County Government and the concerned authorities at the National level put in place stringent measures to curb land degradation as envisaged in the EMCA. The EMCA regulations on mining should be enforced and the Environmental Management Plans (EMP) for respective gypsum mines be implemented as indicated in the Environmental Impact Assessment reports that are usually prepared before extraction activities commence.

iv) Efforts should be initiated to make the surface mined productive, beneficial and visually attractive through re-vegetation. This must be done taking into account the local needs of the community. Effective rehabilitation will not only restore the ecological integrity of the mined area but also the most pleasing aesthetic experience for the Kajiado residents. Care should be taken to ensure the rehabilitation process considers re-establishing pre-existing native habitats and blends the landscape into the greater surrounding of the Maasai community.

v) The mining industry operators should assist the County Government to improve on environmental protection performance through the establishment of an enforcement network to promote information exchange and best practice, and by the provision of appropriate guidance. There should be enforcement in respect of breaches of mining permits, taking action in relation to illegal dumping of tailings, implementation of land restoration requirements and enforcement of polluter pays initiatives.

vi) To make gypsum mining more sustainable, it is recommended that the industry stakeholders be encouraged to gradually shift to less polluting crushing and blasting technologies and take into account the physical sustainability of gypsum as a resource in the context of local ecosystems. This would lead to the management of gypsum in a manner that respects all dimensions of development including economics, politics, technology, local knowledge and spiritual balance. In the long run, the cement manufacture industry must be encouraged to substitute gypsum with more environment friendly materials.

Objective three found that the water quality was very important to the survival of the pastoral economy and residents. The study encourages the Provision of information on treatment, conservation and use of water by the relevant technical departments of the County Government. Community based sanitation extension services especially on the development and use of pit latrines. This could reduce the levels of drinking water contamination observed

Objective four confirmed that public health and safety associated with air quality was also an important aspect in Kajiado County. To minimize the impacts of Pm 2.5 on human health, it is recommended that:

i) The location of mining sites in places near residential areas be discouraged. The mining operation areas should be located at sites buffered by vegetation particularly dust attenuating plant species that would act as sink blocks for the offensive particulate matter in active mining areas and abandoned mine pits. The mining industry stakeholders ought to improve on provision of public health facilities and in due course, safety on the miners in the mines and outside the extraction areas.

Existing abandoned mines should be fenced off to minimize accidental livestock and human deaths.

ii) It is possible to reduce particulate matter concentrations using the current technologies through relevant regulatory measures and structural changes, such as enforcement of land use planning measures. The County Public health office, NEMA and land use planning authorities should be facilitated to implement environmental management regulations.

iii) The mine crushing site should be made safer by installing a bug filter and sprinkler along the conveyor belt to reduce the amount of fugitive dust. The study also recommends the installation of affordable particulate matter sensors at mining sites for real time capture of data on dust pollution and efficient tracking by environmental monitoring institutions.

iv) Since the impact of air pollution associated with particulate matter is significant, even at relatively low concentrations, it is necessary for institutions with vested interest in air quality such as ministry of environment, water and natural resources in close collaboration with the Ministry of mining and health to devote sufficient budget and personnel to facilitate timely diagnosis and treatment of associated health effects and reduce their effect to a minimum.

v) To safeguard the public health and wellbeing of mine workers and residents of villages near the mining sites, there should be extensive public health campaigns in the study area particularly with regard to the effect of dust on human health. This would raise awareness and encourage participation at the grassroots level. Further, institutions responsible for Public Health, such as NEMA and the Directorate of public health should carry out regular inspection of the mining sites and issue warnings, impose fines or even recommend closure of the offending mines in the interest of public health and safety. To reduce outpatient consultation rates and encourage prompt remedial action, the trade union movement in the mining industry should be strengthened to enable reporting of safety breaches in close collaboration with line managers.

5.5 Recommendation for Further Studies

i) The Constitution of Kenya (2010) vests the ownership of minerals in the National Government although the impacts of extraction are felt more at county level. Investigations should be undertaken to establish how host communities could be effectively empowered to engage in the decision making processes and develop localized mitigation measures to protect the environment.

ii) The reported impact on air quality is based on observed particulate matter (Pm 2.5 concentration) and key informant discussions. Aware that Particulate matter concentrations and by extension its impact depend on meteorological conditions, it is recommended that a further study be made to reveal the contribution of temperatures, humidity and wind speeds to the current Pm 2.5 concentration and impacts on air quality in Kajiado County.

iii) The study did not involve an evaluation of radiation risks associated with gypsum tailings in the study area. Since the study area is replete with tailing, it would be necessary to examine their radiation potential and possible health risks.

