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School of Environmental Sciences

Development of an integrated approach of dealing with challenges of selected small-scale rock aggregate mines in Vhembe district, Limpopo province, South Africa

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A Dissertation Submitted to the Department of Mining and Environmental Geology, University of Venda, in fulfillment of Master of Earth Science in Mining and Environmental Geology

June 2016

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DECLARATION

I **Rembuluwani Ndivhudzannyi,** hereby declare that the work contained in this Research Dissertation submitted to the Department of Mining and Environmental Geology, University of Venda, in fulfillment of Master of Earth Science in Mining and Environmental Geology, is my original work and has not previously been submitted at this or any other institution of higher learning for a degree and that all reference materials contained therein have been fully acknowledged.

Student's signature..... Date 06/06/2016

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ABSTRACT

The crushed stone sector of the mining industry is a major source of employment for a significant number of people, particularly in remote rural areas, where alternative livelihoods are rare. It contributes to local economy by generating income and producing major and essential materials for the building, construction, and other industries. However, the sector is confronted with many challenges that hamper productivity and growth. Small-scale rock aggregate producing enterprises are considered to have poor health and safety record and cause environmental problems. It is important that the problems faced by small-scale rock aggregate miners are identified and practical solutions applied to improve the situation.

This study investigates the challenges confronting selected small-scale rock aggregate mines in the Vhembe District of Limpopo province of South Africa, assesses the health, safety, and environmental impacts associated with aggregate production and to develop an integrated approach of addressing the multi-faceted challenges. The research approach used involved a combination of desktop study, questionnaire and personal interviews. An appraisal of the mining methods was conducted in order to gain an in-depth understanding of the technical problems faced by the miners and SWOT analysis was carried out to determine the strength, weaknesses, opportunities and threats of each of the mines. Noise and dust levels were determined, exposure of the workers to these hazards was calculated and Job Safety Analysis tool was developed and used to assess workplace health and safety hazards. Finally, legislation and regulatory framework of the mining industry was examined in order to determine the relevance and appropriateness of these pieces of legislation to small-scale rock aggregate miners.

In this study major challenges facing small-scale aggregate miners were identified. These include lack of: finance, appropriate tools and equipment, technical know-how and theoretical knowledge, and appropriate legal and regulatory framework. The results of the SWOT analysis indicated that the weaknesses and the threats of the aggregate mining companies far outweigh the strength and opportunities. In addition, the study showed that small-scale rock aggregate mining is characterized by poor health and safety, environmental devastation, and poor marketing strategies. The measured noise and dust levels at the aggregate mines were higher than the prescribed limits and this can have potential health effects on workers if exposed to these excessive dust and noise levels over a prolonged period of time. The Job Safety Analysis assisted in evaluating and providing a thorough understanding of the site-specific hazards so that effective hazard prevention and control measures could be identified and implemented.

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Based on the analysis conducted it was concluded that the challenges facing small-scale rock aggregate producers are overlapping. Hence an integrated approach was developed for dealing with these challenges. This approach involved different stakeholders such as government departments and the miners coming together to resolve the problems. These stakeholders will deal with major issues such as pollution mitigation and minesite rehabilitation, business management, acquisition of mining and mineral rights and finally facilitation of the registration processes and mining and rock processing techniques. The last step of this integration will be the training of the miners by specialist from the different departments and organizations. This should be an ongoing process and it should have a feedback mechanism so that small-scale aggregate miners report back to the various departments.

Key words: Small-scale mining, rock aggregate, legislative framework, productivity, health and safety, marketing, integrated approach

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ABBREVIATIONS

ASM	Artisanal and small-scale mining
ASPASA	Aggregate and Sand Producers Association of Southern Africa
CoLTO	Committee of Land Transport Officials
DHET	Department of Higher Education and Training
DME	Department of Mineral Economics
DMR	Department of Mineral Resources
DOL	Department of Labour
DTI	Department of Trade and Industries
DWAF	Department of Environmental Affairs
EIA	Environmental Impact Assessment
EPWP	Expanded Public Works Programme
EMP	Environmental management plan
FEL	Front-end loader
GDP	Gross Domestic Product
ILO	International Labour Organization
JSA	Job safety analysis
LIBSA	Limpopo Business Support Agency
LSM	Large scale mining
MHSA	Mine Health and Safety Act
MPRDA	Minerals and Petroleum Resource and Development Act
NEMA	National Environmental Management Act
NGOs	Non-governmental organizations
OEL	Occupational exposure level
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit

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PPE	Personal Protective Equipment
SANS	South African national Standards
SCI	Standard Industrial Codes
SEDA	Small Enterprise Development Agency
SHE	Safety, health and environmental
SPSS	Statistical Package for Social Sciences
STEL	Short term exposure limits
SWOT	Strength, Weakness, Opportunities and Threat
TWA	Time weighted average
UIF	Unemployment Insurance Fund
XRF	X-Ray Fluorescence

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

South Africa is endowed with a lot of mineral resources, such as precious metals, base metals, precious and semi-precious stones and industrial minerals. This mineralization attracts large and small scale mining. Where large scale mining cannot be done profitably small scale miners mine such areas. Most of these small scale miners mine illegally and this may be attributed to their lack of information on legal issues (Growth et al. 2009). Small-scale mining means different things to different individuals, to some it is dirty, dangerous, disruptive and should be discouraged whereas to others it is profitable, productive and a way of live (Walle and Jennings, 2001). According to the White Paper on Mineral and Mining Policy (1998), in South Africa small-scale ranges from very small operations that produces for subsistence living to junior companies which can have some degree of mechanization and has several employees for which revenue and profit are the prime movers of such operations.

Small-scale miners are confronted with complex problems and these include obtaining finance, environmental degradation, lack of technical assistance and health and safety amongst others. According to the International Labour Organization (1999), the overriding factor is access to finance, because it results into the utilization of inadequate equipment which affects the health and safety of the workers and also affect production of the mine. Artisanal and small-scale miners (ASM) lack information about the type of the ores they mine and this results in the use of inappropriate methods of mining which have a lot of negative impacts on the environment (Hoadley and Limpitlaw, 2004). Some of these small-scale mines are purely manual and the tools that these miners use includes picks, shovels, chisel and wheelbarrows. These turn to affect their productivity negatively and the techniques also result in low revenue generation and poor health and safety. Hence small scale miners remain trapped in a circle of poverty.

The regulatory environment of South Africa is not favorable to small-scale miners because they are supposed to adhere to all the legislations that are used by large mining companies (Treut et al. 2007). These legislations cover environmental, labour, mineral rights, exploration, mining permitting and skills development. The environmental laws require that small-scale miner conduct an environmental assessment and produce an environmental management

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plan before they start mining and also to produce a rehabilitation deposit. Mining permitting is governed by the Minerals and Petroleum Resource and Development Act (MPRDA) 2002 which has a lot of complicated requirements which small-scale miners do not even understand. During stone crushing there is excessive noise that is produced by the screens and the crushers and also a large amount of respirable dust is also produced and this has a health impact on workers (Bhawan, 2009). The health and safety of the workplace is governed by the Mine Health and Safety Act 29 of 1996 (MHSA) of which according to Mutemeri and Peterson (2002), is not applicable to small-scale miners.

There is very little research that has been done on the activities of ASM in South Africa and it is not known how much small-scale mining operations contribute to poverty reduction. This study was undertaken in Vhembe district in Limpopo province of South Africa to investigate the challenges that small scale and artisanal miners are confronted with and an integrated approach to deal with problems were developed to maximize profit, protect workers and the environment.

1.2 Statement of the Problem

Artisanal and small-scale mines worldwide are confronted with a lot of challenges. These challenges may include low production rate, social-economic issues, occupational health and safety, finance and marketing. According to Hentschel (2003), low production rate is due to the fact that these miners use primitive methods which are counterproductive. Health and safety is one of the major issues that small scale and artisanal miners face on a daily basis (Carstens et al. 2009).

Finance and marketing are a far much complicated issues and banks do not want to give credit to small scale and artisanal miners mostly because they are considered unreliable (Onugu, 2005). The Mineral Commission of Ghana, after consultation with different stakeholders to try and resolve challenges facing small-scale miners realized that these problems could not be solved in isolation and therefore such attempts failed. This study will identify the major problems confronting selected small-scale rock aggregate miners in the Vhembe District and come up with an integrated approach of solving the overlapping problems within the context of South Africa.

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1.3 Justification of the Research

Very little work has been done with regard to studying activities of artisanal and small-scale mining (ASM) in Vhembe district of Limpopo province, particularly with regard to challenges they face in conducting the mining activities. ASM lack educational background of mining and ore location and as a result use inappropriate mineral prospecting and mining techniques. This leads to low recovery which in turn means low productivity and lower income and savings. This study aims to help ASM to identify areas where they need to improve in order to flourish.

The rudimentary techniques of ASM result in poor health and safety and have a lot of health problems such as lung diseases, cancer, and respiratory infections, amongst others. Although small scale miners seem not to care about health and safety and the environmental issues, it remains a primary concern to the nearby communities. Addressing the issue of using inappropriate techniques of mining by ASM will significantly decrease the health and safety concerns of miners and the negative impact on the environment.

Airborne contaminants, such as rock dust, are mainly produced during drilling operations, mineral extraction, loading, crushing of rock or ore, and blasting. During stone crushing there is excessive noise that is produced by the screens and the crushers and also a large amount of respirable dust is also produced. These have health impact on workers, persons exposed to excessive dust for prolonged periods may suffer from permanent lung diseases, such as silicosis (Dreschler et al. 2010). The dust and noise levels will be measured to determine whether they are within the allowable limit and whether they demonstrate compliance with the air and noise quality standards. Strategies to minimize the impact of dust and noise will be recommended if the levels exceed the allowable limit.

ASM provides a form of livelihood for the miners, but there is usually no net generation of wealth (Hoadley & Limpitlaw, 2004). The benefits provided by this activity are overshadowed by the costs. Such costs at times are allowed by the miners directly, such includes: poor safety and health conditions in the workings, or may be conveyed onto the surrounding communities, such as environmental degradation in a wider area around the workings and social disruption, such as alcoholism. The significance of ASM was studied in depth in order to comprehend as to whether the existence of this sector is justifiable.

Apart from technical education, small-scale miners also need financial assistance to be able to engage more independently in mining and to obtain greater benefits from their labour. Moreover, they have less or no forms of collateral to guarantee them to get financial support

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from commercial institutions. This denotes that these miners have restricted means to raise capital to purchase mining equipment, finance trips to better markets, or meet application fees for mining leases (Javia and Siop, 2010). The financial records of selected ASM will be studied in order to see how they manage their finances and recommendations will be made on how they can manage their finances better and also identify the organizations that can help them financially.

This study investigated the challenges confronting artisanal and small-scale miners and the environmental impact associated with their approach of mining. An integrated approach of addressing multifaceted challenges of ASM was developed to improve the livelihood of these miners.

1.4 Research Objectives

The main objective of this research was to assess the nature of problems confronting selected small-scale rock aggregate mines in the Vhembe district of Limpopo province and develop an integrated approach of effectively addressing these issues. The specific objectives of this research were:

- To identify and examine major challenges hindering successful operation of the selected small-scale aggregate mines.
- To assess occupational health and safety issues associated with the small-scale mining operations.
- To review and analyze the existing mining and processing legislation and regulations and make recommendations on how these pieces of legislation can be simplified for small-scale miners.
- To come up with a suite of practical interventions to help small-scale miners to improve productivity and to use safer and socially responsible mining techniques that will improve viability of the mines.

1.5 Hypothesis

Artisanal and small-scale mining ventures fail to realize their anticipated profit due to lack of business skills, geological knowledge, finance, market strategies and mining methods among other things. The assumption is that the availability of a combination of the above factors will lead to a profitable mining venture.

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1.6 Research Questions

This section presents questions to be answered in order to achieve the research objectives. The questions are as follows:

- Are the existing South African mining policies and legislations applicable to small-scale mining?
- What are the key issues that hinder productive operation of small-scale rock aggregate mines in the Vhembe district of Limpopo province?
- How do artisanal and small-scale miners market their produce?
- What level of geological knowledge do these miners have?
- What are the methods small-scale miners use to identify the ore bodies?
- What are the occupational health hazards that are associated with the small-scale mining operations?
- What are the mining methods used at the selected small-scale mines?
- How appropriate are the mining methods employed by selected small-scale miners?
- What are the practical strategies that can be implemented to improve the livelihoods of selected small-scale miners?

1.7 Description of the Study Area

This section provides description of the selected study area, in terms of the profiles of the different small-scale mines, the geographical setting of such areas, the geology of the area of study and the material that are produced in the different mines.

1.7.1 Location of the selected mines

Vhembe is one of the five districts of Limpopo province in South Africa. It is the northernmost district of the country and shares its northern border with Beitbridge district in Matabeleland South, Zimbabwe. It is composed of Musina, Mutele, Makhado and Thulamela municipalities. The aggregate mines which were included in this study are Phiphidi Stone Crusher, Mukula Stone Crushers, W.G Wearne Quarry, and Pakama Stone Crushers.

Mukula Stone Crushing Co-operative Mine is situated on the north eastern part of Limpopo province. The mine is found at Mukula village at a distance of about 4 km from the human settlement. The area is rich in boulders of volcanic rocks such as Basalt which is the source rock. This small-scale mine mines basalt as their source rock and they use simple techniques

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to conduct such mining. The stone crusher is owned and operated by 20 villagers and it has been running for a number of years and small-scale mine produces rock aggregate used for construction purposes.

Phiphidi Stone Crusher is located at Phiphidi village within the Vhembe District in Limpopo province. It is about 1km North of Phiphidi Water Purification along the D3681 road from Phiphidi to Donald Fraser. It has been operating for seven years and this mine is mining basalt. This mine is solely owned by one person and the mine was initially owned by Maury Roberts Company which was mainly focused on construction of the Vhufuli-Phiphidi road.

Wearne Quarry is located in Tshikota village about 7 km from Makhado town. It is a small-scale quarry which exploits basalt aggregates. It started operating in the year 1985. This Quarry is part of the W.G Wearne Limited which is a proudly South African company and one of the oldest suppliers to the building and construction industry. This group has different quarries around the country which produces aggregates, ready-mixed concrete, pre-cast concrete products and ready mix concrete pumps.

Pakama Stone Crusher which is located at Mussina area, several kilometres from the Great North main road to Zimbabwe. This company is a small scale mining in terms of its production rate and operational aspect. The production in this crushing plant is useful for primary construction. The company crushes the rocks from the mine dumps of the underground copper mine known as Messina Transvaal development. The rocks which are processed at this stone crusher includes granitic rocks, quartzite and metamorphic rocks. The locations of the selected mines for this study are shown in Figure 1.1.

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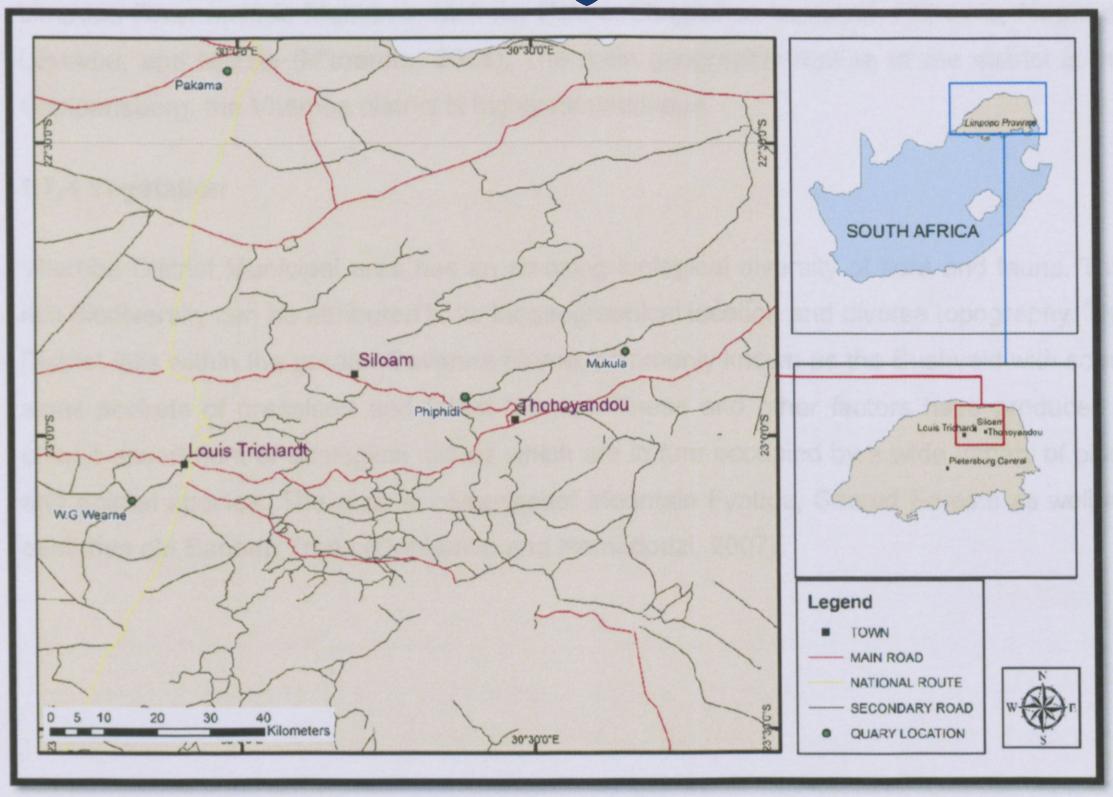


Figure 1.1: Locality map of the Study Area

1.7.2 Climate

Climate of the Vhembe District is characterized by Lowveld (Arid and Semi Arid) with an annual rainfall of approximately 500mm per annum (Odhiambo and Nemadodzi, 2007). The rainfall pattern is largely influenced by the 16 Orographic Rain effect of the Drakensberg Mountains joining the Soutpansberg perpendicularly, hence decreases from east to the west of the District (Odhiambo and Nemadodzi, 2007). The annual temperatures range from a minimum of 10ºC during winter to a maximum of up to 40ºC especially around the Musina Local Municipality. The area experiences frequent droughts most particularly in most parts of the Mutale and Musina Local Municipalities which are predominantly semi-arid.

1.7.3 Topography and drainage

On the northern part of the Vhembe District there is Limpopo River System which is considered as the heart of the Northern Vhembe semi-arid area. This life giving river provides sustenance to the predominantly hot and drylands through which it meanders. Its many tributaries support a variety of thriving farming villages in the region's northern areas. The main tributaries of the

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Limpopo River include Matlabas, Mokolo, Palala, Mogalakwena, Sand, Nzhelele, Nwanedi, Levuvhu, and Mutale (M'marete, 2004). The main geographic feature of the district is the Soutpansberg, the Vhembe district is highly mountainous.

1.7.4 Vegetation

Vhembe District Municipal area has an amazing biological diversity of flora and fauna. This rich biodiversity can be attributed to its biogeographical location and diverse topography. The District falls within the greater Savanna Biome, commonly known as the Bushveld with some small pockets of grassland and forest Biomes. These and other factors have produced a unique assortment of ecological niches which are in turn occupied by a wide variety of plant and animal species. The area is comprisesof Mountain Fynbos, Sacred Forests as well as centuries old Baobab Trees (Odhiambo and Nemadodzi, 2007).

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CHAPTER TWO

LITERATURE REVIEW

This section discusses some fundamental issues with the aim of finding a linkage between the study and the accumulated knowledge on improving the efficiency of aggregate production. In this chapter stages that are involved in aggregate production are discussed, such review significantly contribute to the understanding of the subject matter and its effective investigation. The chapter discusses the overview of ASM in Africa and then narrows it down to South Africa. In addition, significance and the problems associated with small-scale rock aggregate mining are discussed.

2.1 Overview of Artisanal and Small-scale Mining

Small-scale mining traditionally refers to mines with modest dimensions and output, but more particularly, to mines that are labour intensive rather than capital intensive (Dreschler, 2001). Frequently this type of mining is old in terms of equipment and technology. They often lack onsite technical support, with operational staff fulfilling numerous roles to minimize expenses. In some parts of the world, such mines are privately owned and operated and often fall outside the usual regulatory framework.

Small-scale mining does not have a universally accepted definition, there is no single definition satisfactory to all stakeholders. There are many conflicting opinions about the criteria that should be used to define the scale of a mining operation. Some countries opted to use a production-based definition; using annual production in terms of tonnage or value. Some define small-scale mines by the number of employees at the mine whilst others prefer to base their definitions on the types of technologies used or the size of the ore reserve being exploited. Most stakeholders have defined small-scale mining to suit their specific requirements.

According to the White Paper on Mineral and Mining Policy (1998), in South Africa, small-scale mining ranges from very small operations that provide subsistence living thus artisanal mining with pick, shovel and manual equipment, to "junior" companies who employ mechanical equipment involves several employees for which revenue and profit are prime motivators. A typical small-scale mine has also been characterized as a mine that operates at or near the surface, would work with non-complex ore, which requires non-complex mining and processing methods, and would operate on estimated, if not proven, reserves (Franz, 2000).

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Small-scale mining is of significant importance because it has great potential to contribute to national economies, it can be viewed as a tool for poverty alleviation(Growth et al. 2009). It can become an important area in the economic development of the country especially for countries endowed with a diversified mineral resource base such as base metals, precious metals and gemstones. The small-scale mining sector, despite the many problems, generates employment and income and with the high unemployment rate, this sector has also become an easy entry point into self-employment for both men and women, as well as marginalized groups. Small-scale mining is an economic activity that significantly contributes to the rural economy in the world and is very common in all mining communities (Akabzaa et al. 2004). Issues such as occupational health and safety, well-fare, environmental impacts and social disruption are of great concern amongst others, in the small scale mining sector.

2.2 Small-scale Mining in South Africa

There are major challenges ahead for small-scale mining in South Africa. With the advent of the new Minerals and Petroleum Resources Development Act in 2002, many previously disadvantaged South Africans have begun to see small-scale mining as a way to a new life. The government has, through the former Department of Minerals and Energy now known as Department of Mineral Resources (DMR), established the Directorate of Small-scale Mining to develop and address the challenges faced by the small-scale mining sector. The Directorate of Small-scale Mining assists aspiring small-scale miners in the establishment of a legal entity, guidance towards the identification of mineral deposits, environmental impact assessment (EIA), legal and contractual arrangements, mineral rights, reserve estimation of the selected deposits, mining feasibility study, market study; and development of mining equipment (DME, 2002).

In South Africa, the number of miners involved in small-scale and artisanal mining is estimated to be in excess of 30,000 (Hoadley & Limpitlaw, 2004). The South African Government has a stated intention to encourage small-scale mining to provide employment and to benefit the overall economy (DME, 1998). These intentions include educating small-scale miners in geology, business management, mining methods and mining legislations. It is also largely informal and unregulated, short of finance, technologically backward, and a significant proportion of the sector's activities are illegal (Growth et al. 2009).

Aggregate producers in South Africa have their own association known as the Aggregate and Sand Producers Association of Southern Africa (ASPASA) which is a voluntary membership, private sector producers association. ASPASA is a member of the Chamber of Mines, but

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represents those companies that are in the business of producing aggregate and sand by operating quarries, sand pits and crushing operations. This association offers a wide range of services, which are supported through working committees which render services and advice to members. ASPASA offers member with any kind of help that is needed by aggregate miners, the assistance ranges from aggregate production methods and tools, mine health and safety environmental issues, labour issues and the day to day running of the business.

2.3 Significance of Artisanal and Small-scale Mining

ASM activities in Africa engage about 8 million workers, who in turn support about 45 million dependents (Dreschler et al. 2010). Furthermore, the number of ASM miners is growing as a result of rising commodity prices and limited economic opportunities in other sectors (Benkenstein, 2012). According to the South African Institute Of Foreign Affairs (2012), in Zimbabwe, for example, artisanal diamond miners in the Marange area increased from a handful in 2004 to an estimated 35 000 in 2007 and Ghana ASM contributed 9% of total gold production in 2000, but by 2010 this had risen to 23%, with over a million Ghanaians directly dependent on ASM for their livelihoods.

A flourishing small-business sector usually increases competitiveness in the economy and is an efficient vehicle for the creation of jobs. The fall in the real price of minerals has led to the closure of numerous large-scale operations. Well-managed small-scale mining has the potential to take over and mine economically where large-scale mining is unable to operate profitably. In this way small-scale mining can make a meaningful contribution to the total global production (Mutemeri & Petersen, 2002).

It is important to recognize that the concept of ASM encompasses a wide range of mining practices. In certain areas artisanal mining has been a traditional activity for generations, and may be a seasonal enterprise to supplement agriculture-based livelihoods. In some cases significant commodity price fluctuations, mining closures or other economic shocks may lead to large numbers of ASM miners moving rapidly into an area, often with associated stresses to the environment and local communities

2.4 Geology of the Study Area

Geology can be described as the complex structure of rock formation, which occurs in the specific location. The mines are found in the Soutpansberg Group which represents a volcanic to sedimentary succession subdivided into seven formations of which two are confined to the

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outer north of the main outcrop, with total thickness of about 1200 m(Brandl, 2007). The Soutpansberg Group comprises a volcanic and sedimentary rock succession that is structurally subdivided into six formations. These consists of (1) The Tshifefe Formation (2) Sibasa formation (3) Fundudzi Formation (4) Wyllie's Poort Formation (5) Musekwa Formation and (6) Nzhelele Formation (SACS, 1980 and Brandl, 1999).

Phiphidi and Mulkula Stone Crushers are situated on the Sibasa Formation is a dominantly volcanic succession which is estimated to reach a thickness of about 3000 meters (Barker, 1979). Whereas Pakama Stone Crushers are found in the Wyllie's Poort Formation, which is also predominated by Basaltic rocks of volcanic origin. W.G Wearne Quarry is located at the Fundudzi formation and is development mainly in the eastern Soutpansberg reaching a preserved maximum thickness of 1900m and wedges out northwest of Makhado

The volcanic rocks comprise of a repetitive sequence of cyclically erupted basalts, which were subaerically extruded, and numerous lenticular zones of pyroclastic rocks. The basalts are generally dark green, massive and epidotised but are speckled white in frequently developed amygdaloidal zones (Barker et al, 2006). Where the rocks are least altered, clinopyroxene and plagioclase can still be seen in a matrix consisting mainly of epidote, chlorite, quartz (Barker, 1979) and locally prehnite-pumpellyite. The occasional presence of prehnite-pumpellyite suggests that at least the basal volcanic rocks were subjected to very low- grade metamorphism (Barker, 2007).

The selected mines are found within the Limpopo belt, which is a zone of high grade metamorphic rocks forming a suture between the Archean granitoid greenstone rocks of the Zimbabwe craton and the Kaapvaal craton. It is exposed in a E.N.E-W.S.W trending belt which passes through southern-most part of Zimbabwe and the northern-most part of south Africa into eastern Botswana to the west (Bumby et al., 2004). The belt is divided by prominent shear zones into three domains on the basis of lithological and structural characterization, the southern marginal zone, the central zone and the northern marginal zone. Geological structures within the belt include folds, and associated foliation and lineation, faults and shear zones (Chinoda et al., 2009). Figure 2.1 shows subdivisions, major shear zones and adjacent cratons within the belt.

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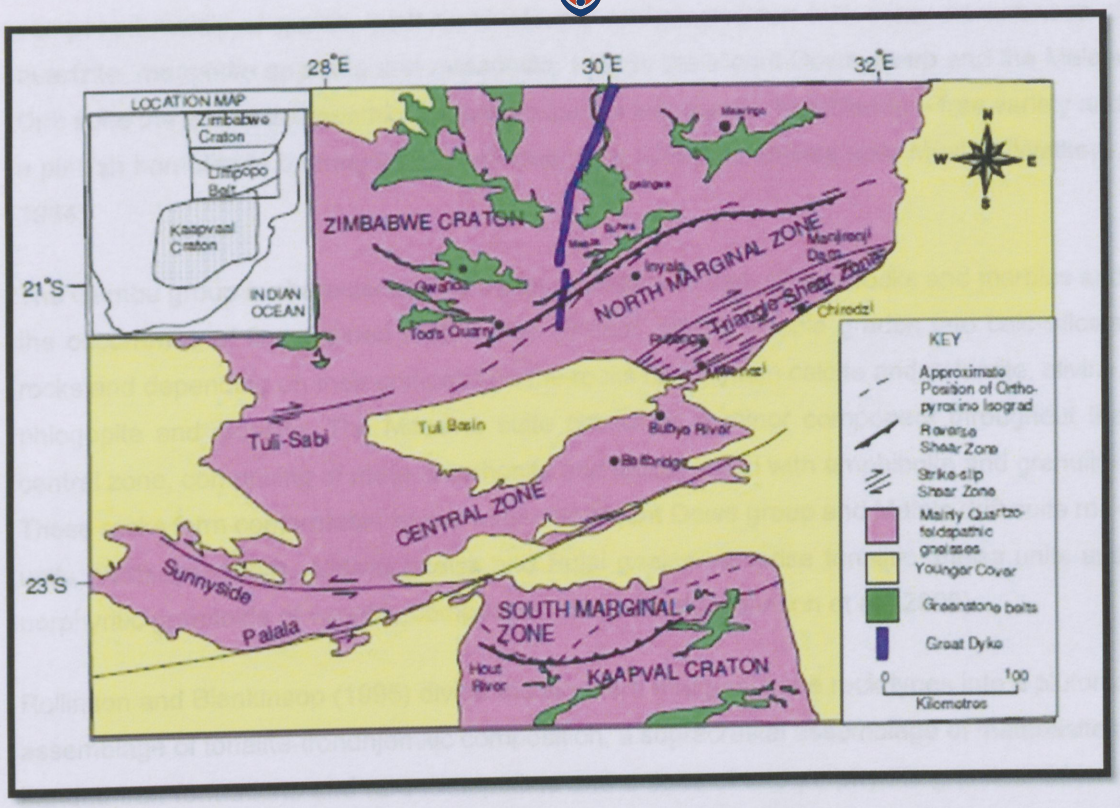


Figure 2.1: Map of the Limpopo belt (Chinado et al., 2009)

Southern marginal zone rocks are subdivided into two categories, the Bandelierkop complex and the Goudplaats- Hout river gneiss hosting granitoid intrusions of the Matok granite and Palmietfontein granite. Bandelierkop complex comprises metavolcanic and metasedimentary supracrustal rocks occurring as a series of discontinuous infolded overturns surrounded by migmatised tonalitic gneisses of the Goudplaats-Hout river gneiss (Johnson et al., 2009). The central zone is underlain by a variety of gneisses, many of which are granitoid in composition forming the basement (Sohnge et al., 1948). The basement gneisses are hyperthene bearing gneisses of quartz diorite and granodioritic composition collectively termed the sand river gneisses. Overlying the basement gneisses are metasedimentary rocks and associated leucogneisses of the Beit bridge complex. The Beit bridge complex is subdivided into three lithostratigraphic groups, Mount Dowe group, Malala Drift suite and Gunbu group (Johnson et al., 2009).

The Mount Dowe group is dominantly metasedimentary comprising of metaquartzites, magnetite quartzite, metapilites and calc-silicate rocks with intercalations of quartz feldspathic gneisses (Johnson et al., 2009). Malala drift suite is dominated by quarzofeldspathic gneisses

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composed mainly of quartz, perthitic K-feldspar and plagioclase with minor occurrences of quartzite, magnetite quartzite and metapelite. In both the Mount Dowe group and the Malala Drift suite the quartzofeldspathic gneisses occur as leucocratic, hornblende – free variety and a pinkish hornblende bearing variety referred to as Singelele Gneiss near Musina (Watkeys, 1984).

The Gumbu group is characterised by a predominance of calc-silicate rocks and marbles and the occurrence of fine grained metapelites (Brandl, 1983). Marble grades into calc-silicate rocks and depending on their composition the rocks can contain calcite and dolomite, olivine, phlogopite and diopsite. The Messina suite occurs as a minor component throughout the central zone, comprising of meta-anorthosite and leucogabbro with amphibolte and granulite. These rocks form conformable layers within the Mount Dowe group and Malala drift suite rock units (Watkeys, 1984). Alldays gneiss and Bulai gneiss comprise tonalitic gneiss units and porphyritic granitoids of variable composition respectively (Johnson et al., 2009).

Rollinson and Blenkinsop (1995) divide the Northern marginal zone rock types into a plutonic assemblage of tonalite-trondhjemitic composition, a supracrustal assemblage of metabasites, banded iron formations and rare metapelites and a suite of late porphyritic granites. 90% of the present surface area consists of granulite intrusions with mappable septa of metabasites and BIF (Ridley, 1992). NMZ granitoids are of granitic to granodioritic composition containing variable amounts of plagioclase, K-feldspar, quartz, orthopyroxene, clinopyroxene, hornblende, biotite and garnet (Chinado et al., 2009).

The Soutpansberg group is developed above the Palala shear Belt which marks the boundary between the central zone and the southern marginal zone of the Limpopo belt. The volcano-sedimentary suite comprises a lower and upper succession, separated by a prominent regional unconformity (Barker et al., 2006). Each succession is subdivided into three formations, Tshifhefhe formation, Sibasa formation and Fundudzi formation for the lower succession and the Wyllie Poort, Musekwa and Nzhelele formation in the upper succession as indicated in Figure 2.2.

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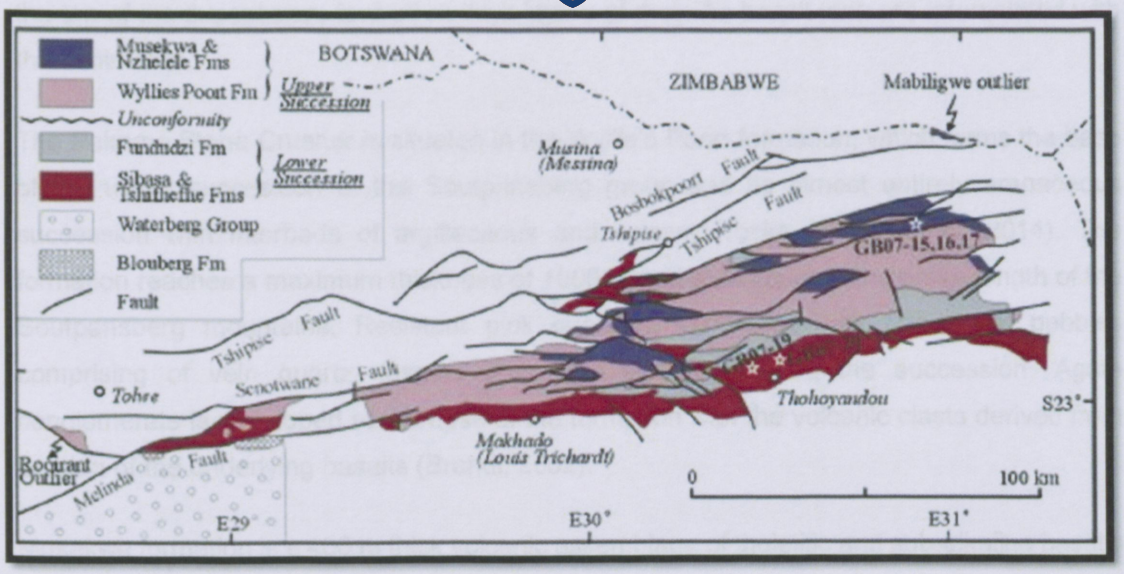


Figure 2.2: Map of distribution of geological formations in the Soutpansberg group (Barker et al., 2006)

Phiphidi and Mukula Stone Crusher falls under the Tshifhefhe formation which make up the base of the Soutpansberg Group is made up of strongly epidotised clastic sediments, including shale, greywacke and conglomerate (Brandl, 1979). Clasts of the conglomerate include round to angular granitoid gneiss and vein quartz with a local derivation. The unit is only a few meters thick with a maximum thickness of 10 m (Geng et al., 2014).

The Sibasa formation overlying the Tshifhefhe formation is dominantly a volcanic succession with several intercalations of clastic sediments. The formation reaches a thickness of 3700 m in the eastern Soutpansberg but gradually decreases to 100 m in the west (Geng et al., 2014). The volcanic rocks comprise a repetitive sequence of sub-aerially extruded tholeiitic basalts and lenticular zone of pyroclastic rocks. The basalt often exhibit amygdales that are epidotised. The interbedded clastic sediments which include quartzite, sandstone, shale and rare conglomerate form persistent markers and can reach a thickness of 400m (Johnson et al., 2009).

W.G Wearne Quarry is located at the Fundudzi formation and is development mainly in the eastern Soutpansberg reaching a preserved maximum thickness of 1900m and wedges out northwest of Makhado. It consists mainly of arenaceous and argillaceous rocks with minor interbedded basalts and thin pyroclastic beds. The arenaceous rocks comprise mainly of well bedded, reddish sandstone which can be feldspathic in some areas (Geng et al., 2014). Near

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the top of the succession, four 50 m thick layers of tholeiitic basalt lava are intercalated with the sediments.

The Pakama Stone Crusher is situated in the Wyllie's Poort formation, which forms the base of the upper succession of the Soutpansberg group and its almost entirely arenaceous succession with interbeds of argillaceous and volcanic rocks (Geng et al., 2014). The formation reaches a maximum thickness of 1000 m and extends over the entire length of the Soutpansberg mountains. Resistant pink quartzitic sandstone with occasional pebbles comprising of vein quartz, jasper, chert and agate dominate the succession. Agate conglomerate is developed at the base of the formation with the volcanic clasts derived from erosion of the underlying basalts (Brandl, 2002).

Musekwa formation is a 400 m thick volcanic assemblage of tholeiitic and sub-alkaline basalts with minor intercalation of pyroclastic rocks and clastic sediments. The basalts of the Musekwa formation are very similar to those of the Sibasa formation with the exception of a very coarse gabbroic texture exhibited by local flow units and jaspilitic veins (Johnson et al., 2009). The Nzhelele formation constitutes the upper most unit of the group and consists of clastic sediments with intercalation of pyroclastic rocks of which one is copper bearing. The sediments consist of red argillaceous and arenaceous sediments and its maximum preserved thickness is 2300 m.

2.5 Small-scale Rock Aggregate Mining

Aggregate mining involves exploration, extraction and mineral processing. This includes material handling, stockpiling and conveyance of the product up to the point where the material leaves the producer's control.

2.5.1 Aggregate exploration

The first step in aggregate production is the process of exploration for natural deposits. This is done in order to locate the suitable resources near the area where mining is taking place. It involves interaction between the aggregate producer and the environment. The first step in aggregate exploration is a preliminary geologic evaluation which involves studying of geologic maps, topographic and engineering reports aid in locating the promising area (Langes, 2004).

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2.5.2 Aggregate extraction

During the process of mining of aggregates ore is extracted from the bedrock or unconsolidated deposits. The methods and equipment used depend primarily on the type of deposit and source rock being worked. The key factor that are taken into consideration are the degree of consolidation of the deposit, the physical properties of the rock thus density, impact strength and abrasiveness and the rate and scale of production required. There are four basic operations of extraction which include overburden removal, drilling and blasting, secondary fragmentation, and digging, loading and hauling (Barksdale, 1991).Alternatively, in mines that do not use the drill and blast method, front-end loader (FEL) is used to clear and extract rocks. The FEL is used to loosen and fragment the consolidated rocks during the process of extraction (Frisk, 2007). After the rocks have been extracted a sledge hammer is used to reduce the size of the boulders, create cracks on rocks for easy crushing, and to make sharp edges on rocks for the crusher to grip because boulders are usually rounded. Then the rocks are transported to the processing plant.

2.5.3 Processing of aggregates

After mining has taken place, the ore undergoes mineral processing. Mineral processing influences mineral quality and integrity, aggregate physical properties, and in particular gradation (size control). Processing is done by using portable crushing and screening equipment or can be processed at a plant using sophisticated equipment connected by a network of conveyors (Langes, 2004). The first stage in most operations is the reduction and sizing by crushing. Some operations, however, provide a step prior to crushing called scalping. Scalping most often is used to divert fines at a jaw primary crusher in order to improve crusher efficiency. In this way the very coarse portion is crushed and then recombined with the portion of crusher-run material before further processing (Assakaf, 2003).

2.5.4 Aggregate productivity

Productivity is defined as the ratio between output and input. Therefore increasing productivity means greater efficiency in producing output of goods and services from labour, capital, materials and any other necessary inputs (Camus and Clayton, 2007). The effectiveness of productive effort, especially in industry as measured in terms of the rate of output per unit of input. Inputs include labour and capital, while output is typically measured in revenues and other GDP components such as business inventories. It can also be the efficiency of a person machine, and factory system. Productivity can be thought of as being about the ability to

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produce outputs, such as goods or services, taking into consideration the amount of inputs, such as raw materials, capital and labour, used to produce them (Hulten, 2000). High productivity means producing as much output as possible using as little input as possible.

Products from quarries include aggregate, river sand, crusher dust, and ready mixed concrete. Aggregates are the primary output from quarries in the South Africa; they are an end product in themselves and are used as the raw material in the manufacture of other construction products such as ready-mixed concrete, and crusher dust. Crushed rock sands are produced; often referred to as crusher dust (ASPASA, 2014). Aggregates are used in road construction, as railway ballast, in private housing, public infrastructure and industrial construction. The quality of quarry products used in the South Africa is controlled by the SANS for Aggregates for concrete, and road construction.

2.6 Problems of Artisanal and Small-scale Miners

Artisanal and small-scale mining (ASM) is a thorny issue for both governments and large scale mining (LSM) companies. Often operating in remote, unregulated and environmentally sensitive areas, difficult to tax and posing a security challenge on the verges of LSM mine sites, artisanal and small-scale miners are generally discussed at major mining forums as a challenge to be managed (Benkenstein, 2012). ASM is faced with a lot of challenges during mining and the problems are responsible for their low production rates. These problems include legal issues, social issues, environmental impact, finance and occupational health and safety. These challenges are discussed in the following sections.

2.6.1 South African legislation on mining

In every country, before mining, one needs permission from the government in the form of mineral rights and mining rights. One should also take into consideration the environment they are mining in. Small scale miners are affected by the same laws that govern large scale miners. For a small scale miner, these laws are just too complex for them to understand. Most of these miners are not even aware that there are laws and regulations which they are supposed to follow. For small-scale mining there are guidelines which were written by the Department of Water Affairs in in terms of the law this guidelines are referred to as soft laws. Soft law refers to instruments that are not binding and are generally not enforceable. According to Green (2012) such instruments may include best practice guidelines or codes of practice that guide a particular activity.

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Current legislation and policy does not unlock the developmental potential of ASM. The DME's White Paper of 1998 does not indicate the government views on artisanal mining as having development potential. The document refers to the advantages of promoting, assisting and developing small-scale mining, but it states that "resources need to be employed by the State to control artisanal mining as effectively as possible" (DME, 1998).

A number of legislative instruments that small-scale miners are expected to follow include Minerals and Petroleum Resource and development Act (MPRDA) 2002. Skills Development Act of 1998, the Basic Conditions of Employment Act of 1997 and the Mines Health and Safety Act of 1996, National Monuments Act, 1969, National Parks Act, 1976, Environmental Conservation Act, 1989, National Environmental Management Act, 1998, Atmospheric Pollution Prevention Act, 1965 and a significant number of other Acts. Only small portion of all these laws are applicable to artisanal and small-scale mining (Treut et al. 2007).