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APPENDICES

APPENDIX I: Letter of Introduction

Dear Participant:

My Name is Kefa Omoti and I'm a graduate student at Kabarak University. For my Dissertation, I'm assessing the environmental impacts of extractive industries: a case study of gypsum mining in Kajiado County.

Because you work in the mines or are resident in the villages surrounding the mines, I'm kindly inviting you to participate in the study by completing the attached questionnaire. The questionnaire will require approximately 20 minutes of your time to complete. There is no compensation for participating nor is there any risk.

Please answer all questions as honestly as possible and return the questionnaire to the research assistant. The data collected will provide useful insights concerning the impacts and the possible policy interventions. If you require additional information or have any questions, please contact me at the number indicated below.

Sincerely,

Kefa Omoti

0718003514

APPENDIX II: Survey Questionnaire for Mine Workers

AN ASSESSMENT OF ENVIRONMENTAL IMPACTS OF EXTRACTIVE INDUSTRIES: CASE STUDY OF GYPSUM MINING IN KAJIADO COUNTY, KENYA

Serial No._______

Location_________Sub-location__________Village_____________ Date_________

SECTION A: BACKGROUND DETAILS OF RESPONDENT

a) Gender of respondent (please tick applicable)

1) Male ☐ 2) Female☐

b) Marital status of respondent

a) Single ☐ 2) Married ☐ 3) Separated/Divorced ☐

4) Widowed ☐ 5) Other☐

c) What is your highest education level attained to date?

1) No formal education ☐2) Primary school ☐

3) Secondary school (not completed)☐ 4) Secondary school (completed)☐

5) Tertiary or other college☐ 6) University ☐

SECTION B: EMPLOYMENT AT THE MINE SITE INFORMATION

a) What is your specific job at the mine site at this particular time? (Please tick one)

1. Casual labourer (mining and loading) ☐ 2) Clerical work☐

3) Supervisor/managerial☐ 4) Transportation ☐

b) Other (please specify)__________

b) Please provide the following work information at the mine.

1. Average number of hours you work per week_________
2. Number of years worked at the mine (please tick one)

c) Approximately how many workers are employed in your particular mine when the mine is operating at full capacity? ______________

SECTION C: IMPACTS OF GYPSUM MINING ON LIVELIHOODS

The following questions ask for ranking based on the scale provided. Using the scale, please indicate how important you consider the mining activity on the various aspects of your economic and physical well-being:

Impacts Of Gypsum Mining On Livelihoods	**NI**	**MI**	**FI**	**I**	**VI**
Provided supporting infrastructure(such as roads) which has encouraged secondary economic activities					
Provided social infrastructure such as schools and hospitals which have benefited the community					
Land owners Benefited from compensation for land acquired for mining					
Provides opportunity to obtain formal education and literacy through programmes with local schools					
Gypsum mining contributed to the county revenue in form of direct payments, royalty payments and community trust funds					
Gypsum mining supports community cultural values and heritage					

activities					
Gypsum mining facilitates linkages between the local community and the government at the county and national level					
Gypsum mining contributes towards accumulation of dust on crops and pasture					
Community members have benefited from local procurement opportunities					
Gypsum mining has improved employment opportunities					
Gypsum mining has improved local trade opportunities					

Key: NI- Not Important, **MI**- Minor Importance, **FI**- Fairly Important, **I**- Important, **VI-** Very Important

SECTION D: IMPACT OF GYPSUM MINING ON LANDSCAPE

Using the scale given below where. Indicate the extent to which you feel the statements reflect the impact on the gypsum mining on the landscape:

Impacts of Gypsum Mining on landscape	**VP**	**P**	**NI**	**N**	**VN**
What do you feel is the impact of gypsum mining on the overall land cover/Use?					
What influence does gypsum mining have on vegetation and Habitats					
What effect does gypsum mining have on the physical appearance (Morphology) of land?					
What contribution does gypsum mining make towards accumulation of dust on crops and pasture?					
What contribution does gypsum mining companies make to environmental management programmes					

Key: VP- Very positive, **P**- Positive, **NI**- No impact, **N**- Negative, **VN**- Very negative

SECTION E: IMPACT OF GYPSUM MINING ON WATER QUALITY

Using the scale given to what extent do you agree or disagree with the following statements:

Impact of gypsum mining on water quality	**SA**	**A**	**U**	**D**	**SD**
Gypsum mining negatively affects the quality of surface water					
Gypsum mining negatively affects the quantity of water available					
Storm Water runoff mixed with gypsum waste contaminates water sources					
Gypsum mining might affect ground water table					