The mining sector of South Africa is regulated through the Minerals and Petroleum Resource and development Act (MPRDA) 2002, this is a primary statute which governs all mineral resources and regulates the extraction of such minerals. The custodian of all the minerals belongs to the state and the Act also sets out a comprehensive regulatory regime governing the exploitation of any mineral resource which is applied through the administration of various rights, permissions and permits (Green, 2012). The process of applying for the mining related permits is time consuming and require a lot of red tape so most small-scale miners view this process as a complication, this process is indicated in Figure 2.3.

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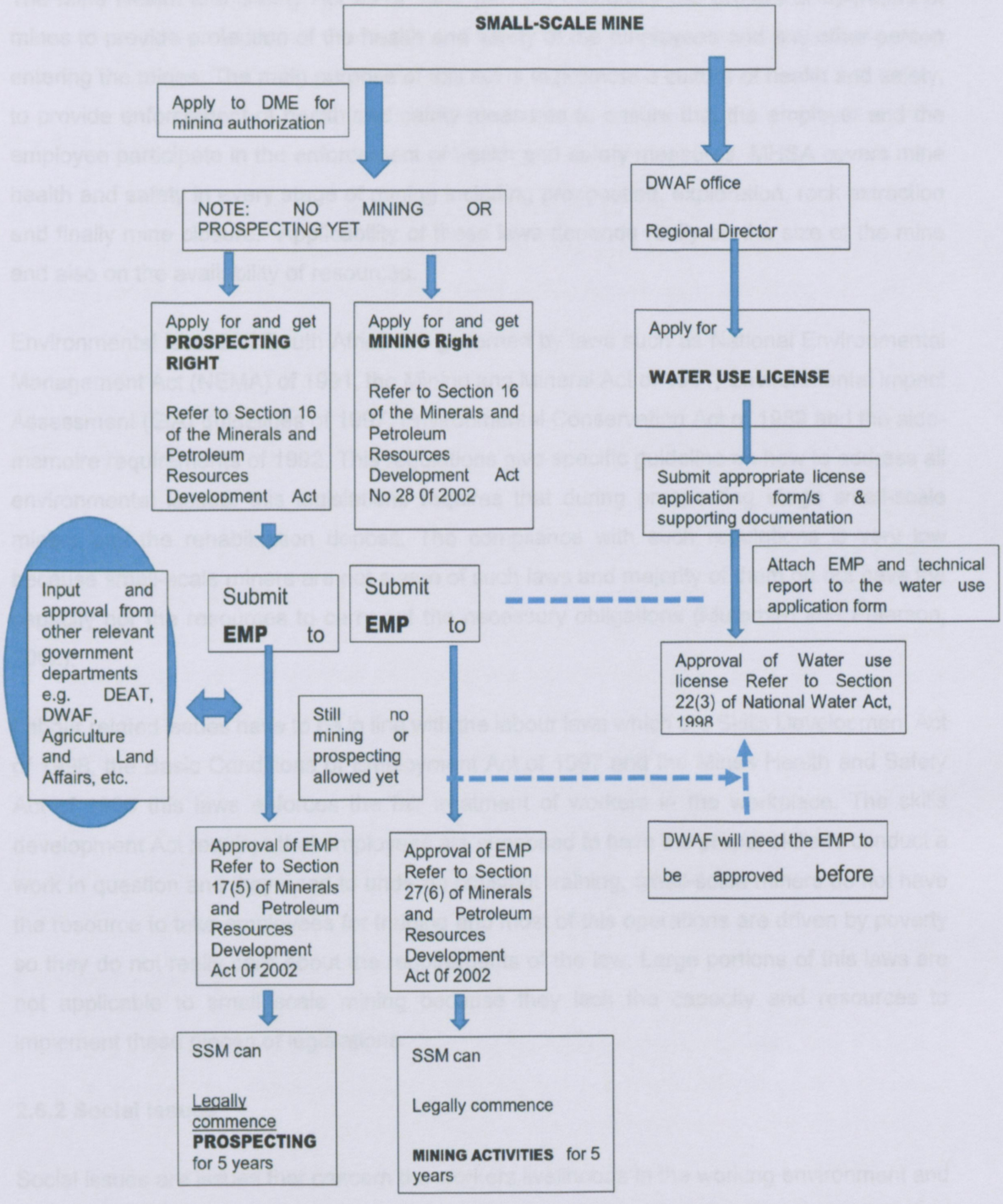


Figure 2.3. Schematic representation of the procedure of mining application (Department of Water Affairs and Forestry, 2006).

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The Mine Health and Safety Act 29 of 1996 (MHSA) mandates the owners or operators of mines to provide protection of the health and safety of the employees and any other person entering the mines. The main purpose of this act is to promote a culture of health and safety, to provide enforcement of health and safety measures to ensure that the employer and the employee participate in the enforcement of health and safety measures. MHSA covers mine health and safety in every stage of mining including prospecting, exploration, rock extraction and finally mine closure. Applicability of these laws depends really on the size of the mine and also on the availability of resources.

Environmental issues of South Africa are governed by laws such as National Environmental Management Act (NEMA) of 1991, the Mining and Mineral Act of 1991, Environmental Impact Assessment (EIA) guidelines of 1997, Environmental Conservation Act of 1989 and the aide-memoire requirements of 1992. This regulations give specific guideline on how to address all environmental issues, this legislations requires that during prospecting stage small-scale miners pay the rehabilitation deposit. The compliance with such regulations is very low because small-scale miners are not aware of such laws and majority of them do not have the capacity nor the resources to carry out the necessary obligations (Mutemeri and Peterson, 2002).

Labour related issues have to be in line with the labour laws which are Skills Development Act of 1998, the Basic Conditions of Employment Act of 1997 and the Mines Health and Safety Act of 1996 this laws enforces the fair treatment of workers in the workplace. The skills development Act requires that employees are supposed to have the proper skills to conduct a work in question and they need to undergo constant training, small-scale miners do not have the resource to take employees for training and most of this operations are driven by poverty so they do not really care about the requirements of the law. Large portions of this laws are not applicable to small scale mining because they lack the capacity and resources to implement these pieces of legislations.

2.6.2 Social issues

Social issues are issues that concern the workers livelihoods in the working environment and at their respective homes. These issues include gender inequality, child labor, and personal viability. Production in artisanal and small-scale mining has resulted in the generation of some income in the form of cash. Migration of people into mining communities have resulted in the increase of alcohol and drug abuse, gambling, violence against women, prostitution, marital problems, lack of education and general lawlessness. As a consequence of this social

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disorder, HIV/AIDS is a growing concern in all small scale mining communities. Young women and mothers, struggling to make a living, tend to get involved in sex trade and prostitution to support themselves and their families (Javia and Siop, 2010).

2.6.3 Child labor

Children as young as 6 or 7 years can be seen in small-scale mines breaking rocks with hammers, washing ore, sieving it and transporting it (Ayamdoo et al., 2004). Children who are about 9 years old work in underground mines, setting explosives and fetching and carrying for adult workers. In areas where there are active small-scale mines children will, rather miss school and go make quick money at such mines. Since many mining sites are seen as temporary, there is little incentive for the local authorities to provide schooling. Some children work to augment the family income; others are orphans or have left home and are working to survive.

There is increasing public consciousness of the problem of child labour in small-scale mining. In practice, however, it is a complex issue, with economic, political and social implications. Considerable care is needed if incentives for removing children from hazardous work are to succeed. The solution for eliminating children has to be site specific. The local situation must be carefully studied and the children concerned, and their parents if they have any, consulted. Experience has shown that child labour is not an issue that can be tackled in isolation (Javia and Siop, 2010). Simply removing children from the workplace without providing the means for them to go to school and ensuring a compensatory contribution to the family income will eventually result in them drifting back to the work they left or, perhaps, to worse occupations.

2.6.4 Health and safety

Conditions in small-scale mining are not the most favorable in many countries. Since it is also informal, there are no specific regulations regarding health and safety within small-scale mines unlike with large scale mine. A number of deaths have been recorded in many countries as a result of small scale mining. However, more deaths have been recorded in large scale mining in total (Dreschler, 2001). Many miners die or sustain critical bodily injuries each year due to unsafe mining practices with poor adherence to health and safety standards in small-scale mines (Mutemeri and Pertersen, 2002). Accidents and deaths result either directly from unsafe mine practices or indirectly from mining related diseases and illnesses.

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According to ILO (Jennings, 1999), the five major health risks in rock aggregate small-scale mining and processing are exposure to dust (silicosis), effects of noise and vibration inadequate work space, and inappropriate equipment. The five most frequently cited causes of accidents in small-scale mines, rock falls; isuse of explosives; lack of knowledge; lack of training; violation of regulation, obsolete and poorly maintained equipment (Jennings, 1999). Aggregate mining is associated with many noise-generating activities - removal of topsoil and overburden, excavation with machinery, drilling and blasting of rock, crushing and screening of aggregates, transport of raw materials and finished products within the site and on public roads (Brich *et al.*, 2007). According to the research conducted at Leeds University 2011, vibrations transmitted through the ground (seismic waves) and pressure waves through the air (overpressure) shake buildings and people and may cause nuisance or, in extreme cases, damage. Over pressure is accompanied by audible noise. This noise can cause annoyance, nuisance, sleep disturbance and can also affect wildlife.

According to Jennings (1999), it is widely acknowledged that accidents in small-scale mines are under-reported or not reported at all because they mostly operate illegally and have no wish to draw attention to themselves. In fact there is frequently no form of compensation or social security provision for injury and even for death, hence reporting an accident will merely lead to unwanted administrative, legal and operational problems. The International Labour Organization (1999), acknowledged that lack of safety regulations and enforcement, education and training, and functional infrastructure and equipment may lead to elevated injury rates in low- and middle-income countries, particularly in ASM. Thus in small-scale work related accidents are more likely to occur.

2.6.5 Environmental impacts

Creating the pits or quarries requires the removal of virtually all natural vegetation, top soil and subsoil to reach the aggregate underneath. Not only does this lead to a loss of existing animal wildlife, it also leads to a huge loss of biodiversity as plants and aquatic habitats are destroyed (Castrilli, 2005). Moreover, adjacent eco-systems are affected by noise, dust, pollution and contaminated water (Winfield and Taylor, 2005). Pits and quarries disrupt the existing movement of surface water and groundwater; they interrupt natural water recharge and can lead to reduced quantity and quality of drinking water for residents and wildlife near or downstream from a quarry site.

All quarrying and stone processing operations including surface mining, crushing, screening, material handling and transfer operations are potential sources of particulate emissions.

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These sources may be categorized as either process sources or fugitive dust sources. Fugitive Emissions are generated during various mining activities such as drilling, blasting, excavation, breaking and loading (Charbonnier, 2001). During transportation of mined stones by heavy vehicles like trailers, trucks, dumpers, there is fugitive dust emission. The quantity of emissions depends on various aspects like climatic conditions, moisture in the soil, speed of the vehicle, frequency of the vehicles.

It is certainly true that small-scale miners tend to do more damage to the environment than those working in modern mining enterprises - with a greater environmental cost per unit of output (Nyambe and Amunkete, 2009). A lack of awareness - particularly of the less visible or long-term environmental impacts of activities - combined with a lack of information about affordable methods to reduce impacts and a lack of obvious incentives to change all contribute to this problem (Ellmies, *et al.*, 2001). Since their operations are often subsistence activities, small-scale miners tend to focus more on immediate concerns than the long term consequences of their activities. This is compounded by the fact that in many cases, governments do not attempt to control these activities, which fall outside the regulatory framework, or they lack the capacity to monitor or control them, as the activities often occur in remote and inaccessible locations.

2.6.6 Work related hazards

Occupational health and safety hazards are governed by the Occupational Health and Safety Act (Act No. 85 of 1993). Airborne contaminants, such as rock dust, are mainly produced during drilling operations, mineral getting loaded, crushing of rock or ore, and blasting. Persons exposed to excessive dust for prolonged periods may suffer from permanent lung diseases, such as silicosis. As far as practicable, the escape of dust into the atmosphere should be prevented, particularly in stagnant zones (Walles and Jennings, 2001). The allowed dust limit is 1.00 mg/m^3 recommended by NIOSH (the National Institute for Occupational Health and Safety) in every work place.

Repeated exposure to excessive noise levels will lead to hearing loss. Potential sources of noise emissions include compressors, drilling machines, pick-hammers and other mechanical equipment used at a mine. The most practical and simplest way to reduce noise is by increasing the distance between the noise source and the listener. Practical personal hearing protection devices, such as approved ear plugs or ear muffs, should be worn by every person exposed to noise levels exceeding 90 dBA in cases where the worker and the noise level cannot be separated (National Institute for Occupational Health and Safety, 2011).

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2.6.7 Finance and credit

Access to finance is essential to enable the formalization, improved production, strengthening of artisanal mining and its potential transformation into small-scale mining or medium scale mining (Krappmann, 2006). Apart from technical education, small scale miners also need financial assistance to be able to engage more independently in mining and to obtain greater benefits from their labor. Small in general, small scale miners find it hard to obtain financing from commercial institutions. The banks and investors are cautious of getting involved with the small-scale mining business as they consider it to be of high risk. For this reason, they are unable to obtain the necessary machinery and only have access to measly hand tools. In cases where miners are able to rent machinery, they are often faced with the costly challenge of having to transport these machines (Woolard and Leibbrandt, 1999).

2.6.8 Marketing

Another common problem faced by small-scale miners is the issue of markets and buyers. In most cases, miners sell their products at below market value due to lack of formal market structures and processing facilities and also due to lack of knowledge as to the real value of their products and the fact that in many cases, miners are not in much of a bargaining position as they are in need of the money at the given time. Their illegal nature also results in small-scale miners selling their products illegally. These small-scale miners do not have a pricing system in place hence they usually price their products in relation to the buyers' price.

2.7 Role of Women in Small-scale Mining

In addition to their household chores, women are involved in small scale mining as either miners (producers) or support service providers to the mining communities. On mining sites, women are solely engaged in the carrying of sand, stones, rocks and soil for processing (Ayamdoo *et al*, 2004). Women all over the world have become more independent and they are now breadwinners and they are also involved in small scale mining. The women miners need technical skills such as know-how to mine, how to sell, how to source finance, how to manage income from the sale of the product (D'souza, 2002).

The lack of basic education and widespread illiteracy has compounded the problems of women and greatly hindered the participation and progress of women in small-scale mining. Women have less technical know-how than their male counterparts. A number of factors contribute to this lack of know-how. First, women in general tend to shy away from getting

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involved in anything of technical nature. Second, the stereotype view of society that women are not capable of handling anything technical (Hoadley and Limpitlaw, 2004).

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CHAPTER THREE

RESEARCH METHODOLOGY

This chapter describes the methods and procedures that were used during the course of data collection. The methodology employed in this research involved a combination of desktop study, questionnaire, personal interviews, and measurement of noise and dust levels. An appraisal of the mining methods was conducted and after the challenges of small-scale miners were identified, a SWOT analysis was used to determine the strength, weaknesses, opportunities and threats of each business to analyze and compare different mining operations. Data analysis for the questionnaire was conducted using social statistical data analysis and laboratory analysis were done for the dust samples. A comprehensive review of the mining regulation was conducted to analyze the relevancy of the laws to small-scale mining. These methodologies are described in the following sections.

3.1 Preliminary Work

This section describes the work which was done in preparation for the field research such includes Desktop studies and reconnaissance survey. This done in order to acquire understanding of the scope of the work that will be required in the field.

3.1.1 Desktop study

Desktop study generally involves obtaining existing data for better understanding and gaining knowledge of the study area. It includes the review of material related to the topic. The aim of desktop the study in this research work was to get a better understanding of the challenges facing small scale and artisanal miners all over the world. This knowledge helped in deciding the methodology to be used in collecting data in this study and gave the researcher a better understanding of issues that surfaced during fieldwork.

3.1.2 Reconnaissance survey

Reconnaissance involved visiting the study area to check the conditions of the physical environment. This helps in getting an overview of the study area. It was conducted to assess the accessibility of selected small-scale mines and also to get permission from the owners to conduct the study. This also help in getting a better understanding of the processes involved in aggregate small scale mining and also to check as to whether the proposed research

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methods will be applicable to the different small-scale mining companies. The selected small-scale miners were more than willing to allow there mining operations to be studied.

3.2 Data Collection and Analysis

Data collection was done using Questionnaires, personal interviews, measurement of noise and dust levels. An appraisal of the mining methods was conducted and sales records were studied in order to determine the rate of production. SWOT analysis was used to determine the strength, weaknesses, threats and opportunities of the selected small-scale aggregate mines. Visual observations was done to verify the responses given during the answering of the questionnaire and the interview.

3.3.1 Research Questionnaires

Before the preparation of the questionnaires and questions for personal interviews a detailed literature review was conducted in order to understand the problems that small scale and artisanal miners encounter during mining. It was necessary to first distinguish amongst key variables and explicative variables. The key variables are those challenges which directly lead to the development of an integrated approach of dealing with identified challenges. Explicative variables are those variables which may be correlated to the key variables (Corp, 2005).

On the development of integrated approach of dealing with challenges that confront small scale and artisanal miners, the explicative variables which included are: production process, marketing, equipment, social issues, work hazards, legislation issues, financial issues and working environment. The steps that were followed when preparing research questionnaires included describing the aim of the study, listing all variables which have link to the key variable and preparing the form of questionnaires. This identification of key variables was based on literature review and field survey. Provision was made for any form of improvement which was influenced by the study at the selected small-scale mines. After identifying the key challenges facing small-scale miners a questionnaire was prepared to capture views of small-scale mining operators. This questionnaire is presented in appendix A.

Diverse questions were prepared with the aim of acquiring knowledge and understanding of the lives of miners at their place of work and also to view their perception of the working environment. The questionnaire for the owners of small scale miners was prepared to give the researcher an understanding of the ways in which the owners view their operations and the constraints they face and how they deal with such problems.

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Personal interviews were used to complement the questionnaire because they represent an excellent media for close interaction and rapport between the researcher and the respondents. This enabled the former to draw forth more information and data, which the questionnaire alone was not be able to capture nor provide for. In addition, personal interviews provided a source of presenting the researcher to the search light of the respondents' personality, composure and psychology. The personal interviews also give the researcher the flexibility to cater for and appreciate the passion with which the respondent had while answering the questions. The answers obtained from personal interviews also aided the researcher in validating responses. The Statistical Package for Social Sciences (SPSS) was used to analyze the questionnaires.

Statistical analysis tool was used to analyze the data collected through interviews and questionnaire. Results were presented in a form of charts and tables. The questionnaires were also checked to see if there was any missing data and to ensure that this tool can be a true representative of what is on the ground. Subjects who have failed to follow the filters and answered every single question can also be identified at this stage, and if necessary, contacted to verify information (Black *et al.*, 1998).

Once the open-ended questions had been coded the data was entered a directly from the completed questionnaires into a computer programme for analysis. The Statistical Package for Social Sciences (SPSS) was used software package for questionnaire surveys because it is flexible and easy to use.

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3.2.2 Analysis of the challenges of the mining operation

The activities which are carried out at each mine, the equipment in use and the challenges that the mines are facing were identified through the field survey and analyzed using SWOT analysis. SWOT analysis was done to get an understanding of the strengths, weaknesses, opportunities and threats of the selected aggregate mining operations. This was designed to help the selected mines understand how they relate to their external and internal environment from a business point of view. This analysis was conducted in order to determine negative and positive aspects of the mines and opportunities for small-scale mining to be transformed to viable ventures and to contribute to sustainable livelihoods, economic efficiency and environmental integrity. The strength, weakness; opportunities and threats of each mine were identified and weights for the data were assigned based on the determination of weights for individual influence factors of the relational SWOT matrix (Michal et al, 2012).

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The evaluation of the SWOT matrix factors were given values in the interval of -10 to 10. It resulted from the logic that weaknesses and threats were assigned a negative sign because they affect the mining operation negatively. The strength and the opportunities were assigned a positive, since they are the positive aspects of mining. The entire SWOT matrix (strengths and weaknesses, opportunities and threats) was evaluated by the sum of the weights of items. The SWOT matrix was then summed up, and then the value of the strength and the weakness was added up. If the value is positive then the strength outweighs the weakness. If the value of the sum of the problem is negative then the weakness outweighs the strength. The same was done for the opportunities and strength.

3.3.3 Worksite health and safety hazard analysis

A comprehensive hazard identification survey was conducted and this enabled most hazardous areas to be determined. The survey also assisted in identifying areas of non-compliance with prescribed standards. A comprehensive hazard survey is the most basic of all the tools used to establish the inventory of hazards and potential hazards at the workplace. This survey was conducted in a form of Job safety analysis (JSA). A job safety analysis tool was developed and this was used for assessment of safety hazards in the working environment. According to the Occupational Safety and Health Administration (OSHA) 2002, a job safety analysis is a technique that focuses on job tasks as a way of identifying hazards before they occur. It focuses on the relationship between the worker, the task, the tools, and the work environment.

After the identification of uncontrolled hazards was undertaken, ways in which the risk was to be eliminated or reduced to an acceptable risk level were recommended. Before beginning the job safety analysis, the general conditions under which the job is performed was assessed and a checklist developed. Aggregate mining processes were broken down into job tasks or steps. The jobs were then listed in the sequence of occurrence thus drilling, blasting, loading, transportation, crushing, screening, product handling and storage. In the first part of the job safety analysis, each step of the job was listed in order of occurrence as observed in the different mines when the different employees are performing the job. After recording the job steps, each step was examined to determine the hazards that exist or that might occur.

The second step was to conduct detailed risk analysis, which is the combination of the likelihood and severity of a specified hazardous event occurring. Severity and likelihood were determined using Table 3.1 for each hazard which was identified, the information was then used to assess the likelihood and severity of each hazard.

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Table 3.1: Likelihood and severity ranking (U.S. Department of Health and Human Services, 2006)

Likelihood		Severity	
Description	**Rank**	**Description**	**Rank**
Very likely (daily)	4	Fatality (permanent disability)	4
Likely (weekly)	3	Major injuries (> 4days medical consultation)	3
Unlikely (monthly)	2	Minor injuries (<4days medical consultation)	2
Highly unlikely (yearly)	1	Negligible injuries (first Aid and near misses)	1

Determination of noise exposure levels

Noise surveys provided very useful information for identifying areas where employees are likely to be exposed to harmful levels of noise, machines and equipment which generate harmful levels of noise, employees who might be exposed to unacceptable noise levels, and noise control options to reduce noise exposure. In this study the highest level of noise were identified at the crusher plant. The sample points which were selected for sampling are the primary crusher, the secondary crushers, bomarc and the screens. The noise reading was taken over a period of a month in order to determine the different noise variation levels. According to the National Institute for Occupational Health and Safety (2011), allowable noise at any work environment should not exceed 90 dBA. Noise levels were measured using sound level meter and compared with the allowable noise limits. A Sound Pressure Level Meter (SPL) was used to measure the different noise levels in the mines, the SPL was calibrated each time before and after use to ensure true representation of the noise levels and the results were presented in dBA.

Sound exposure level measurement formula developed by Meyer (2015) was adopted. The noise level exposure was calculated using the measured noise level and the time of exposure. The recorded noise level was used to determine the sound exposure level per eight hours shift. The formula o as follows:

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$$L_{ex,8} = \left(\frac{\left[\sum_{i=1}^{N} (ti \times 10^{0.1SPLi}) \right]}{8} \right)$$

where,

$L_{ex,8}$ is the equivalent sound exposure level in 8 hours,
$\sum$ is the sum of the values in the enclosed expression for all activities form I= 1 to i= n,
I is a discrete activity of a worker exposed to a sound level,
ti is the duration in hours of i,
SPLi is the sound level of i in dBA, and
n is the total number of discrete activities in the worker's total workday

The noise level measurements which were taken in the field were used to calculate the time employees are allowed to be in a certain work condition per eight hour shift. The following equation which was adopted form the National Institute for Occupational Health and Safety (2011), was used to calculate allowable times:

$$T = \frac{8}{2^{(L-90)/5}}$$

where: T is the permissible duration (in hours) and

L is the measured sound level (in dBA).

Determination of Dust exposure level

Exposure to mineral dust was determined by the gravimetric method, using a sampling pump and filter cassette (pre-weighed) to determine dust concentrations in the mine atmosphere. Gravimetric sampling was used to determine personal exposure (breathing zone) and was also used to screen for other mineral dusts that may require particle counting to determine compliance. A mobile dust sampler attached to workers was used to determine the total amount of dust being inhaled. Table 3.2 was used to rate the different exposures.

The first stage of the analysis was to determine the mineral content of the ore. The mineral content of the rock helped in identification of the possible respiratory disease. Two rock samples were collected per mine for X-Ray Fluorescence analysis (XRF) to give an understanding of the possible health effects due to occupational exposures. Sample

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preparation for XRF involved milling of samples in a tungsten-carbide milling pot to achieve particle sizes <75micron. The samples were dried at 100°C and roasted at 1000°C to determine Loss On Ignition (LOI) values. 1g Sample was mixed with 6g Lithiumteraborate flux and fused at 1050°C to make a stable fused glass bead. Fot trace element analyses the sample was mixed with PVA binder and pressed in an aluminium cup @ 10 tons. Results indicated with an asterix (*) should be considered semi-quantitative. The Thermo Fisher ARL Perform'X Sequential XRF with OXSAS software was used for analyses.

Calculations of Exposure Levels

The exposure standard of 0.1 mg/m^3 refers to the airborne concentrations of respirable crystalline silica in the breathing zone of the employee, determined by "personal sampling". 8-hour time weighted average (TWA) exposure is the standard used for calculating eight hour exposure for airborne concentration of respirable crystalline silica that is permitted over an eight-hour working day, and a 5 day working week. Concentration of airborne contaminants may vary considerably in the course of one 8-hour working period. By calculating the time weighted average concentration, the exposure level of a worker can be determined more readily as a summary measure over that 8-hour shift. The TWA then means the average airborne concentration of a particular substance when calculated over a normal 8-hour working day (Meyer, 2015).

Equation for exposure limit: $$TWA = \frac{C_i X T_i}{8\text{hours}}$$

Where: TWA is the time weighted average,

C_i is the air concentration

XT_i is the duration of the exposure

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Table 3.2 Criteria for rating exposures (International Council of Mining and Metals, 2007)

Exposure rating	OEL exposure band	Definition	Action zone
Low	Less than 50% of OEL (<0.5 x OEL)	(Frequent contact with the potential hazard at low concentrations, or infrequent contact with the potential hazard at moderate concentrations. Frequently can expect the exposure to be less than 10% of the OEL, or infrequently can expect the exposure to meet or exceed 10% of the OEL, but less than 50% of the OEL). Exposures are at or well controlled to below the OEL, there are less likely to be breaches of the OEL and this level of exposure is likely to cause little or no adverse health effect.)	SUPERVISORY Sampling strategy is aimed at routine checks
Medium/Moderate	Between 50-100% of OE (>0.5 - 1 x OEL)	Frequent contact with the potential hazard at moderate concentrations, or infrequent contact with the potential hazard at high concentrations. Frequently can expect the exposure to meet or exceed 10% of the OEL, but less than 50% of the OEL, or infrequently can expect the exposure to meet or exceed 50% of the OEL, but less than 100% of the OEL Exposures are at or controlled up to the OEL, there is a potential for breaches of the OEL and this may cause an adverse health effect in some workers e.g. vulnerable groups.	CONTROL Workplace sampling strategy is aimed at quality control and checking on controls Medical surveillance of workers exposed at >50% of OEL
High	At or greater than OEL (>OEL)	Frequent contact with the potential hazard at high concentrations, or infrequent contact with the potential hazard at very high concentrations. Frequently can expect the exposure to meet or exceed 100% of the OEL. Exposures are above and/or not controlled to the OEL and are likely to cause adverse health effects in the majority of workers exposed either in the short or long term.	INTERVENTION Controls must be put in place according to the hierarchy of controls. The objective should be to reduce exposure to below the OEL

*OEL = Occupational Exposure Limit (or other health standard)

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3.2.4 Review and analyses of laws and policies

A comprehensive study of the laws was conducted to identify and scrutinize the different laws that deal with small-scale mining, mining and environmental issues. This was done in order to make analysis of such laws to determine their relevance and appropriateness to small-scale miners. A law analysis tool was developed to analyze the current laws with respect to small-scale miner. The development of the analysis tool was based on the analysis of the individual small-scale mining establishment and the requirements of the laws. Suggestions were made on how to make them more accommodating for small-scale miners.

The review involved the examination of laws and policies that regulate mining with particular reference to small-scale aggregate mining. In particular, the analysis of the legal and regulatory framework examines the registration, extraction, processing and transportation, and inadequacies in planning for society's future construction and maintenance needs. In addition, the analyses determined the extent to which the regulatory framework meets best practices and standards of corporate conduct and the extent to which self-regulatory mechanisms are accommodated under the framework. This was accomplished through reviews of mining related Acts, laws and relevant Statutes on corporate environmental practices in South Africa.

Laws analysis tool that was developed was used to critically analyze aspects of the law such as legal reference, requirements of an act, the document which are required for the application process. In the case of the mining and prospecting rights the duration of the licenses was also analyzed. This tool expounded the requirements of the different laws to critically analyze their applicability in small-scale mining. Small-scale miners were interviewed on the application of mining related laws in their mining ventures and their understanding of the different laws. During the fieldwork, analysis of the mining operation was conducted to assess the applicability of the mining legislations in small-scale rock aggregate mining. The workers were assessed in order to see whether they have the capacity to understand and implement the given laws and regulations.

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CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter is based on analysis of the data that was collected during fieldwork. The data discussed is based on the results of the analysis of the different mining methods, the field survey, the health and safety practices, the South African legislations and the challenges encountered by the selected small-scale miners.

4.1 Field Survey and Analysis

This section is based on the questionnaire and personal interviews which were conducted during data collection from the selected small-scale mines. Statistical Package for Social Sciences (SPSS) was used to analyze the questionnaires. Results of the SWOT analysis are also presented in this section.

4.1.1 Mukula Stone Crushers

Mukula Stone Crushers is a cooperative which is owned and operated by 20 people from the Mukula village. This business was started with assistance from different organizations. Firstly Limpopo Business Support Agency (LIBSA) gave them a grant of R 100 000 and R 200 000 worth of processing plant. Department of Trade and Industries (DTI) helped in fixing the crushing equipment. Department of Mineral Economics (DME) gave them a front end loader. Lastly Public Works Programme (EPWP) employs temporary staff to assist for a month every year. Of the 20 workers one was appointed a manager to oversee the running of the operation. Equipment that are available in this stone crusher includes: a 6 m^3 tractor, one front end loader, one 20m^3dump truck and the crushing plant that contains one Jaw crusher. Since this equipment were bought they have not been replaced and they are no longer in workable condition.

This small-scale aggregate mine is not registered, hence they do not follow any mining regulations and legislations. These aggregate mine is only registered as a cooperative and all the permanent workers are registered with Unemployment Insurance Fund (UIF). The targeted rocks for crushing are basically the basalts rocks of the Sibasa Formation of the Limpopo Belt. The outcrops are broken lose using simple equipment such as sledge hammers and chisel. This method of rock identification and collection was identified as one of the factors that negatively affects the productivity of the Mukula Stone Crusher. Because at time they are not

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even sure of the rock they are collecting. Figure 4.1 shows rock collection processes at Mukula Mine.



Figure 4.1: Rock collection at Mukula Stone Crusher

This establishment gets its customers solely based on word of mouth and they do not see the importance of advertising their products. As a result of lack of advertising this cooperative narrows its client base to the local people who needs aggregates for small projects. Mukula Stone Crushers operate 8 hour per day and of the shift the rock collectors start at 7 am and at 12 mid-day they return to the plant. The crushing crew then start crushing at 12pm until 3 pm, and this results to low production. During raining seasons production at this mine is low because they cannot collect nor process the rocks.

The rocks are excavated using a chisel and broken down to manageable size by the use of a sledge hammer. After the rocks have been broken down they are then loaded manually by the workers into the 6 m^3 tractor for transportation to the crushing plant. At the plant the rocks are sorted and manually loaded into the conveyor belt that feed the rocks to the jaw crusher. The

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loading of the rocks into the crusher is monitored and controlled by the operator of the crusher. The "stop" and "go" sign are used by the crusher operator to control the loading which is done by manually the workers that work at the feeder point of the primary conveyer belt. After crushing sieves of different sizes are used to sieve the processed rock. The rocks are then transferred to different conveyors for stockpiling. The products of the crushing process are classified as ballast (19mm diameter stones); aggregate (12mm diameter stones) and crusher dust which is a fine material with 6mm diameter. On a normal day without breakdowns 10 tons of rock aggregate is crushed and in their worst days at least 3 tons of crushed rocks are produced. The condition of the machinery is poor hence they have more breakdowns, in a day the processing plant can break down at least twice or thrice and this negatively affect production.

The mine cannot afford to buy PPEs for its workforce, workers buy their own PPEs and 90 percent of them do not have the PPEs because they do not see the need for the PPES since they consider their working environment safe. During rock collection workers need work suits and protective gloves because they are exposed to harsh conditions. Rock breakage is associated with fly rocks which can damage the eyes. Rock collection is done in the bush and workers encounter snakes on a daily basis which exposes them to dangers from snake bites.

At this stone crusher there are twenty workers of which eight are males and twelve are females with the age ranging from 36 to 65 years. 50 percent of the workers do not have any formal education whereas of the remaining percentage only 12 percent have high school education. About 62.5 percent of the workers claim they do not have any training in rock identification and rock processing. Although the salaries of the workers are not guaranteed every month they are motivated by the profit the mine makes per month and salaries range from R 500 – R 1000 per month.

This cooperative is run and operated by old people, this is one of the contributing factors towards the low productivity, and workers work half day every day which means a lot of production time is lost whilst workers are idling. The equipment at this mine are very old and they need servicing but the mine cannot afford it since it does not generate enough capital, a large sum is invested in fixing the daily breakdowns. The manager of this stone crusher is a woman, when she is trying to address the challenges the male workers feel reluctant to follow which makes managing the business difficult. The rock collection and crushing cannot be done during rainy seasons since the plant does not have corrugated roofing sheets. The roads are too slippery to collect rock hence the production is affected during such times.

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After the full evaluation of the SWOT analysis for Mukula Stone Crusher it has emerged that there are a lot of issues to be addressed because the weaknesses and the threats outweighs the opportunities. Table 4.1 summarizes the assessment of the Stone Crushers strength, weaknesses, opportunities and threats.

Table 4.1: SWOT analysis of Mukula Stone Crusher

Internal environment			
Strength	**Score**	**Weakness**	**Score**
Equipment • They are semi-mechanized	+5	**Equipment** • Equipment lack maintenance • The equipment are old • Lack of complimentary health and safety gear	-7 -9 -6
Workforce • High levels of dedication	+3	**Workforce** • Poor understanding of the work • Lack skills of operation • Use of indigenous knowledge	-5 -3 -1
Health and safety		**Health and safety** • Lack of personal protective equipment • Lack of understanding of health implications associated with aggregate rock mining	-3 -8
Production		**Production** • Weather affects production • Production is subjected to the efficiency of the machinery used • Low levels of production • Too much down time of equipment • Use of inappropriate tools	-2 -4 -5 -6 -8

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Table 4.1: SWOT analysis of Mukula Stone Crusher (continuation)

Education levels • Use indigenous knowledge	+7	**Education levels** • Lack of geological knowledge • Lack of technical skill • Lack of business management skills • Lack of marketing skills	-9 -6 -4 -7
Financial resources • They have working capital • NGOs help with finances	+4 +3	**Financial resources** • Limited financial resources • Mismanagement of funds • There is a lack of production resources and funds	-6 -8 -9
Sum of scores =	+22	**Sum of scores =**	-116
External environment			
Opportunities	**Score**	**Threats**	**Score**
• Abundant source rock • Provision of jobs • Business opportunities for the surrounding communities • Opportunity for students to conduct their research work and practical training	+8 +6 +5 +6	• Legislation requirements • Unavailability of access roads • Limited funding support • Subsistence economy • Employing unskilled labour and this lead to slow down production • Using modern and sophisticated methods and machinery will require more capital • Poor market	-9 -7 -7 -6 -9 -8 -9
Sum of scores =	+25	**Sum of scores =**	-54

4.1.2 Phiphidi Stone Crusher survey

Phiphidi Stone Crusher is a small-scale mine owned by a person who took over from a company known as Murray Roberts which crushed the stone for road construction. It is

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operated by the owner under management of one of the six workers. The workers work 8 hours per day and work is schedule in such a way that rock collection takes place Mondays-Wednesdays whilst Thursdays and Fridays are earmarked for rock processing. This arrangement is subject to change depending on the demand for the rock aggregates.

This mining operation is not registered as a mine and the workers are not registered as well. The mine does not follow any mining or environmental laws because they do not know about them. Equipment at this small-scale mine include a front end loader, one dump truck, a processing plant with one crusher and an excavator. This establishment does not have any marketing strategies in place and therefore depends on word of mouth and they do not see the importance of advertising their aggregates and believes the customers they has are enough.

This mine has 6 workers of which two are females and four males. The ages of the workers range from 35-51 years and they have no formal education therefore they are considered as general workers. All the workers have no formal education hence they are general workers and their salaries range from R1000 to R1500 per month depending on the years one has worked at the company. They work 8 hours per day. Different activities are performed in specific days as follows: Mondays-Wednesdays are earmarked for rock collection whereas Thursdays and Fridays are for rock processing, but this is subjected to change depending on the demand for the rock aggregates.

The steps that are involved in mining and processing at Phiphidi Stone Crusher includes locating of the source rock, rock breakage, haulage and crushing. The primary task involved stripping of the overburden by use of hydraulic excavator to expose the buried basalts. Rock breakage is done using the sledge hammer and bigger outcrops are broken down by burning of tire. The tires are burned on the rocks and then cold water is poured when the rock is still hot, this results in rock breakage. The process of rock excavation and breakage is shown in Figure 4.2.

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Figure 4.2: Rock excavation and breakage activities at Phiphidi Stone Crusher

After the rocks have been broken down they are then loaded manually into the bucket of a front end loader and then transported to the processing plant. At the plant the rocks are loaded these are 27mm and 19mm sizes. In Phiphidi Stone Crushers rock collection and crushing take place on Monday to Wednesdays and Thursdays and Fridays respectively. The separation of the two operation is due to the fact that there are six workers hence both operations cannot be done simultaneously. During the crushing period a quantity of 20-30 tons are produced per day.

The workers are provided PPEs once a year and if the PPEs get damaged it is the responsibility of the worker to replace them. The workers see the importance of wearing PPEs but they think it will be a waste of their meager salaries to replace such PPEs when damaged hence they work without them. Health and safety can also be viewed as another factor that small-scale miners need to take seriously. The provided PPEs can only last a few months and after which the workers will be exposed to the harsh working conditions without PPEs. The main limitation of this mining operation is the size and condition of the equipment.

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In this stone crusher their main limitation is the equipment that is available for use. The machines have a lot of limitations in terms of their capacity and condition. The equipment in use are old and damaged, they also lack maintenance. The workers operating such equipment have no knowledge on operating them to a maximum hence production is affected negatively.

Results of the SWOT analysis shows that the weaknesses and the threats for this company outweighs the strength and weaknesses. Table 4.2 summarizes the assessment of Phiphidi Stone Crushers strength, weaknesses, opportunities and threats. From the evaluation results presented in Table 4.2 it is evident that this stone crusher stands a greater chance of closing if the weaknesses and the threats are not addressed.

Table 4.2: SWOT analysis of Phiphidi Stone Crusher

Internal environment			
Strength	**Score**	**Weakness**	**Score**
Equipment • They are semi-mechanized	**+4**	**Equipment** • Equipment lack maintenance • The equipment are old • Lack of complimentary health and safety gear • Lack of functional equipment	**-9** **-8** **-9** **-7**
Workers • High levels of dedication		**Workers** • Poor understanding of the work • Lack essentials skills	**-6** **-8**
		Health and safety • Lack of personal protective equipment • Lack of understanding of health implications associated with aggregate rock mining	**-7** **-9**

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Table 4.1: SWOT analysis of Mukula Stone Crusher (continuation)

Production		**Production**	
		• Weather affects production	-9
		• Production is subjected to the efficiency of the machinery used	-8 -5
		• Low levels of production	-8
		• Too much down time of equipment	-7
		• Use of inappropriate tools	
Education levels		**Education levels**	
• Use indigenous knowledge	+6	• Lack of geological knowledge	-6 -8
		• Lack of technical skill	-7
		• Lack of business management skills	-9
		• Lack of marketing skills	
Financial resources		**Financial resources**	
• NGOs help with finances	+5	• Limited financial resources	-6
		• Mismanagement of funds	-7
		• There is a lack of production resources and funds	-5 -8
		• They lack working capital	
Sum of scores =	**15**	**Sum of scores =**	**-156**

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Table 4.1: SWOT analysis of Mukula Stone Crusher (continuation)

External environment			
Opportunities	**Score**	**Threats**	**Score**
• There is a good market for the aggregate products and availability of technical economic advice from Small Enterprise Development Agency (SEDA) • Provision of jobs • Business opportunities for the surrounding communities • Opportunity for students to conduct their research work and practical training	+7 +5 +4 +6	• Legislations requirements • Unavailability of access roads • Limited funding support • Subsistence economy • Employing unskilled labour slow down production • Using modern and sophisticated methods and machinery will require more capital	-9 -3 -4 -5 -8 -9
Sum of scores =	**22**	**Sum of scores =**	**-38**

4.1.3 W.G Wearne Quarry survey

W.G Wearne Quarry is a South African owned mining company which forms part of W.G Wearne Limited which owns eight quarries around South Africa. This company owns a number of equipment which include front end loaders, excavators, dump trucks, mobile processing plant and a fixed processing plant which has one primary crusher and three secondary ones. The operation at this quarry is highly mechanized. The company is registered as a mining company and the management of the company have and understanding all the mining related laws and abide by them strictly.

In this mine there is an environmental management plan (EMP) which is implemented. The implementation of the EMP is enforced by a consulting environmental consultant company. To ensure the success of the EMP general mining workers are taught of environmental issues.

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Government official from DMR visits the mine once a month to assess the environmental conditions and implementation of proposed management strategies.

The quarry has an onsite geotechnical laboratory to test the strength of the aggregate produced. This gives the customers and company confidence in the quality of the aggregates. WG Wearne determines its product prices through the use of a weighing scale, which implies that all the product sold is accounted for. Marketing is considered to be very important by management of this quarry and their marketing is done via internet, posters, radio and flyers.

The quarry operates 24 hours and the work-force is divided into day and night shift, this means that there is production 24 hours. The manager has over 10 years of experience in the field of mining and has qualifications in management and aggregate mining and processing. It has 40 workers of which 20 are general mine workers with no formal education. The remaining 20 are divided into administration, marketing, health and safety managers and laboratory technicians The general workers at the quarry are 20 employees and their ages range from 23 to 60 years, of which 90% have families and they have no formal educational background in mining but 80% have high school education. The salary range for the general workers is R1500-R2500, depending on the number of years an employee has been working for the company.

The production cycle of W.G Wearne comprises of rock breakage by drilling and blasting, material handling using trucks and excavator and also processing of the material. Such production is achieved by making use of different types of equipment such as: excavator, trucks, jaw crusher, drilling machine, and conveyor belts. Operations in this quarry involves excavation and breaking of consolidated and unconsolidated material.

Before any work is done at this quarry a surveying company is given a contract to survey the area of interest in order to determine the leveling of the area and to determine where the drilling and blasting will take place. For the consolidated material, a drilling and blasting contractor is appointed to drill and blast a total of 60 000 tons which is then processed over a space of three months. The blasted material is then loaded into dump trucks to the primary crusher, the primary crushing is controlled by an operator who regulates the amount of material to be crushed at a given time. The loose rocks which do not require blasting are excavated and processed using a mobile crushing plant.