Key: **SA**- Strongly Agree, **A**- Agree, **U**- Unsure, **D**- Disagree **SD**- Strongly Disagree

SECTION F: AIR QUALITY IMPACTS

Using the scale given below, indicate the extent to which you feel the statements reflect the impact on the gypsum mining on the air quality in your area

Public Health Impacts	**LI**	**SI**	**NI**	**I**	**EI**
Dust generated by gypsum mining causes Upper respiratory infections such as coughs, sneezing and running nose					
Dust generated by Gypsum mining causes cardiovascular infections					
Dust generated by mining causes Eye infections					
Dust generated by gypsum mining leads to allergic skin conditions					
Gypsum mining activities and equipment cause loss of hearing					

LI- Little Importance, **SI**- Somewhat Important, **NI**- Not Important, **I**- Important, **EI**- Extremely Important

SECTION G: THE INTERVENING POLICY ENVIRONMENT

Mining policy & regulation	**SA**	**A**	**U**	**D**	**SD**
Gypsum mining in this area is well regulated					
The environmental impacts of gypsum mining in this area have been well addressed by the government authorities					
Enforcement of health issues is well taken care of by the government					
The mining policy has been followed in guiding the mining in this area					
I am adequately represented in decision making in regards to sharing and benefitting from natural resources in my county					
There is sufficient information and education on risks of mining					

What additional ideas, comments, or concerns regarding gypsum mining would you wish to share with us?

Thank you for taking the time to fill out this survey.

APPENDIX III: Survey Questionnaire for Residents near Mining Sites

AN ASSESSMENT OF ENVIRONMENTAL IMPACTS OF EXTRACTIVE INDUSTRIES: CASE STUDY OF GYPSUM MINING IN KAJIADO COUNTY, KENYA

Serial No.________

Location__________Sub-location___________Village______________ Date__________

SECTION A: BACKGROUND DETAILS OF RESPONDENT

d) Gender of respondent (please tick applicable)

2) Male ☐ 2) Female☐

e) Marital status of respondent

c) Single ☐ 2) Married ☐ 3) Separated/Divorced ☐

4) Widowed ☐ 5) Other☐

f) What is your highest education level attained to date?

2) No formal education ☐2) Primary school ☐

3) Secondary school (not completed)☐ 4) Secondary school (completed)☐

5) Tertiary or other college☐ 6) University ☐

SECTION B: EMPLOYMENT AT THE MINE SITE INFORMATION

d) What is your specific job at the mine site at this particular time? (Please tick one)

2. Casual labourer (mining and loading) ☐ 2) Clerical work☐

3) Supervisor/managerial☐ 4) Transportation ☐

d) Other (please specify)__________

e) Please provide the following work information at the mine.

3. Average number of hours you work per week_________

4. Number of years worked at the mine (please tick one)

f) Approximately how many workers are employed in your particular mine when the mine is operating at full capacity? ______________

SECTION C: IMPACTS OF GYPSUM MINING ON LIVELIHOODS

The following questions ask for ranking based on the scale provided. Using the scale, please indicate how important you consider the mining activity on the various aspects of your economic and physical well-being:

Impacts Of Gypsum Mining On Livelihoods	**NI**	**MI**	**FI**	**I**	**VI**
Provided supporting infrastructure(such as roads) which has encouraged secondary economic activities					
Provided social infrastructure such as schools and hospitals which have benefited the community					
Land owners Benefited from compensation for land acquired for mining					
Provides opportunity to obtain formal education and literacy through programmes with local schools					
Gypsum mining contributed to the county revenue in form of direct payments, royalty payments and community trust funds					

Gypsum mining supports community cultural values and heritage activities					
Gypsum mining facilitates linkages between the local community and the government at the county and national level					
Gypsum mining contributes towards accumulation of dust on crops and pasture					
Community members have benefited from local procurement opportunities					
Gypsum mining has improved employment opportunities					
Gypsum mining has improved local trade opportunities					

Key: NI- Not Important, **MI**- Minor Importance, **FI**- Fairly Important, **I**- Important, **VI-** Very Important

SECTION D: IMPACT OF GYPSUM MINING ON LANDSCAPE

Using the scale given below where. Indicate the extent to which you feel the statements reflect the impact on the gypsum mining on the landscape:

Impacts of Gypsum Mining on landscape	**VP**	**P**	**NI**	**N**	**VN**
What do you feel is the impact of gypsum mining on the overall land cover/Use?					
What influence does gypsum mining have on vegetation and Habitats					
What effect does gypsum mining have on the physical appearance (Morphology) of land?					
What contribution does gypsum mining make towards accumulation of dust on crops and pasture?					
What contribution does gypsum mining companies make to environmental management programmes					