The crushed materials are then transported to three different cone crushers for further processing and different aggregate size are produced ranging from 19.5 mm, 9.5mm stones, 13.2mm stones (crusher dust), to 6.7mm stones. The 19.5 mm size aggregates the usually

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have sharp edges and these are then removed using the rock shaper (bomac) to make it usable for road construction. This quarry produces a variety of products starting from the aggregate rock, the ready mix and the 6.7 mm stone which is produced and washed on site before it is sold. For every stockpile produced a sample of material is taken to the geotechnical laboratory to determine the strength of the material. The products at W.G Wearne are highly marketed hence they have a wide customer base. The geotechnical analysis give customers confidence in the product. The mineral processing plant is shown in Figure 4.3.



Figure 4.3: The W.G Wearne processing plant

The required PPEs are made available by the company and before the workers start working. At this quarry there is a formal induction that is conducted prior to commencement of work. There is an onsite health and safety officer who ensures the implementation of health and safety measures

This quarry is highly mechanized and the workforce is available 24 hours a week hence production never stops. The level of education of the manager can also be viewed as a positive attribute towards high production. For W.G Wearne the SWOT analysis results shows that the

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opportunities and strength for this business outweighs the weaknesses and threats and the business has a better chance of flourishing. Table 4.3 presents the findings of the SWOT analysis.

Table 4.3: SWOT analysis of W.G Wearne Stone Crusher

Internal environment			
Strength	**Score**	**Weakness**	**Score**
Equipment • They are semi-mechanized to mechanized	+7	**Equipment** • Equipment lack maintenance	-5
Workers • High levels of dedication	+8	**Workers** • poor understanding of the work	-3
Health and safety • Governed by DMR • Enforce health and safety guidelines • They have health and safety manger on site	+9 +8 +9	**Health and safety** • Lack of personal protective equipment • Lack of understanding of health implications associated with aggregate rock mining	-4 -4
Production • Higher demand, thus high production rate	+9	**Production** • Weather affects production • Production is subjected to the efficiency of the machinery used • Low levels of production • Too much down time of equipment • Use of inappropriate tools	-5 -4 -3 -6 -3
Education levels • Have level of educated people • Have different experts at different departments	+7 +7	**Education levels** • Half of the general workers lack formal education	-3

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Table 4.3: SWOT analysis of W.G Wearne Stone Crusher (continuation)

Financial resources		**Financial resources**	
• They have working capital	+8	• Mismanagement of funds	-2
• They have private investors	+7		
Sum of scores =	**+79**	**Sum of scores =**	**-42**
External Environment			
Opportunities	**Score**	**Threats**	**Score**
• Extensive market for aggregate rocks	+9	• Legislations requirements	-3 -2
• Abundant source rock	+9	• Subsistence economy	-4
• There is a good market for the aggregate products and availability of technical economic advice from Small Enterprise Development Agency (SEDA)	+9 +8	• Employing unskilled labour slows down production • Using modern and sophisticated methods and machinery will require more capital	-5
• Provision of jobs	+7		
• Business opportunities for the surrounding communities	+8		
• Opportunity for students to conduct their research work and practical training			
Sum of scores =	**+50**	**Sum of scores =**	**-14**

4.1.4 Pakama Stone Crusher Survey

Pakama Stone Crusher is an establishment that is formed by family members and friends who are just investors and are not involved in the daily running of the business. It is registered as a crusher at level 4 of the black economic empowerment contributors. The equipment owned by the company includes; 3 dump trucks, 1 front end loader and a processing plant which has 4 crushers of which two are secondary crushers and two primary crushers. The management

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of this establishment has a lot of marketing strategies in place and includes dissemination of flyers, radio announcements and internet advertisement.

The Pakama Stone Crusher has 15 employees of which 3 are plant operators, 2 laboratory technicians, 3 boiler makers, 3 general workers, 1 front end loader operator, 2 mechanics, 3 drivers and a manager. Of the workforce 50% are aged between 40 and 60 and 50% are 30-40 years old. The workers at this stone crusher are educated and they have done on the job training. They have sound understanding of the processes involved onsite. The salary range is from R1200-R3000 depending on the type of job. The company management is well aware of the required PPEs and they are made available by the company.

Production cycle of Pakama Stone Crusher consists of waste rock material collection from old Venetia Mine, processing of the material is through crushing and screening, they also conduct a geotechnical test of the strength of the product. The rocks that are processed are collected from the old Venetia Mine as waste rocks. These rocks are then dumped at the primary crusher and after primary crushing the materials are then transported by a series of conveyors to different secondary crushers. The sizes of aggregates produced are 10 mm stones, 14 mm stones, crusher dust, 7.1 mm stones, and 20 mm stones. After every cycle of production the stockpiled materials are taken to the geotechnical laboratory for testing. This stone crusher does not just focus on rock aggregates, they have diverse products which includes river sand, plaster sand, building mix, ready mix dry and filling. The sand that is sold at this stone crusher is sourced from the Limpopo River and the processing only involves the removal of foreign material from the sand. Health and safety at Pakama Stone Crushers is lacking enforcement because the mine does not provide PPEs for the workers and these workers are exposed to high levels of noise and dust.

The staff at Pakama Stone Crushers is highly qualified for whatever work they do which can be viewed as one of the factors resulting to its success. The degree of mechanization increases its productivity. This stone crusher has Venetia mine and N1 road Construction Company as the main customers so there is a large demand for its product. The contracts between the companies and the stone crushers are worth thousands of rands. The pricing strategy of this company makes it more productive because they weigh the product and then charge the material per cubic metres. This stone crushers show a lot of potential for growth and the SWOT analysis evaluation results attest to this statement and the findings are presented in Table 4.4.

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Table 4.4: SWOT analysis of Pakama Stone Crusher

Internal environment			
Strength	**Score**	**Weakness**	**Score**
Equipment • They are semi-mechanized to mechanized • The equipment is new	+9 +9	**Equipment** • Lack of complimentary health and safety gear	-4
Workers • High levels of dedication • Skilled workers • Middle aged workers	+9 +8 +6	**Workers** • Few workers • Male workers only	-5 -6
Health and safety		**Health and safety** • Lack of personal protective equipment • Lack of understanding of health implications associated with aggregate rock mining	-3 -2
Production • Have appropriate tools • Have a good market	+5 +9	**Production** • Weather affects production	-4
Education levels • Educated workers		**Education levels**	
Financial resources • They have working capital • NGOs help with finances • They have contracts with big companies	+9 +6 +9	**Financial resources**	
Sum of scores =	+79	**Sum of scores =**	-24

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Table 4.4: SWOT analysis of Pakama Stone Crusher (continuation)

External environment			
Opportunities	**Score**	**Threats**	**Score**
• Board market for aggregate rocks	+8	• Legislations requirements	-4
• Abundant source rock	+9	• Unavailability of access roads	-2
• There is a good market for the aggregate products and availability of technical economic advice from Small Enterprise Development Agency (SEDA)	+8	• Subsistence economy	-4
• Provision of jobs	+7	• Using modern and sophisticated methods and machinery will require more capital	-3
• Business opportunities for the surrounding communities	+6		
• Opportunity for students to conduct their research work and practical training	+8		
Sum of scores =	**+46**	**Sum of scores =**	**-13**

4.1.5 Summary of field survey for all the mines

This section summaries analysis of the questionnaire and personal interviews which was conducted during data collection from the selected small-scale mining activities. Data presented in this subsection in comprises analysis of all the selected small-scale mines and compares the results obtained through questionnaires and personal interviews. The data is presented in form of graphs and pie charts. The tool which was used to analyse the following results was the Statistical Package for Social Sciences (SPSS).

Socio-economic features of small scale miners

A total of 81 people participated in the survey. 43.8 % of the respondents were female while 56.3% were males. Which shows that there are 12.5% less women are involved in aggregate small-scale mining activities. The involvement of less females in small-scale aggregate mining

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is due to the fact that it is labour intensive, thus high degree of energy is required to break the rock and also extensive ore search is also involved.

In Figure 4.5, 65% of the workers are older than 46 years of age. This tells us that small-scale aggregate mining is done by old people. Those between 41-45 and 22-26 constitute 10% each and those between ages 36-40 contributes 15%. The implication of the above statistics is that people between the ages 22-45 years are not heavily involved in small-scale aggregate mining. In small-scale aggregate mining there is no issue of child labour because youth of 21 years and younger are not involved.

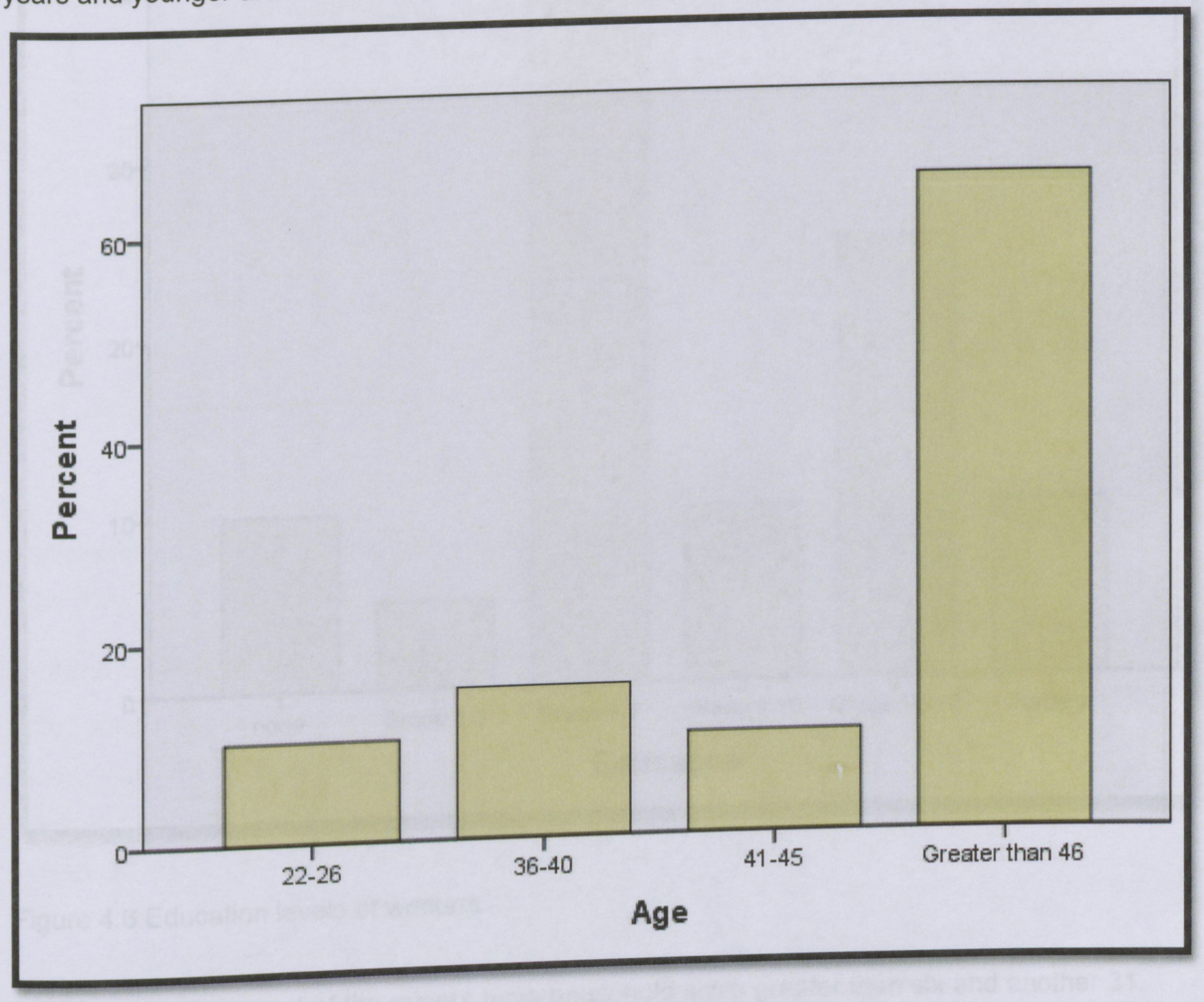


Figure 4.5 Age of respondents

Figure 4.6 clearly indicates that of the total workers interviewed, only 25% have attained a grade 12 certificate. However 65% of the workers have attained grade ranging from one to ten whereas 10% do not have any form of education at all. When it comes to tertiary education

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only 10% of the miners have this form of education. The issue of low level of education is evident through the way these small-scale workers identify and extract their source rocks and the way they manage their enterprises. Checking the variation of the prices of their products one can conclude that it is due to the level of understanding which is purely based on instinct. Be it what it may there is hope for these small-scale miners because some of them have received on the job training which helps them in running their businesses.

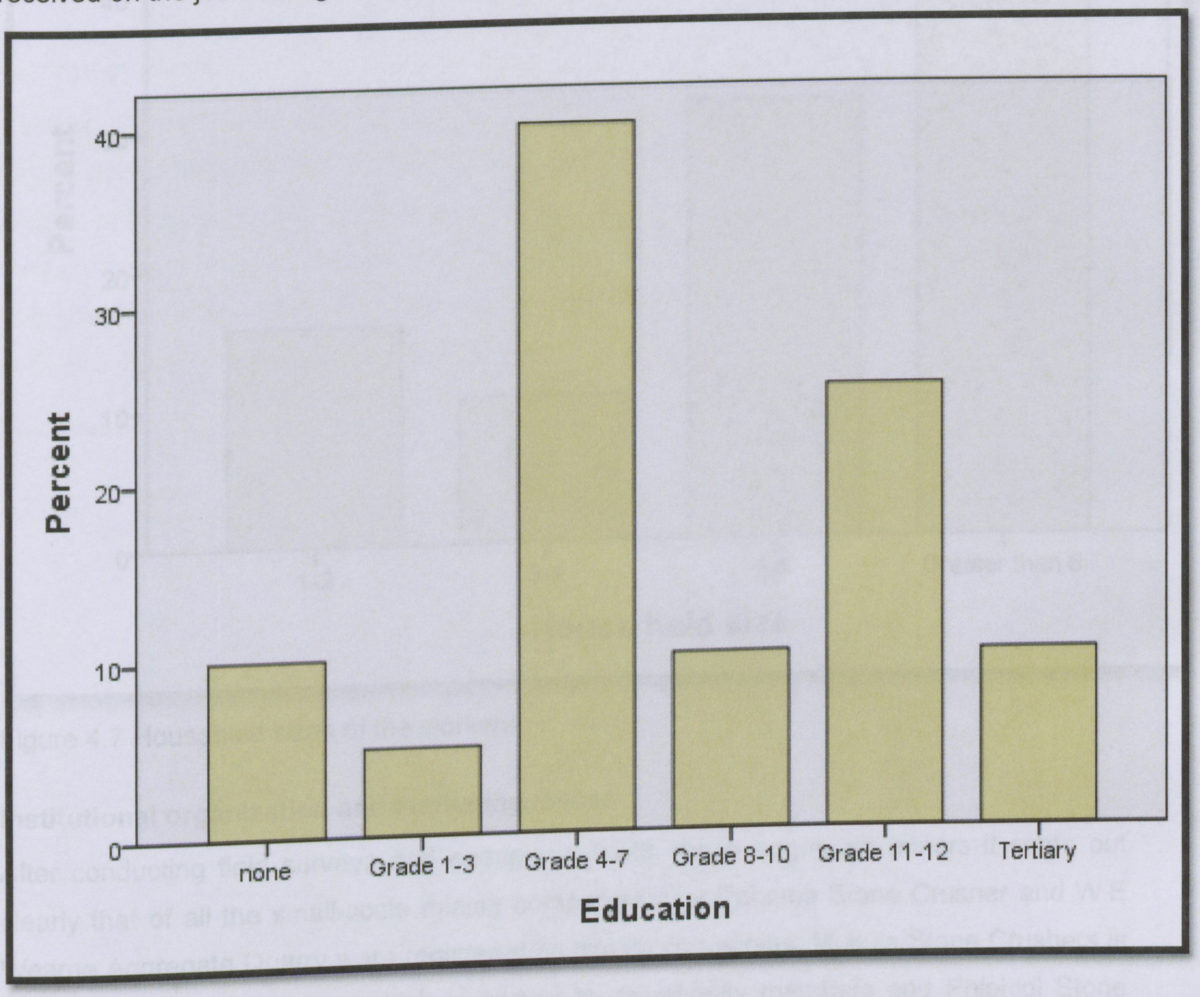


Figure 4.6 Education levels of workers

A significant 42 percent of the miners have household sizes greater than six and another 31 percent have five to six dependents. Only 27 percent of the miners have dependents who are four and less. The statistics in Figure 4.7 shows that there is a high number of people dependent on small-scale mining.

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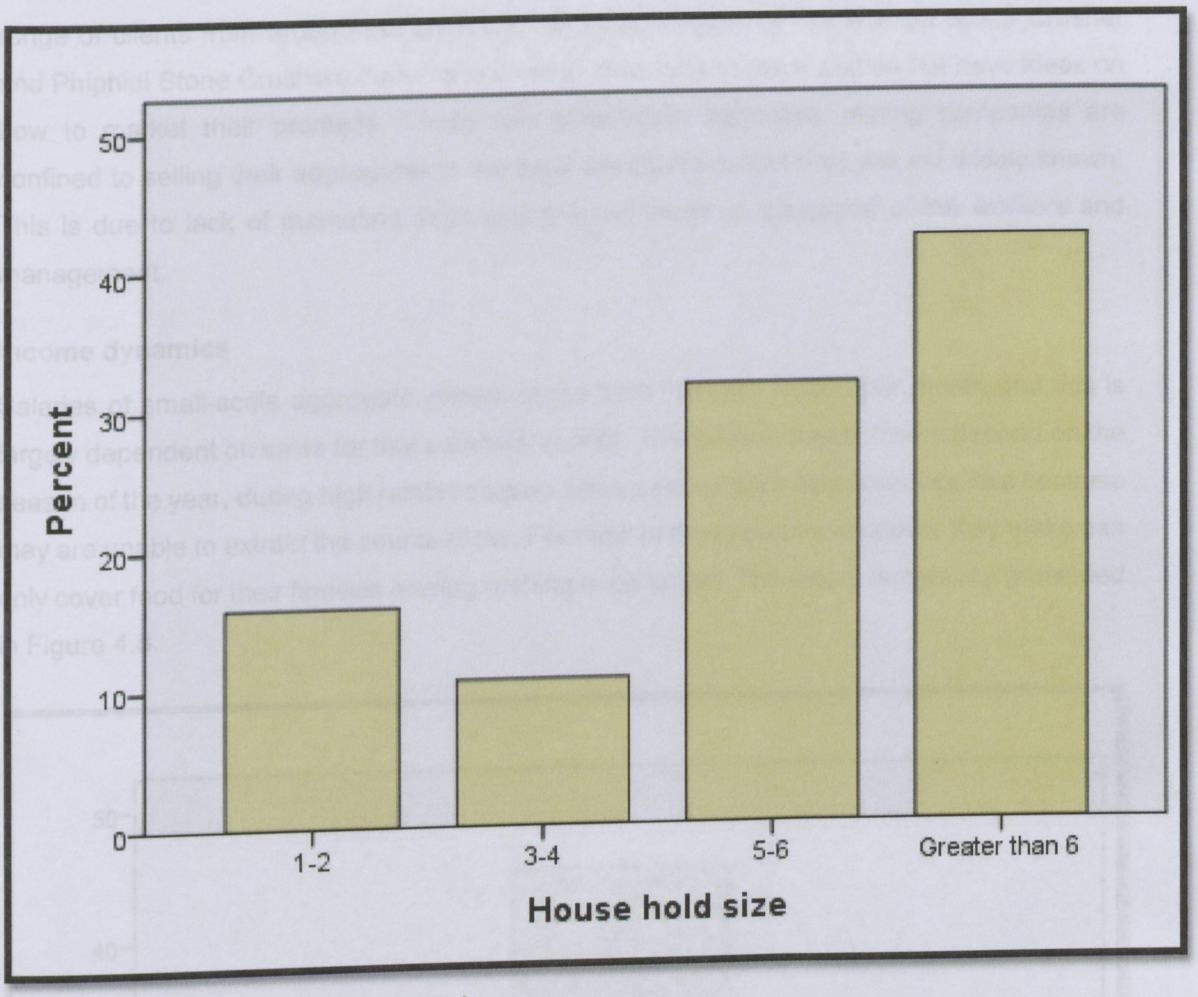


Figure 4.7 Household sizes of the workers

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Institutional organization and marketing issues

After conducting field surveys and engagement with these aggregate miners it came out clearly that of all the small-scale mining companies only Pakama Stone Crusher and W.E Wearne Aggregate Quarry were registered as mining companies. Mukula Stone Crushers is registered as a cooperative which is owned by community members and Phiphidi Stone Crushers is not registered at all and it just operates without any form of legal documents. The former two which are registered are more organized in terms of management and handling of finances whereas the latter are faced with a lot of financial constraints and mismanagement of funds.

Marketing is referred to as the action or business of promoting and selling products or services, including market research and advertising. Pakama Stone Crusher and W.E Wearne Aggregate Quarry have marketing strategies in place. These strategies include flyers, radio and local newspaper articles. The two mining companies are well known and have a wide

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range of clients from around the province. Whereas companies like Mukula Stone Crusher and Phiphidi Stone Crushers have no marketing strategies in place and do not have ideas on how to market their products. These two small-scale aggregate mining companies are confined to selling their aggregates to the local communities and they are not widely known. This is due to lack of marketing skills and the low levels of education of the workers and management.

Income dynamics

Salaries of small-scale aggregate miners range from R500 to R5000 per month and this is largely dependent on sales for that particular month. The sales of these miners depend on the season of the year, during high rainfall season these small scale miners produce less because they are unable to extract the source rocks. For most of these miners whatever they make can only cover food for their families leaving nothing to be saved. The salary ranges are presented in Figure 4.8.



Figure 4.8 Salary range of miners

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Although the majority of small-scale miners do not earn high incomes from this activity, the results presented by Figure 4.9 shows that 72 percent of the respondents save their money at the bank. About 18 percent of workers do not save their money because they do not generate enough capital to save and they are sole bread winners at home. Despite the lack of education, it is evident that many of the small-scale miners prefer to save their money in commercial banks and they understand the need to save money. About 50 percent of these small-scale miners do not depend solely on the mining activities but they have their other small businesses which helps them to generate more income.

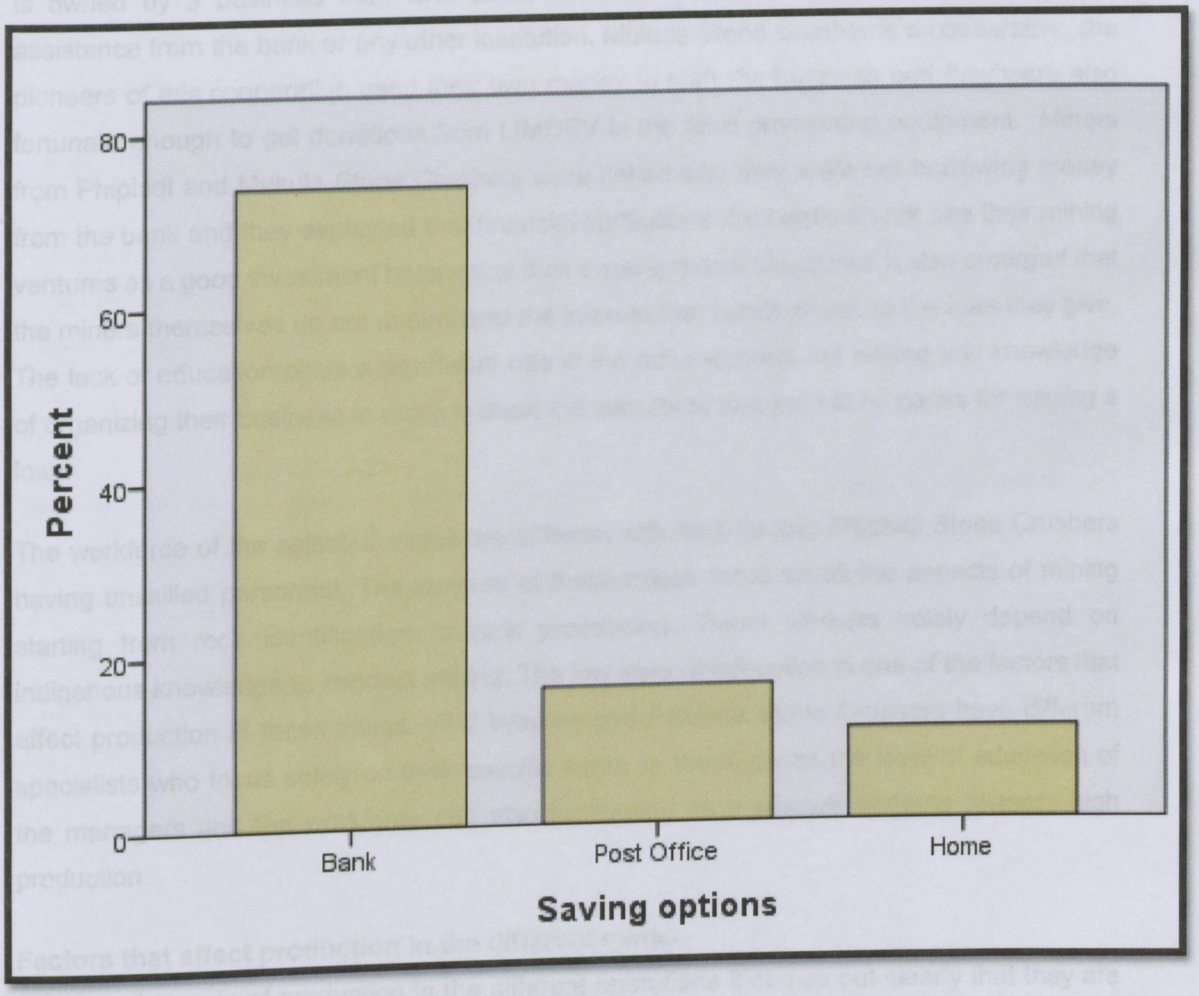


Figure 4.9 Saving options of workers

Short-term training

Of the total respondents 87.5 percent have not received any form of formal training but they admit that they have had on the job training conducted by other co-workers. About 12.5

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percent of miners have received training sponsored by the local non-profit organizations. In all the mines visited Mukula and Phiphidi Stone Crushers are semi-mechanized and W.G Wearne and Pakama Stone Crushers are highly mechanized, hence formal training is necessary because this machines are associated with a lot of health hazards. Training is needed when it comes to rock identification, crushing of the rocks, health and safety and business management.

Sources of startup and working capital

Results shows that two of the small-scale mining ventures namely Pakama Stone Crusher and W.G Wearne Aggregate Quarry borrowed money from commercial banks and their families also invested money in the business as well. In the case of Phiphidi Stone Crusher it is owned by a business man who solely invested in the company without getting any assistance from the bank or any other institution. Mukula Stone Crusher is a cooperative, the pioneers of this cooperative used their own money to start the business and they were also fortunate enough to get donations from LIMDEV in the form processing equipment. Miners from Phiphidi and Mukula Stone Crushers were asked why they were not borrowing money from the bank and they explained that financial institutions like banks do not see their mining ventures as a good investment because of their organizational structures. It also emerged that the miners themselves do not understand the interest that banks attach to the loan they give. The lack of education plays a significant role in the mine workers not having any knowledge of organizing their business in order to meet the standards that are set by banks for issuing a loan.

The workforce of the selected mines are different with Mukula and Phiphidi Stone Crushers having unskilled personnel. The workers at these mines focus on all the aspects of mining starting from rock identification to rock processing. These workers solely depend on indigenous knowledge to conduct mining. The low level of education is one of the factors that affect production in these mines. W.G Wearne and Pakama Stone Crushers have different specialists who focus solely on their specific fields. In these mines the level of education of the managers and the workforce can also be viewed as a positive attribute towards high production.

Factors that affect production in the different mines

Studying the cycle of production in the different operations it comes out clearly that they are not at the same level of small-scale mining. W.G Wearne and Pakama are more advanced small-scale aggregate mines than Mukula and Phiphidi Stone Crushers. Starting from rock identification Mukula and Phiphidi Stone Crushers use indigenous knowledge to identify their

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rocks and their rock collection methods are labour intensive and purely manual. The rocks which are collected per day in Mukula and Phiphidi Stone Crushers are 18 cubic metres. This affects the daily production of these mines negatively because the rocks which are crushed per day are less than the collected 18m^3. At W.G Wearne and Pakama Stone Crusher, trucks of capacity 20m^3 are used to haul rocks. The two mines process 20 000 tons of rock per month, hence their production is high.

Mukula and Phiphidi Stone Crushers have only one crusher, whereas in the other mines they have four crushers to ensure maximum crushing of the rocks. Hence this increases the quality of their products since the aggregates are processed more than once. After stockpiling rock samples are taken for geotechnical analysis and the rocks are also shaped to finish the edges so that they can be used for road construction. Pakama and W.G Wearne Stone Crushers have a variety of products with a wide range of sizes, a ready mix and also river sand. This widens their market because they are not solely focused on aggregate rock crushing

4.2 Health and Safety Measurements and Analysis

This section covers the results of the analysis of noise, dust and aggregate mining related work hazards. Noise and dust are the prominent health hazards in aggregate mining due to crushing and screening of the rock.

4.2.1 Noise level analysis

Table 4.5 shows the different noise levels produced at different stages of extraction and processing of the aggregate rocks at different mines in the study area. The smallest value calculated for the duration of eight hours was 100 dBA and this value is way above the recommended value by the National Institute for Occupational Health and Safety which is 90 dBA. Furthermore as can be seen in Table 4.5 the allowable time which a worker is allowed to spend at 100dBA is only 120 minutes per day without any health implications. Thus in the selected mines workers spend more time than they are suppose in areas with high noise levels and this can have negative impact on their health.

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Table 4.5 Noise level readings

Stone crusher	Activity	Averaged reading	Permissible duration (hrs)	Permissible duration (min)
Mukula	Primary crushing	111	0.44	26.12
	Secondary crushing	106	0.87	52.23
W.E Wearne	Secondary crushing	108	0.66	39.59
	Rock shaping	108	0.66	39.59
	Secondary crushing	108	0.66	39.59
Phiphidi	Primary crushing	105	1.00	60.00
Pakama	Primary crushing	104	1.15	68.92
	Rock shaping	100	2.00	120.00
	Secondary crushing	109	0.57	34.46

The highest average value for noise exposure which was measured was 111 dBA, for this level of noise a worker can only be allowed to be in such an environment for 26.12 minutes without earplugs. The average value is 21dBA above the allowable limits which call for immediate intervention measures. From the selected small-scale mines in the study area only two of the mines provide earplugs for the workers, thus for the other two they work without earplugs and this will result in serious health implications in the long run. From this study the conclusion made is that the exposure to the health hazard which is noise is very high, since the high levels of noise are from the crushing and shaping of the rocks, it is recommended that workers in these mines are provided with earplugs.

4.2.2 Dust analysis

According to the X-Ray Fluorescence (XRF) analysis which was conducted the results show high levels of silica (SiO_2). The concentration of silica in all the samples from all the small-scale mines ranged from 45.6-78.56 percent. Whilst the concentrations of other major oxides were far lower. Exposure to respirable silica for prolonged periods may results into different lung diseases. This results are presented in Table 4.6.

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Table 4.6: X-Ray Fluorescence results from different small-scale mines

Major element analyses results:

	SARM49									
%	Certified	Analyzed	PhD1	MK 1	PK 1	PK 2	PK3	WG1	WG 3	WG 2
SiO_2	99.6	99.48	45.06	46.96	74.68	62.06	78.56	73.53	62.70	51.63
TiO_2	0.01	0.00	1.89	1.76	0.02	0.80	0.41	0.07	1.09	1.61
Al_2O_3	0.05	0.01	14.00	13.58	14.56	13.34	8.67	14.36	10.34	13.86
Fe_2O_3	0.05	0.01	16.28	15.04	2.70	10.49	3.87	2.45	12.08	15.73
MnO	0.01	0.00	0.23	0.23	0.06	0.21	0.07	0.03	0.16	0.18
MgO	0.05	0.01	6.01	6.30	1.18	4.14	1.95	3.54	2.68	3.92
CaO	0.01	0.01	9.20	7.91	0.52	1.63	0.54	0.01	4.67	6.49
Na_2O	0.05	0.02	2.03	2.86	2.86	0.79	1.11	0.20	2.42	3.92
K_2O	0.01	0.01	0.15	0.13	3.88	3.15	1.29	3.29	2.07	0.78
P_2O_5	0.00	0.03	0.20	0.19	0.08	0.09	0.20	0.05	0.14	0.20
Cr_2O_3	0.00	0.00	0.04	0.03	0.00	0.05	0.01	0.00	0.00	0.01
NiO	0.00	0.00	0.02	0.02	0.00	0.02	0.01	0.01	0.01	0.01
V_2O_5	0.00	0.00	0.06	0.06	0.00	0.02	0.01	0.00	0.03	0.05
ZrO_2	0.00	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.03
CuO	0.00	0.00	0.03	0.02	0.00	0.00	0.07	0.00	0.01	0.01
LOI	0.00	0.10	4.29	4.47	0.02	3.04	2.41	2.13	1.22	1.70
TOTAL	100	99.68	99.50	99.57	100.58	99.85	99.18	99.68	99.64	100.12

Sampled dust analysis

Crushing and screening are major sources of dust at the aggregate processing plant. Dust level measurements for the selected small-scale aggregate mining were taken from the primary crusher, secondary crusher and the screens at 900m radius. Ten samples were taken at 100m interval from the source. The dust levels which were measured from the primary crusher as a single entity and the secondary crusher and screens as another entity since they are closely located in terms of distance. The results for the dust measurements of the secondary crushers and the screen are discussed in the following sections. According to South African National Standards (2011), the allowable dust exposure levels in South Africa is 35mg/m^3 per eight hours shift.

The measurement from W.G Wearne indicated that the dust levels for both the primary crusher and the secondary crusher and the screens are very high. The maximum dust level recorded at the primary crusher was 68.55 mg/m^3 respirable dust level as shown in Figure 4.10 and the secondary crusher and screens producing 71.33mg/m^3. It was observed that the respirable

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dust levels at both sources were almost double the recommended environmental safe emissions. A decreasing trend in dust levels with increasing distance from both sources was noted and the R^2 values for both primary crusher and secondary crusher of 0.9809 and 0.99 respectively were all above 0.5 which show a strong and statistically significant relationship between dust levels and distance from the crusher. The R^2 represent the relationship between the emitted dust and the distance from the source, when this value is less than 0.5 there is no relationship between the source the dust concentration and the dust source.

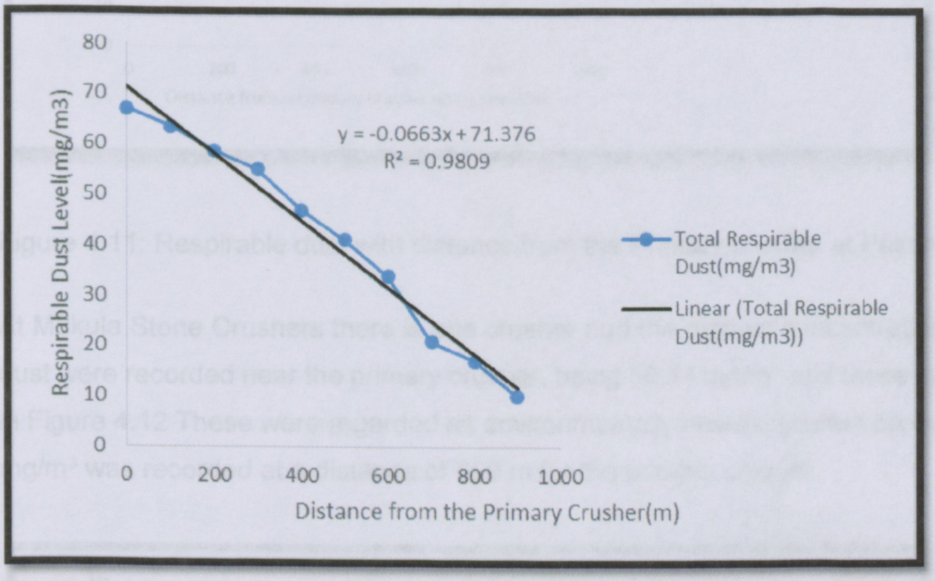


Figure 4.10: Respirable dust with distance from the Primary crusher at W.G Wearne

The highest respirable dust concentrations at Pakama Stone Crusher were recorded near the primary crusher and near the secondary crushers and screens as 57.65 mg/m^3 and 65.12 mg/m^3 respectively the results are presented in Figure 4.6. The lowest dust concentrations were recorded on distance interval 900m and the recorded values were 10.25 mg/m^3 from the primary crusher as indicated in Figure 4.11 and 17.27 mg/m^3 from the secondary crushers and screens. The results showed decrease in dust levels when moving away from both sources as compared to the results for W.G Wearne. This shows that the amount of dust generated at Pakama Stone Crushers is less as compared to that of W.G Wearne Stone Crusher. This may be attributed to the fact that Pakama Stone Crushers has dust management strategy in place.

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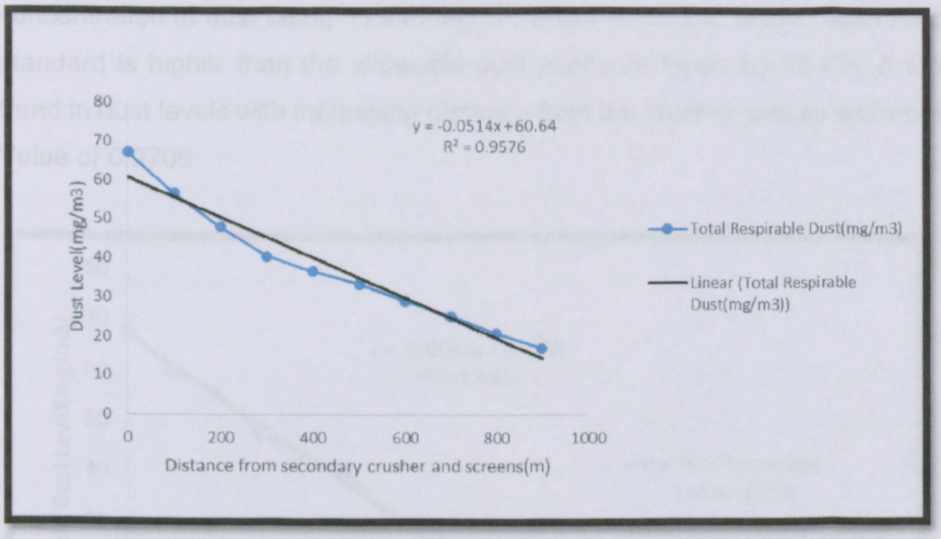


Figure 4.11: Respirable dust with distance from the Primary crusher at Pakama

At Mukula Stone Crushers there is one crusher and the highest concentrations for respirable dust were recorded near the primary crusher, being 30.14 mg/m^3 and these results are shown in Figure 4.12 These were regarded as environmentally unsafe. Lowest concentration of 1.18 mg/m^3 was recorded at a distance of 900 m for the primary crusher.

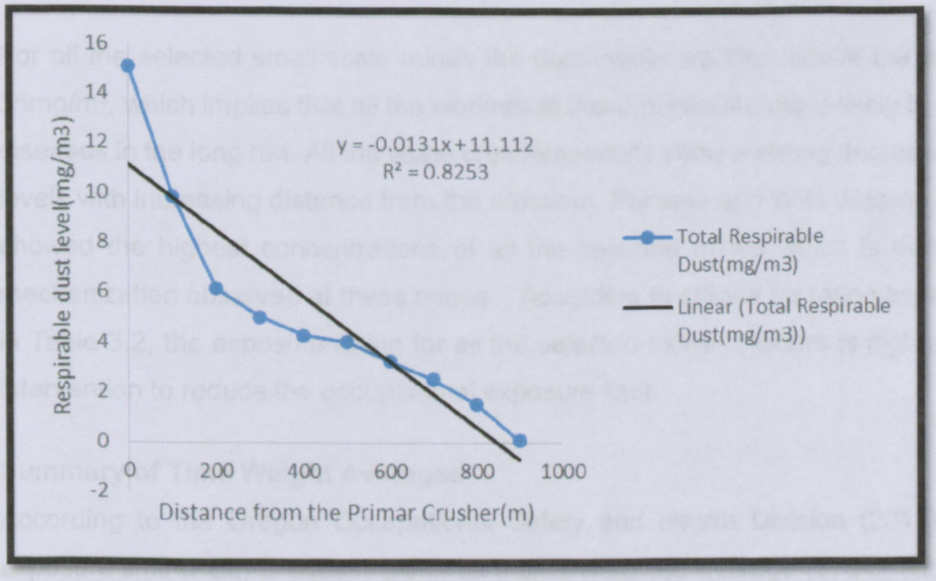


Figure 4.12: Respirable dust with distance from the primary crusher at Mukula

In Phiphidi Stone Crusher there is one crusher and one screen in the processing plant and therefore the dust source was regarded as a single entity. Measurements showed a highest

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concentration of dust being 46.948 mg/m^3, which according to the South African government standard is higher than the allowable dust exposure levels by 13.4%. A strong decreasing trend in dust levels with increasing distance from the crusher was as well noted having the R^2 Value of 0.9706.

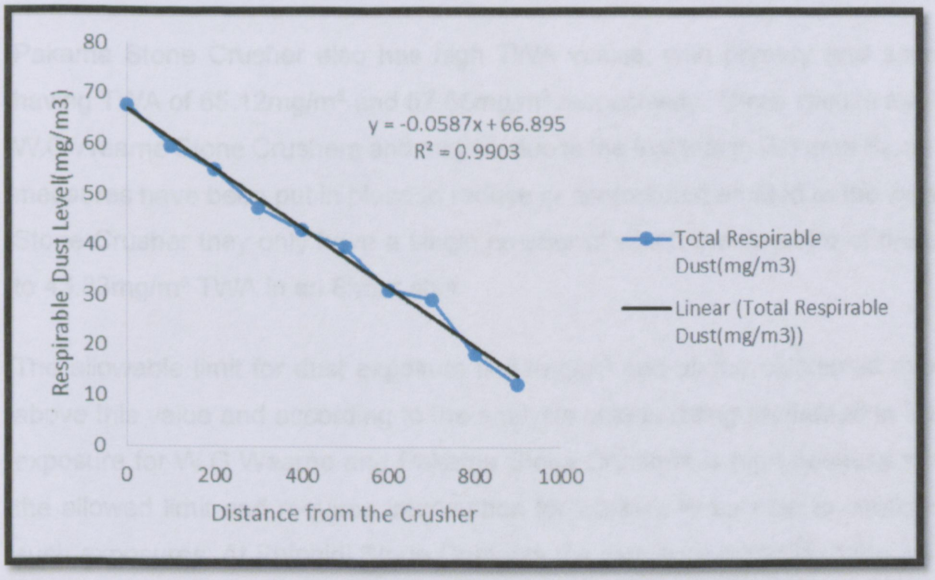


Figure 4.13: Respirable dust with distance from the primary crusher at Phiphidi

For all the selected small-scale mines the dust levels are high above the allowable limit of 35mg/m^3, which implies that all the workers at these mines are more likely to suffer from lung diseases in the long run. All the stone crushers results show a strong decreasing trend in dust levels with increasing distance from the crushers. Pakama and W.G Wearne Stone Crushers showed the highest concentrations of all the selected mines which is due to the level of mechanization observed at these mines. According to criteria for rating exposure presented in Table 3.2, the exposure rating for all the selected stone crushers is high and they require intervention to reduce the occupational exposure limit.