Key: VP- Very positive, **P**- Positive, **NI**- No impact, **N**- Negative, **VN**- Very negative

SECTION E: IMPACT OF GYPSUM MINING ON WATER

Using the scale given to what extent do you agree or disagree with the following statements:

Impact of gypsum mining on water quality and quantity	**SA**	**A**	**U**	**D**	**SD**
Gypsum mining negatively affects the quality of surface water					
Gypsum mining negatively affects the quantity of water available					
Storm Water runoff mixed with gypsum waste contaminates water sources					
Gypsum mining might affect ground water table					

Key: **SA**- Strongly Agree, **A**- Agree, **U**- Unsure, **D**- Disagree **SD**- Strongly Disagree

SECTION F: AIR QUALITY IMPACTS

Using the scale given below, indicate the extent to which you feel the statements reflect the impact on the gypsum mining on the air quality in your area

Public Health Impacts	**LI**	**SI**	**NI**	**I**	**EI**
Dust generated by gypsum mining causes Upper respiratory infections such as coughs, sneezing and running nose					
Dust generated by Gypsum mining causes cardiovascular infections					
Dust generated by mining causes Eye infections					
Dust generated by gypsum mining leads to allergic skin conditions					
Gypsum mining activities and equipment cause loss of hearing					

LI- Little Importance, **SI-** Somewhat Important, **NI-** Not Important, **I-** Important, **EI-** Extremely Important

SECTION G: THE INTERVENING POLICY ENVIRONMENT

Mining policy & regulation	**SA**	**A**	**U**	**D**	**SD**
Gypsum mining in this area is well regulated					
The environmental impacts of gypsum mining in this area have been well addressed by the government authorities					
Enforcement of health issues is well taken care of by the government					
The mining policy has been followed in guiding the mining in this area					
I am adequately represented in decision making in regards to sharing and benefitting from natural resources in my county					
There is sufficient information and education on risks of mining					

What additional ideas, comments, or concerns regarding gypsum mining would you wish to share with us?

Thank you for taking the time to fill out this survey.

APPENDIX IV: Key Informant Interviews Guide

What do you think has been the impact of gypsum mining on the following aspects in the County?

a) Supporting cultural activities
b) Income opportunities through direct employment at the mines
c) Human capital development through supporting educational programmes
d) Supporting local small businesses through procurement
e) Providing assistance to environmental programmes

1. Do you feel that there have been sufficient compensation payments (in form of direct taxes, royalties, and community trust funds) to the county Government coming from gypsum mining? *(Probe*
2. Who would you say has benefited the most from gypsum mining in this County? Why has that been the case?
3. What is your estimate of the total development expenditure that has come into the County on account of the mining activities relating to gypsum? Can this be expected to increase in the future?
4. What would you consider to be the main impediments to the employment of more people in the mining sector especially as regards the gypsum mining?
5. How would benefits in the mining sector as regards to gypsum mining be improved?

6. What do you think are the major issues that should be considered by County and National governments in the mining sector?

7. To what extent do you consider Mining Policy as being of value to the local community? What do you think should be the role of the County Government in mineral extraction?

8. In your opinion, what would be the ideal revenue sharing proportion between community, County Governments and National Government? (*Please discuss)*

APPENDIX V: Key Informant Interview Transcriptions

A: INTERVIEW WITH OFFICER IN CHARGE, PCEA HEALTH

Date: 28/09/2025

The clinical officer identified the following diseases as the most prevalent in the study area.

URTI

i. Coughs
ii. throat pains
iii. fever
iv. headaches
v. Sneezes
vi. running nose
vii. chest pain across the ages**.**

SKIN DISORDERS

i. Fungal infections
ii. Taeniasis (ring worms)
iii. Wounds from thorn pricks and scratches

EYE DISORDERS

i. Aye allergic reactions
ii. Infections
iii. Discharge from eyes
iv. Eye redness
v. Itching eyes
vi. Tearing
vii. Scabies caused by water shortage and hot weather

GASTRO INTESTINAL/STOMACH ISSUES

i. Abdominal pains
ii. Diarrhoea
iii. Vomiting affecting all ages due to water scarcity and poor hygiene

MUSCULAR/SKELETAL MUSCLE ACHES

i. Muscle aches/joint pains
ii. Long distance walks(in search of water and firewood)
iii. Poor sleeping and sitting position