Summary of Time Weight Averages

According to the Oregon Occupational Safety and Health Division (2014), a permissible exposure limit (PEL) is usually given as a time-weighted average (TWA), although some are short term exposure limits (STEL). A TWA is the average exposure over a specified period of time, usually a minimal eight hours. This means that, for limited periods, a worker may be exposed to concentration excursions higher than the PEL, for as long as the TWA is not exceeded and any applicable excursion limit is not exceeded.

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Based on the studies conducted, W.G Wearne quarry has the highest time weighed average. With the secondary and primary crushers having the time weighed average of 71.33mg/m^3 and 68.55mg/m^3 respectively. Meaning that the workers at this operation are exposed to the highest levels of dust during their 8 hours shift. Mukula Stone Crushers has a TWA 31mg/m^3 which is the lowest of the selected mines. This may be due to the fact that the size of their crusher is small and less material is crushed compared to other operations.

Pakama Stone Crusher also has high TWA values, with primary and secondary crushers having TWA of 65.12mg/m^3 and 57.65mg/m^3 respectively. These results are less than that of W.G Wearne Stone Crushers and may be due to the fact that in Pakama Stone Crusher control measures have been put in place to reduce or control dust emitted to the workers. In Phiphidi Stone Crusher they only have a single crusher of which the operator of the plant is exposed to 43.83mg/m^3 TWA in an 8hour shift.

The allowable limit for dust exposure is 35mg/m^3 and all the calculated exposure limits are above this value and according to the analysis criteria rating presented in Table 3.2 the dust exposure for W.G Wearne and Pakama Stone Crushers is high because it is almost double the allowed limit and requires intervention for workers to be able to continue to work under such exposures. At Phiphidi Stone Crushers the exposure rating is moderate so they require constant sampling of the work area point towards putting air quality control measure and also the workforce should be under medical surveillance. For Mukula Stone Crushers the exposure per 8 hours shift is less than the OEL and therefore there is a need for routine checks so as to maintain the current conditions.

4.2.3 Job safety analysis (JSA)

The Mine Health and Safety Act (MHSA) of 1996 requires that before commencement of any work job safety analysis should be conducted to assess whether the particular activity is safe or not. In all the visited small-scale mines the safety of activities are not assessed before commencement of work. In this study JSA was conducted at all selected mines. Different hazards were identified for different activities depending upon the equipment used and the activity conducted. Activities in aggregate mining were divided into three namely rock extraction, rock crushing and rock shaping.

The potential hazards for rock extraction differed in relation to the method used to extract the rocks. Stone Crushers like Mukula and Phiphidi extract their rocks using manual labour through the use of chisels and hand picking the rocks. For Mukula Stone Crusher the rocks

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are extracted from the village in farms and equipment such as chisels and hammers are used. The hazard that is associated with this activity is fly rocks. There is no way these miners can protect themselves because rocks are not always located in advantageous positions. Phiphidi Stone Crusher use tyres and manual labour to break the rocks as illustrated in Figure 4.14. The hazards associated with this type of rock breakage are flying rocks and exposure to the smell associated with the burning of tyres.



Figure 4.14: Rock breakage at Phiphidi Stone Crusher

At Pakama Stone Crushers rock breakage is not part of the process because the rocks are collected from the old Venetia Mine. These rocks are waste rock. W.G Wearne Stone Crusher extract their rocks through drilling and blasting of the source rock and the dangers associated with this method are flyrocks. Drilling and blasting at W.G Wearne is done by a sub-contractor, who in the presence of health and safety officers ensures that all necessary precautionary measures are taken into account and this minimizes the potential hazard.

Rock crushing and shaping are done mechanically. The hazards that are associated with these operations are flying rocks, exposure to high levels of noise and dust. With reference to JSA analysis form the identified hazard exposure rating ranged from medium to high because workers are exposed to these hazards on a daily basis and they do not have the

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required protective equipment. These small-scale mines require intervention measures that can be used to eradicate the hazards. According to the recommended Best Practice guidelines small-scale miners are not expected to work in such conditions unless these hazards are addressed. The job safety ranking is presented in Table 4.7.

Table 4.7: JSA analysis

Mine	Activity	Likelihood	Severity
Mukula	Rock collection	4	3
	Crushing	4	3
	Haulage	4	2
Phiphidi	Rock collection	4	3-4
	Crushing	4	3
	Haulage	4	1-2
W.G Wearne	Drilling and Blasting	2	1
	Crushing	4	2-3
	Haulage	4	1-2
Pakama	Rock collection	4	2-3
	Crushing	4	2-3
	Haulage	4	1-2

In Mukula Crushing Stone there are several activities which poses risk on workers, these activities include rock collection, crushing and haulage. From all the activities there is high rate of the risks to occur daily since the activities are undertaken daily and there severity of the risk occurrence depends on the activity of which rock collection and crushing is rated 3 which is to say that major injuries can be obtained from those workers and haulage being rated at 2 which is to say minor injuries can occur from such activity.

Phiphidi Crushing Stone constitute of activities such as rock collection, crushing and haulage which their likelihood of occurring is rated at 4 which is to say that they occur daily. The rock collection is rated 3-4 on the severity which is to say that workers can experience major injuries to fatality. Crushing activity is rated at 3 on the severity which implies that workers can be exposed to major injuries. Haulage is rated at 1-2 which pose that workers can experience negligible to minor injuries from the activity.

In W.G Wearne Quarry they undertake drilling and blasting to fragment their rock material and that activity has been rated 2 in the likelihood this due because they blast after months. And other activities such as crushing and haulage have been rated 4 because they occur daily.

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Drilling and blasting have been rated 1 this is to say that the likelihood of occurrence of injuries is low since it is conducted by hired professionals. Crushing is rated 2-3 which is to say they pose minor to major injuries to workers. Haulage activity is rated 1-2 so to say it pose negligible to minor injuries.

Pakama Crushers have activity which include rock collection, crushing and haulage this has been rated 4 which occurs daily and the severity of rock collection and crushing has been rated 2-3 which is to say they pose minor to major injuries. Haulage activity is rated 1-2 which is to say it pose negligible to minor injuries.

4.3 Examination of Legislative and Regulatory Framework

According to the field survey 50 percent of the small-scale mines in this study are not registered hence the study of the legislative environment was very important in order to get a better understanding of the laws and the understanding of these miners. In South Africa there are different laws which deal with mining and these include the Mineral and Petroleum Resource Development Act, Health and Safety Act, National Environmental Act, National Qualification Framework Act, Skills Development Act, Basic Condition of Employment Act and Employment Equity Act.

4.3.1 Mining laws and regulations

The mining sector of South Africa is regulated through the Minerals and Petroleum Resource and Development Act (MPRDA) of 2002. Mining is undertaken in steps starting from prospecting through to mineral processing, according to the MPRDA every step of mining requires a permit. For the permit to be granted there are requirements that need to be met and these include a registration fee which is non-refundable. According to this Act an applicant of a prospecting permit and mining permit is supposed to submit an environmental management plan (EMP) and the applicant should also have a plan on how the prospecting or the mining will be conducted and also provide evidence that he/she has technical ability to conduct such wok. During the prospecting and the mining the applicant needs to prove beyond reasonable doubt that he/she can provide a healthy and safe working environment as indicated in the Health and Safety Act 29 of 1996.

In this study, W.G Wearne and Pakama Stone Crushers have complied with this Act and are registered as mining companies. Mukula and Phiphidi Stone Crushers are not registered as mining companies. These companies seem not to know that the need to register as a mining company and the do not even see the importance of it. After making a detailed study of the

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requirements of the law it was clear that these small-scale miners have no idea of how to draft an EMP and do not even have an understanding of managing the environment, which is one of the requirements of registration.

When it comes to issues of occupational health and safety small-scale miners do not even have personal protective equipment. MPRDA requires that one needs to have a technical and financial means to conduct mining. Mukula and Phiphidi Stone Crushers do not have financial means nor technical means. They do not have a business plan and they use equipment that are rudimentary so there is no way they will be able to meet the conditions of registration even if they knew about it.

Further analysis of the MPRDA shows that this law addresses the mining industry as a whole without any mention of small-scale mining. After studying the level of education of these small-scale miners it became apparent that they lack the capacity of understanding the mining laws and regulations. Even though there is a Directorate of Small-scale Mining which was established by the Department of Mineral and Resource to assist small-scale mines, miners are not even aware of it and it does not seem to be active in the implementation of the MPRDA.

4.3.2 Mine health and safety

The health and safety of small-scale mines is regulated by the Mine Health and Safety Act (MHSA) of 1996. The MHSA promote working in a safe environment in all mines in South Africa. Since there are no laws which are specific to small-scale mining, small-scale miners are required to implementing the health and safety requirements of the MHSA. This Act requires that the mining company should have a health and safety representative who has the appropriate qualifications. At Mukula and Phipidi Stone Crushers their highest level of education is grade twelve of the workers, and there is no understanding of health and safety. Pakama and W.G Wearne have a health and safety representatives who were employed due to the requirement of the MHSA.

Small-scale miners are aware of the hazards which are associated with the extraction and crushing of aggregates but there is little they can do about it since they do not have the capital and the know-how of dealing with hazards. The MHSA further requires that there should be a job safety assessment before commencement of any activity, and where there is a high potential of risk to occur worker should not enter such a work area. But some of these small-scale mines do not conduct job safety analysis.

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The amendment of section 10 of the MHSA (Act 74, 2008) has certain requisites about provision of safety, health and environmental (SHE) training which should be paid for by the employer. Small-scale miners do not have training related to the extraction and processing of their produce, for there to be provision for health and safety training seems like an impossible mission. According to MHSA Personal protective Equipment (PPEs) are to be provided by the mining company but visits to the small-scale mine showed that the miners do not have any PPEs.

4.3.3 Environmental Management

In South Africa the environmental legislation is administered by the National Environmental Management Act (NEMA) of 1991, the Mining and Mineral Act of 1991, Environmental Impact Assessment (EIA) guidelines of 1997, Environmental Conservation Act of 1989 and the aide-memoire requirements of 1992. According to the new Minerals and Petroleum Resource and Development Act (MPRDA) of 2002 all mining companies including small-scale mining are required to pay a fee for rehabilitation in order for them to get prospecting and mining rights. Small-scale miners are not even aware of such legislations and they do not even have the capacity to develop an Environmental Management Plan. Basically what is required by NEMA is for the developer to pay for whatever environmental problem which were caused before and after mining.

The Questionnaire was used to identify the environmental impacts and also to get the understanding of the miners on environmental issues. The impacts which were identified included soil erosion of the mined out are and open pits were rocks were extracted. Figure 4.15 clearly shows erosion and Phiphidi Stone Crusher. It is of paramount importance that small-scale miners get information about environmental management. Amongst the small-scale mines that were visited, two of the mines have knowledge about environmental management and delegates from Department of Mineral Resource (DMR) visit them once in a while. Whereas at Mukula and Phiphidi Stone Crushers there is no knowledge about environmental management. It emerged that officials from DMR have never visited the mines.

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Figure 4.15: Erosion at Phiphidi Stone Crusher

4.3.4 Labour and skills development

The laws that deal with labour and skills issues of mining in South Africa are the Labour Relations Act, National Qualification Framework Act of 2008, Skills Development Act of 1998, Basic Conditions of Employment Act of 1997, and Employment Equity Act of 1998. The responsibility of enforcement of these pieces of legislation lies with the Department of Labour (DOL) and the Department of Higher Education and Training (DHET). DOL is responsible for the fundamental issues and enforcing of labour legislations, for example the Standard Industrial Codes (SCI) are constituted and outlined by DOL (Mutemeri *et al.*, 2010).

Basic conditions for employment include: leave days, signing of a contract, notice upon termination of contract and stipulated pay per hour amongst others. Small-scale miners do not follow any of these conditions in the Act and are happy to at least have a job. These pieces of legislations requires that workers have to be Registered Unemployment Insurance Fund (UIF),

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workers are supposed to belong to unions and workers need to be trained in whatever job they are doing (skills development).

The results of the study indicated that three of the selected mines namely W.G Wearne, Pakama and Mukula Stone Crushers, have registered their employees with UIF. Phiphidi Stone Crusher the owner does not see the need to register workers and the workers themselves are afraid to raise the issue to the owner because they are afraid of losing their jobs. The workers who were interviewed seemed to know their rights but the rights are just simply not applicable in their context. They also have fear of losing their jobs because they have families to support. Small-scale miners are aware of the importance of skills development but they do not have the financial capacity to send workers for training since they do not generate enough capital to cover salaries, equipment repairs and maintenance and the operational cost.

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CHAPTER FIVE

INTERVENTIONS FOR SUSTAINABLE AGGREGATE MINES

Small-scale rock aggregate mining is an integral component of our society and it provides jobs and makes significant contribution to the local and national economy. However, the sector faces overlapping challenges that require redress to enable aggregate production to be more viable and sustainable. This chapter focuses on the development of an integrated approach of dealing with constraints that small-scale miners are facing. This study revealed that for the selected aggregate small-scale mines to flourish the operators need an interdisciplinary approach of dealing with the challenges. This approach should cover all the aspects of small-scale mining ranging from the exploration, mining and mineral processing techniques, environmental management, health and safety through to business management skills.

5.1 Health and Safety Management

Safety is one of the major challenges for small-scale miners and this is due to the lack of knowledge of the dangers associated with aggregate mining and lack of finance to buy PPEs. There are PPEs which should be made available for aggregates mines, these PPEs includes helmets, gloves, earplugs, dust mask, work suits and boots. Rock aggregate mining involves the crushing of rock during mineral processing and this can be associated with flyrocks which can injure the workers. In this regards, small-scale miners need helmets for protection. In the crushing plant there are excessive noise levels which are above the standard of 90 dBA and therefore workers need earplugs to protect them from this noise. During the crushing of the aggregate rocks excessive levels of dust are generated and therefore workers need to be protected from such dust by the use of dust masks.

Mukula and Phiphidi Stone Crushers get their deposits through manual breaking of rock which involves a lot of fly rocks hence safety googles are necessary for eye protection and the workers needs to wear gloves which will protect workers when picking up rocks or handling material. Small-scale mining companies need to provide full working gear for the workforce to promote safety in the workplace. Small-scale mines need to have a first aid kit available in case of minor injuries which can occur on site. Some of the dangers in aggregate mining can be avoided by posting warning signs to show the dangers which are associated with a particular activity. For every part of the processing plant there should be signs indicating the required PPEs. Some of the hazards in small-scale mining are due to the miners walking

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where they are not supposed to walk like workers walking under the conveyor belts. In these mines there should be a clearly indicated path which is to be followed by workers to avoid such hazards of falling material. These miners also need training on the importance of wearing PPEs and the dangers that are associated with aggregate mining and how such dangers can be avoided.

5.2 Environmental Management

Aggregate extraction and processing are of environmental concerns and these include increased dust, noise, and vibrations; increased truck traffic near aggregate operations; visually and physically disturbed landscapes and habitats; and affected surface or groundwater. Small-scale miners do not have adequate knowledge about environmental deterioration of their mining activities. Properly designed and operated aggregate production minimizes the impact on landscape, surface and groundwater, and surrounding communities. The extraction and processing techniques and the natural site conditions determine which specific impacts may occur, how extensive they will be, and how long they will last.

Aggregate mining is a temporal land use and when it is completed should be converted to another use which will be beneficial for the community. Consequently, the overall environmental impact of aggregate extraction is usually relatively small over the long term and the impacts can depend on the level of mechanization. Aggregates are environmentally inert materials and their processing commonly requires only crushing, screening, and washing.

Pakama and Mukula Stone Crushers do not extract consolidated material. Rather unconsolidated materials are collected for processing and as such there is no physical disturbance. These crushers have minor environmental impacts on the landscape, and on the surface since their operations do not conduct drilling nor blasting of the rocks. On the contrary W.G Wearne Quarry and Phiphidi Stone Crushers extract consolidated material which involves drilling and blasting activities. Phiphidi operation poses greater threat to the physical environment because it is being operated by unskilled workers who are not educated and have little or no knowledge about the environmental impacts.

W.G Wearne is a developed small-scale mining operation and it has people who are educated and have knowledge about the environmental impacts. Occasionally health and safety inspectors to visit the mine to assess the health and safety performance of the mine. The environmental impacts from Pakama and Mukula Stone Crushers includes dust and noise from the plant and moving equipment. Although these part of aggregate mining they can be

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minimized and adverse effects can be avoided. A carefully prepared and implemented operational plan will keep dust and noise within the required regulatory limits. For Mukula and Phiphidi Stone Crushers there is a need for training on environmental issues and their management.

5.3 Mining and Mineral Processing Techniques Improvement

Production and process technologies are a key aspect of any aggregate operation. The type of equipment and process configuration used is largely dependent upon the local market for construction materials, company experience and preferences, acceptance of new ideas and attitudes towards capital investment, the legacy of past production and the nature and geology of the mineral exploited (Brown, 1998).

Primary aggregate stone are produced by extraction and processing; most extracted rocks cannot be used from their natural state. They require some level of processing that prepares the rock to be used as a construction material. Processing is typically carried out in a production plant and involves crushing and screening. The key parameters for aggregates are particle size and distribution, particle shape, physical and mechanical properties and lack of contaminants. Production of hard rock aggregate involves screening or scalping to remove fines and waste material followed by crushing and screening to produce material with specified size grades. Crushing is carried out to reduce the size of the rocks. This size reduction is carried out in stages, typically with a low size reduction ratio and is characterized by the use of certain types of crushing equipment, such as jaw crusher, gyratory crusher, and cone crusher.

Mukula and Phiphidi Stone Crushers lack operating equipment having only one jaw crusher and they are more focused on old technologies since the work is being carried out only by older people who have no knowledge about mining. As such Mukula Stone Crushers fails to maximize production because of the lack of equipment and skilled labour. W.G Wearne Quarry and Pakama Crushers are well equipped to have effective production and that allows them to meet the demands from the people as well as producing material with good quality. These two operations have skilled workers of different specialty hence the operation are growing and are as well largely recognized by the department.

In Mukula and Phiphidi Stone Crushers there is need for training in rock identification, extraction and processing. This will enable the miners to be more efficient in their mining ventures. The equipment used at the two crushers are old and are not adequately maintained.

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There is a need for large cash injection in order to train workers to do maintenance in-house and also to buy new equipment. This will boost their production.

5.4 Regulatory Framework and Legislations

Analysis of the different laws and comprehensive study of the situation of small-scale miners indicate low levels of understanding of the laws and lack of implementation and enforcement on the part of the government.

The requirement of the Minerals and Petroleum Resource Development Act entails the development of an environmental management plan, obtaining of prospecting and mining rights and setting up of rehabilitation funds for mine closure. For Mukula and Phiphidi Stone Crushers there is need for the intervention by the government officials of the Department of Environmental Affairs and the Department of Minerals Resources to workshop the miners about mining and environmental issues. Training should be the first step towards assisting the miners but financial assistance is also needed in conducting environmental impact assessment and the development of environmental management plan. Issues of acquiring mining permits involves paying of a deposit to facilitate the processes and these miners do not have the financial means.

Health and safety issues are amongst the most disturbing in small-scale mining and implementation of the Health and Safety Act is also lacking. These miners have to be educated about health and safety issues to make them aware of the dangers they encounter during their mining ventures and the possible hazards. They should be educated about the requirements of the relevant laws. The implementation of the laws will require emotional and financial commitment from the miners, hence training and financial assistance are necessary for the miners to follow through with the requirement of the laws.

The selected small-scale mines completely ignore labour and skills development issues. It is required by the law that miners need to be trained for the work they do for self enhancement and better understanding of the work. In these mines workers do not go for any training because the mine cannot afford. There are training bodies in South Africa selected by the government like the MQA which need to have mobile offices which will move around the country training small-scale miners about health and safety issues. This should be done at no cost to the mining company because they cannot afford.

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The common factor in the laws examined was the need for training and financial assistance for small-scale miners. The laws that govern mining in South Africa do not make provision for small-scale mining so there should be laws that are specific to this subsector and such laws have to be simplified to a level that these miners can understand. Small-scale miners are mostly people who are uneducated so they need training to understand the need to implement laws. Such training should entail a lot of pictures to make them understand.

5.5 Integrated Approach of Addressing the Challenges

An integrated approach is a strategy that brings together different disciplines in order to solve problems which are overlapping. The issues of these aggregate small-scale mining can be categorized into two namely mining and business management. One issue cannot be implemented without consideration of the other since small-scale aggregate mining is a business meant to generate capital. Running a business involves a broad understanding of the dynamic nature of the business world like the market, pricing and the consumer. For a mining venture to be a success there is need for the miners to have understanding on the geological issues such as rock identification, mining and mineral processing. Every country has laws that apply to mining so there is a need for the miners to have a good understanding of the laws which are applicable to aggregate small-scale mining. In view of this there is need for intervention measures that cut across all the disciplines of geology, mining, environment, business and legal issues. Such an integrated approach of resolving issues confronting small-scale rock aggregate mines and making operations more viable and sustainable is illustrated in Figure 5.1.