EAR INFECTIONS

i. Pain
ii. Discharge
iii. Fever mainly affecting under five year olds

The Clinical officer related URTI infections to dust in the study area and added that URTI are not treated in time and left to spread to the ears they cause other infections. She helped the researcher summarize the outpatient consultation rates for the month of August 2015 as follows:

condition	Under 5	Over 5
URI	13	62
EAR	1	7
SKIN	5	26
GASTRO INTESTINAL	7	13
MEASLES	3	-
UTI	3	-
ANGENIA	4	-
DENTAL	14	-
HYPETENSION	2	
TOTAL	21	118

She attributed the URTI challenges in the study area to gypsum mining dust but also caused that other confounding factors for the URTI problem included

i. Deforestation that enabled wind to move at high speed thereby transporting dust to areas outside mining
ii. Pastoral lifestyle that did not facilitate high hygienic standards
iii. Homesteads built very close to livestock sheds which makes the livestock owners breath in a lot of far rich dust
iv. Environment very windy the local population does not fence the compound, and like to sit anywhere on the grass and therefore the dust gets ready access/entry point.

B: INTERVIEW WITH MR BARSANGUI LEONARD A LIASON OFFICER WITH EAST AFRICAN PORTLAND CEMENT

Date: 20/09/2015
Place of Interview: EAPC Headquarters, Athi River
Assistance Given To The Community By The Mining Company in form of CSR

EDUCATIONAL SUPPORT TO LOCAL COMMUNITIES

i. million bursary to students per financial year
ii. construction of Classrooms
iii. Kibini primary school and the entire school dormitory
iv. Dining hall constructed
v. Water tank provided to school
vi. Employing three preschool teachers (ECD teachers)
vii. Equipping the dormitory with beds and mattresses
viii. Piped water from the company borehole supplied to school.

ERELAI PRIMARY

i. Two classrooms
ii. Elerai girls secondary school-constructed
iii. Clearing of playgrounds /leveling of schools
iv. Donates cement occasionally to schools, between 50-100 bags whenever need arises

WATER SUPPLY

The EAPC runs and service six boreholes for the community and at the borehole, two people employed while twelve other people from the community are engaged to supply water to surrounding communities in case the boreholes.

ROADS

i. The roads leading to the borehole are graded at least once a year
ii. In case of loss of life of community function the company grades the road
iii. 60 km of road is graded the company once in a year.

HEALTH

In cases of emergency the company gives the ambulance so that the patient is transported to hospital

EMLPLOYMENT

Out of the two hundred employees who work for the company 120 are from the local community in all levels from management to non skilled staff

MITIGATION OF DUST EFFECTS BY THE EAPC

i. Water boozers provided to spray water
ii. Filter installed at conveyor belt
iii. masks(goggles) industrial) provided to staff
iv. safety boots provided to staff
v. aprons, gloves and dustcoats provided to staff

C : ENTERVIEW WITH MR WACHIRA ENVIRONMENT OFFICER EAPC

Place of Interview: EAPC Headquarters, Athi River

i. Main Activities Undertaken in Mitigation of Environmental Effects of Mining
ii. risk profiling
iii. to identify high risk areas of operations, dust in quarries is done once in a week and the scope of operation is within the mining compound

DUST MITIGATION

Factory dust is risky in presumed dust because it is crushed into small particles that are trapped within the breathing mechanisms/respiratory tract

Mr. Wachira explained that the gypsum mining process started with exploration and prospecting which gave way to land acquisition before the actual mining processes and benefication begins. After mining, some primary crushing meant to reduce the size of gypsum ore is done

DUST MITIGATION

i. mitigation we use murram roads to minimize dust generation the material used for road construction that is not prone to dust
ii. buffer of trees to shield the dust
iii. blasting design is optimal to ensure boulders are not thrown to a long distance to minimize dust and good to minimize occupational safety risks and noise impact
iv. Blasting done early in the morning, once per week to minimize interruption and nuisance
v. Use of siren to notify the community that blasting is being done to minimize risk of injury

CRUSHING

i. bughouse/bug filter installed in the crusher to trap all the dust generated
ii. within the conveyer system there is an overhead sprinkler system
iii. Dropping chute-adjusted to ensure sufficient/appropriate right and discourse residue dust
iv. Transportation-all tracks are covered with tarporines

QUALITY ASSESMENT

i. Nairobi university department of chemistry
ii. Regular inspection to ensure all mechanisms are working well according to maintenance schedule
iii. Gaseous emissions from the trucks-fleet policy of disposing old inefficient vehicles

ASSISTANCE TO THE COMMUNITY

i. Capital development
ii. The community does not value human capital a instead they value money
iii. Partnership for issuing and planting trees
iv. Sponsorship of schools, complete infrastructure development
v. Bursary for education who come from needy families
vi. Employ more than 50% from the local community

APPENDIX VI: Conference and Publications

Appendix VII: Permissions and Endorsements