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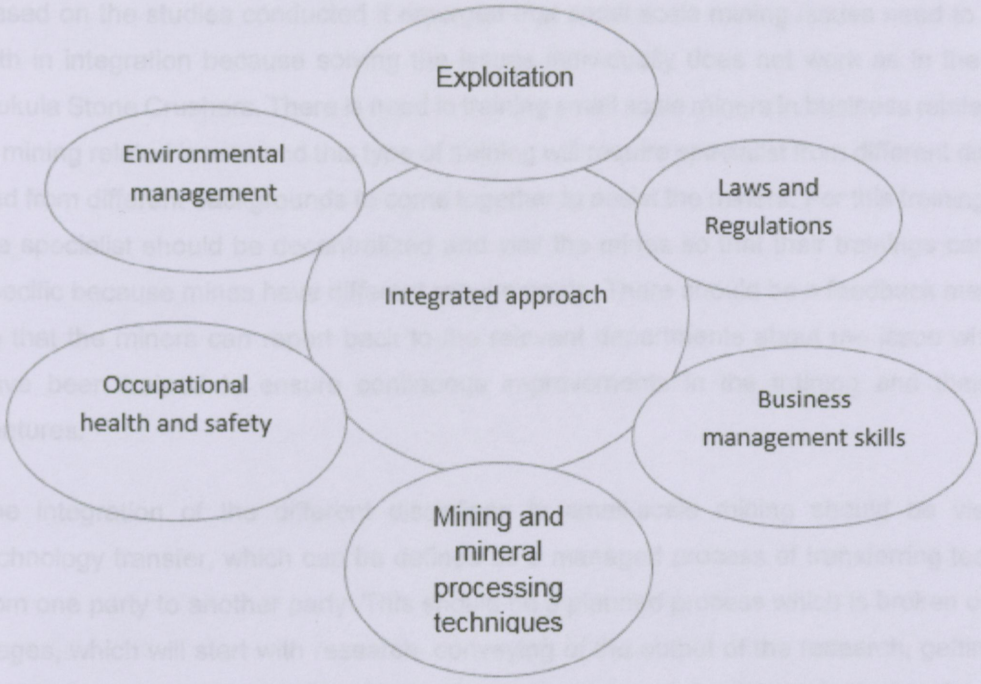


Figure 5.1: Schematic representation of the integration of small scale issues

Mukula Stone Crusher was given equipment and financial support for the smooth running of the operation. The money was used for salaries and the equipment not maintained and as a result the mining operation did not improve in anyway and the only source of income is profit which is not enough to buy or service equipment. Mukula Stone Crusher is a practical example of a mine which was give support in two forms and they failed to use the support productively. Because with new equipment the small-scale miners were in a position to grow their business. Instead of investing the given financial support in skills development and equipment maintenance. This is obvious that for a small-scale mine to flourish there is need for different disciplines be integrated. If there was a worker with sound financial management skills proper advice would have been given on spending the acquired money.

From the field survey and SWOT analysis it came out clearly that W.G Wearne and Pakama Stone Crushers are flourishing because they have different specialists in their mining operations. There are different departments which deal with specific issues and when they come together the small-scale operation is run successfully. These two stone crushers can be seen as an example of mines who are integrating their skills in running the mine.

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Based on the studies conducted it emerged that small scale mining issues need to be dealt with in integration because solving the issues individually does not work as in the case of Mukula Stone Crushers. There is need in training small scale miners in business related issues to mining related issues and this type of training will require specialist from different disciplines and from different backgrounds to come together to assist the miners. For this training to work the specialist should be decentralized and visit the mines so that their trainings can be site specific because mines have different requirements. There should be a feedback mechanism so that the miners can report back to the relevant departments about the issue which they have been trained to ensure continuous improvements in the training and their mining ventures.

The integration of the different disciplines in small-scale mining should be viewed as technology transfer, which can be defined as a managed process of transferring technology from one party to another party. This should be a planned process which is broken down into stages, which will start with research, conveying of the output of the research, getting small-scale miners involved in the process, passing on of knowledge of equipment and geological knowledge to complement their indigenous knowledge and finally emotional and financial commitment. For the small-scale miners to be helped it should be a process which will require commitment from the miners and the government.

The government needs to establish a small-scale training centers which should address relevant issues and such training should be mobile such that it can be given to different provinces. The trainers need to be workshopped first in order for them to understand the type of people they will be working with. These trainers should have different backgrounds and professions ranging from geology, mining engineering, environmental sciences, chemistry, teaching, business and technical background. Having diverse specialists will help train the miners in all aspects of mining and running a business. The course content of the modules to be taught should contain the following: background information on small-scale mining in South Africa, laws governing artisanal and small-scale mining, geology, prospecting techniques, mining and processing techniques, occupational health and safety, environmental impacts of mining and making small-scale mining a business.

There should also be an outreach programme which involves delegates visiting small-scale mines to provide capacity development support for workers in their actual mining situations. During such visits the trainers will check whether the miners are applying the knowledge that they acquired during training.

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CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

This research was carried out in order to identify the challenges confronting small-scale aggregate miners and to develop an integrated approach of dealing with the identified challenges. The chapter provides summary of the purpose of the study, the methods used in collecting data, the research findings and the conclusion of the study. Furthermore recommendations for further addressing the overlapping issues of small-scale rock aggregate production in a holistic manner are presented.

6.1 Summary of the Study

Artisanal and small-scale mines worldwide are confronted with a lot of challenges. These challenges may include low production rate, social-economic issues, occupational health and safety, finance and marketing. Health and Safety is one of the major issues that small scale and artisanal miners face on a daily basis. Small-scale miners lack the financial means to improve their ventures and financial institutions do not give them loans because they are viewed as unreliable. Several attempts were made in the past to resolve the challenges facing small-scale miners and have not been successful because it was a piece-meal approach. This study developed an integrated approach of solving the overlapping problems confronting selected small-scale rock aggregate miners in the Vhembe District of South Africa.

The main objective of this research was to assess the nature of the problems confronting selected small-scale rock aggregate mines in the Vhembe district of Limpopo province and develop an integrated approach of effectively addressing these issues. Questionnaires were used in the identification of the existing problems and SWOT analysis conducted to determine the intensity of the problems. Sound Pressure Level Meter was used to determine the noise exposure levels and gravimetric sampling was also conducted to measure the dust levels. Job safety analysis was conducted in order to identify and assess health hazards. In addition, a study of the regulations was carried out in order to determine the applicability of the laws in aggregate small-scale mining. Finally intervention measures were developed to deal with the identified challenges.

The challenges identified were lack of skills such as business management, financial management, mining and mineral processing skills and occupational health and safety measures. The absence of these skills has resulted to low production in the mines. Dust and

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noise levels in the selected aggregate mines were found to be higher than the recommended health and safety standards. The study revealed that aggregate small-scale miners do not adhere to any mining of the legislations. These legislations are even too complex for the miners to understand. The miners are either not aware of the legislations or lack resources to implement them. In view of this there is need for the miners to be trained about the legal requirements of mining. Intervention measures addressing the challenges were develop.

6.2 Conclusion

Small-scale rock aggregate miners produce materials that are predominately used for local construction purposes. These miners provide employment for the local folks and contribute to the economy. Incidentally these small-scale miners are faced with a lot of challenges. The study conducted identified these challenges and the most pressing issues are lack of adequate mining and rock processing techniques and absence of financial and business management skills which results to low production in the mine. The lack of geological and mining knowledge results in the miners using rudimentary tools in rock extraction and processing. As a result production at the mine is lower than expected. Financial management and business management skills are very important when running a business, the miners lack such skills. These miners need training in mining and business management in order for their mining ventures to flourish.

Occupational health and safety is one of the major problems associated with aggregate small-scale mining operations. The identified health and safety issues in aggregated rock mining were dust and noise. The dust levels were 13-49% greater than the recommended standard. The highest noise level measured was above the recommended value by the National Institute for Occupational Health. A job safety analysis was conducted and the hazard that was identified in aggregate mining was flying rocks during the mining and rock processing. These small-scale miners lack the basic PPEs for protection during mining and rock processing which leaves them exposed to harsh working conditions. They also lack the understanding of the need to wear the PPEs. There is need for the miners to be trained on occupational health and safety issues and the importance of PPEs.

A comprehensive analysis of the existing mining and processing legislation and regulations was conducted. A law analysis tool was developed to analyze the current laws with respect to small-scale mining. Recommendations which were made included simplification of the existing laws, having small-scale mining specific laws and having government department help the miners in implementation of the laws. In the selected small-scale aggregate mines there is a

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lack of adherence with regard to the existing mining and rock processing regulations. This is due to the fact that miners are not aware of the laws and regulations and they do not have the capacity to implement these laws. The implementation of the laws and regulations involve the use of financial and intellectual resources. The laws and regulations are also too complex for the miners to understand. Simplifying the laws and regulation and providing specific laws for small-scale miners can solved this problem. The aggregate miners will require a person who is knowledgeable about the regulations to educate them about the requirements of the law.

The last objective of this study was to develop a suite of practical interventions to help aggregate small-scale miners to improve productivity and to use safer and socially responsible mining techniques that will improve viability of the mines. After analysis of the identified challenges it was acknowledged that these challenges are overlapping. Hence an integrated approach of dealing with these challenges was developed. This approach involves different stakeholders coming together to address the problems facing small-scale miners. These stakeholders include different government departments and the miners to resolve the challenges.

The departments which need to work together to address the problems facing small-scale miners are the Department of Mineral Resources, Department of Environmental Affairs and Forestry and Department of Trade and Industries. The Department of Environmental Affairs and Forestry will have to deal with environmental issues. The Department of Trade and Industries will have to assist aggregate miners in business and financing. Finally the Department of Mineral Resources will deal with the mining related issues such as facilitation of the registration processes and mining and rock processing techniques. The last step of this integration will be the training of the miners by specialist from the different departments. This should be an ongoing process between all the stakeholders because it will require a feedback mechanism by the small-scale aggregate miners and the various departments.

6.3 Recommendations

Based on the analysis of the key issues that are hindering the success of small-scale aggregate miners there were specific issues that need special attention. The issues are provision of training for small-scale miners in financing, geology, mining, mineral processing and implantation of laws and regulations.

In two of the selected small-scale mines it emerged that the small-scale miners lack geological background about the commodity they mine. Hence there is a need to make such information

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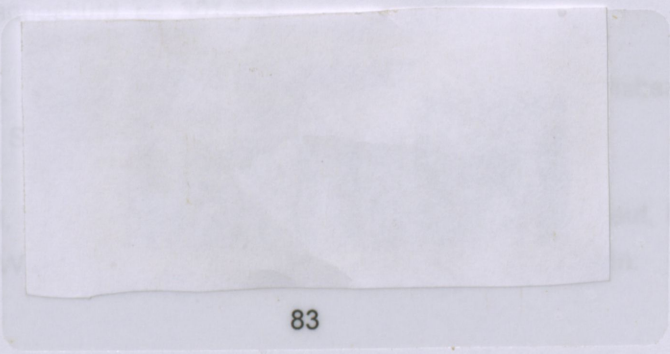
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available for these miners to enable them to improve on their production. This can be done through the use of the Directorate of Small-scale Mining, by assisting in training the miners about rock identification and the use of geological maps. Through this directorate and the Council of Geoscience small-scale miners can get updated geological data which will help in rock identification and extraction methods.

One of the key issues in small-scale mining is the issue of financing, these miners lack the much needed financial support and management skills. Mukula Stone Crushers is one of the mines that was given financial support by LIMDEV and SEDA, but still they are not flourishing due to poor management of such funds. These miners need to be assisted with financing and financial management skills. The government and NGOs can assist in providing financial management skills to small-scale miners. These miners also lack awareness of the different financing agencies hence availing such information can be of great help to small-scale miners. National, regional and local miners associations should be established to assist individual miners to have access to loans and other financial support.

Small-scale mining is associated with a lot of environmental degradation and they do not have rehabilitation strategies in place. Hence there is a need of an outreach programme to increase environmental awareness and consciousness. Training should be provided for the identified issues, followed by a series of follow up meetings to ensure the implementation of the environment management programme. These outreach programmes should include a proposal of a rehabilitation plan. International environment organizations and local NGOs, research centers can assist in providing technical expertise on rehabilitation.

Specific laws/regulatory frameworks on small scale mining should be drafted to address legal aspects of small scale mining. These laws need to be specified to a level that small-scale miners themselves can read and implement. The Department of Mineral Resource should assist small-scale miners in acquiring prospecting, exploration and mining rights. There is also need for DMR officials to reach out to small-scale miners on mining related issues and enforcement.



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APPENDICES

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A -Questionnaire

Dear Respondent,

This is a questionnaire which is aimed at identifying and collecting data about the problems, concerns and issues that affect the operations and performance of Small scale mines. It is meant for MSc research purpose at the University of Venda and it will not be published. In order to ensure confidentiality do not put down your name on the questionnaire but please answer the questions as honestly and objectively as possible.

Name of mine.....

Address.....

1. Socio-economic features of miners

1.1 Gender ☐ female ☐ male

1.2 Age ☐ <18 ☐ 18-21 ☐ 22-26 ☐ 27-30
☐ 31-35 ☐ 36-40 ☐ 41-45 ☐ >46

1.3 Education ☐ none ☐ grade 1-3 ☐ grade 4-7
☐ Grade 8-10 ☐ tertiary

1.4 Marital status ☐ single ☐ married ☐ divorced ☐ widowed

1.5 House hold size ☐ 1-2 ☐ 3-4 ☐ 5-6 ☐ >6

2. Work related issues

2.1 How many hours are you required to work per week?

2.2 Does the mine provide any training programs to workers? Yes ☐ no ☐

2.3 Do you think it is important for workers to be trained? ☐ Yes ☐ no

If yes

why?.....

.....

.....

If no what are the possible reasons why you are not getting any form of training?

.....

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.....

2.4 Does the mine provide PPE? Yes ☐ no ☐

2.5 What type of PPE is provided?

- Gloves ☐
- Mask ☐
- Earplugs ☐
- Safety boots ☐
- Safety goggles ☐
- Work suits ☐
- Safety hat ☐

2.6. Does the mine have good working environment? yes ☐ no ☐

why?

.....

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.....

.....

.....

.....

2.7 What are challenges that you face as workers?

.....

.....

.....

.....

.....

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3 **Regulatory/institutional framework component**

3.1 Is the type of small scale mine legal yes ☐ no ☐

3.2 If no why is it not legal

.....

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3.3 If yes what where the challenges that you came across during the process

.....

.....

.....

.....

.....

.....

4 **Do you get any support from the government and what kind of support is it?**

- Is it financial support?
- Training?

.....

.....

.....

5 **How do you deal with issues of marketing**.....

.....

.....

.....

.....

6 **income dynamics**

6.1 how much do you get paid per month

☐ <R100 ☐ R101-500 ☐ R 501-1000

☐ R1000-5000 ☐ >R5001 ☐ >R10000

6.2 Do you save money? Yes/ no, if yes where?

Bank ☐ Post office ☐ Home ☐

6.3 Do you have any other source of income? Yes ☐ No ☐

If yes specify .....

.....

7 **Perceptions about performance of mining activity**

7.1 Is this mine growing ☐ agree ☐ disagree ☐ neutral

7.2 Reason for the above answer and to you think should be needs improvement?

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.....

.....

.....

7.3 What are your views on the mining environment.....

.....

.....

.....

7.4 Do you feel as though you are safe in this working environment yes ☐ no ☐

7.5 Reason for the answer above.....

.....

.....

.....

.....

7.6 What are your views on child labour

.....

.....

.....

.....

7.7 Do you have any knowledge about the commodity you are mining? Yes ☐ ☐
no

7.8 If yes explain

.....

.....

.....

7.9 Do you have any knowledge about rights at your working place? yes ☐ ☐
no

7.10 Explain your above answer

.....

.....

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7.11 Do you encounter any work hazards?

Yes ☐ no ☐ always ☐ sometimes ☐

7.12 What are the working hazards that you encounter during working and how do you deal with such hazards.....

.....

.....

.....

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.....

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.....

7.13 If you are injured at work who takes responsibility of the hospital bill?

You ☐ employer ☐

7.14 Do you have any representative amongst the workers? Yes ☐ no ☐

7.15 If yes what are her/his responsibilities?

.....

.....

.....

7.16 If no why not and do you think you need a representative?

.....

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7.17 If you get injured at work who do you report to and why?

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Appendix B-TWA calculations of different small-scale miners

Mukula Stone Crusher

Secondary crusher	
Concentration (mg/m^3)	Time (8 hours shift)
C_1 = 43.88	09h30
C_2 = 42.11	12h00
C_3 = 40.07	15h00
C_4 = 38.22	17h00
Average = 41.07	

$$TWA = \frac{C_i X T_i}{8\text{hours}}$$

$$TWA = \frac{(43.88\ \text{X}\ 2) + (42.11\ X\ 2) + (40.07\ X2) + (38.22\ X2)}{8\ \text{hours}}$$

= 31.05mg/m3

Primary crusher	
Concentration (mg/m^3)	Time (8 hours shift)
C_1 = 33.10	09h30
C_2 = 30.05	12h00
C_3 = 29.15	15h00
C_4 = 28.26	17h00
Average = 30.14	

$$TWA = \frac{C_i X T_i}{8\text{hours}}$$

$$TWA = \frac{(33.1\ \text{X}\ 2) + (30.05\ X\ 2) + (29.15\ X2) + (28.26\ X2)}{8\ \text{hours}}$$

= 30.14mg/m3

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Pakama Stone Crusher

Primary crusher	
Concentration (mg/m3)	Time (8 hours shift)
C_1 = 59.64	09h30
C_2 = 59.16	12h00
C_3 = 56.03	15h00
C_4 = 55.77	17h00
Average = 57.65	

$$TWA = \frac{C_i X T_i}{8\text{hours}}$$

$$TWA = \frac{(66.25 \text{ X } 2) + (66\ X\ 2) + (64.34\ X2) + (63.89\ X2)}{8 \text{ hours}}$$

= 65.12mg/m3

Secondary crusher	
Concentration (mg/m^3)	Time (8 hours shift)
C_1 = 66.25	09h30
C_2 = 66	12h00
C_3 = 64.34	15h00
C_4 = 63.89	17h00
Average = 65.12	

$$TWA = \frac{C_i X T_i}{8\text{hours}}$$

$$TWA = \frac{(59.64 \text{ X } 2) + (59.16\ X\ 2) + (56.03\ X2) + (55.77\ X2)}{8 \text{ hours}}$$

= 57.65mg/m3

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W.G Wearne

Crusher	
Concentration	Time (8 hours shift)
C_1 = 48.93	09h30
C_2 = 48.64	12h00
C_3 = 47.47	15h00
C_4 = 46.28	17h00
Average = 47.83	

$$TWA = \frac{C_i X T_i}{8\text{hours}}$$

$$TWA = \frac{(68.37 \text{ X } 2) + (72.20\ X\ 2) + (69.63\ X2) + (75.12\ X2)}{8 \text{ hours}}$$

= 71.33mg/m3

Secondary crusher	
Concentration(mg/m3)	Time (8 hours shift)
C_1 = 75.12	09h30
C_2 = 72.20	12h00
C_3 = 69.63	15h00
C_4 = 68.37	17h00
Average = 71.33	

$$TWA = \frac{C_i X T_i}{8\text{hours}}$$

$$TWA = \frac{(71.07 \text{ X } 2) + (69.31\ X\ 2) + (67.27\ X2) + (66.55\ X2)}{8 \text{ hours}}$$

= 68.55mg/m3

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Phiphidi Stone Crusher

Primary crusher	
Concentration	Time (8 hours shift)
C_1 = 71.07	09h30
C_2 = 69.31	12h00
C_3 = 67.27	15h00
C_4 = 66.55	17h00
Average = 68.55	

$$TWA = \frac{C_i X T_i}{8\text{hours}}$$

$$TWA = \frac{(48.93 \text{ X } 2) + (48.64\ X\ 2) + (47.47\ X2) + (46.28\ X2)}{8 \text{ hours}}$$

= 47.83mg/m3

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Appendix C: Job safety Assessment form

JOB SAFETY ASSESSSMENT FORM

Date: _____ Section: _____ Working Place / Area / Equipment: _____

Time: _____ Task: _____

Pre Check Questions			
Answer the following questions:			Explain why, if one of the Pre Check questions, answers is No!
Are all the people trained to do the job?	Yes	No	
Do have I have all the correct tools and equipment?	Yes	No	
Do we have all the correct PPE?	Yes	No	
Is the area safe?	Yes	No	
Identify your 3 high risks?	1		
2		3	

Risk Assessment Questions				
What Hazard or Energy is present	What can go wrong?	What must we worry about or need to rectify	What controls is required	Risk Severity See Below

Levels of risk	Recommended Guidelines
High	No work will continue until the Team agrees on effective additional control measures
Medium	Certain work activities may proceed under controlled conditions ex. Placing a guard, barricading off.
Low	Work activities may proceed if the team feels confident that it is safe to do so.

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Appendix D: Law Analysis

	Prospecting right and mining permit or authorization	health and safety of small-scale mines	Environmental authorization	Labour and skills development
Legislation reference	Section 16 or 27 of Minerals and Petroleum Resources Development Act, No 28 of 2002	Mine Health and Safety Act (MHSA) of 1996	National Environmental Management Act, 1998 (Act No. 107 of 1998), (the Act) and the Environmental Impact Assessment Regulations, 2010 (the Regulations	Skills Development Act No. 97 of 1998 and South Africa Qualifications Authority No. 58 of 1995
Who can apply	Owner of land/miner	Miner	Owner of land\miner	Miner
Procedure	Apply for mining authorization. • Collect EMP form and complete. • Make 6 copies (one to be kept by the miner). • Submit to DME, Regional Manager	Register the mine to DMR and affiliate to Occupational Health and Safety standards	Apply for environmental authorization: • Appoint an EAP and undertake EIA • Collect Environmental Authorization form and complete. • Submit to Department of Environmental Affairs, Director: Integrated Environmental Authorisations	Register the mine to SETA and national skills authority
Where	DME- Regional office	DMR	DEA	Department of labour
Document/s required	EMP		• SIP • List of SGIDs • Project map • Project schedule • Declaration of Applicant • Declaration of EAP	
Cost	Yes - non-refundable fee	None	Yes-non-refundable fee	None
Duration	Prospecting right: < 5 years Mining permit: < 2 years Mining right: > 2 years		EIA<3 years	
Renewable	YES	YES	Yes	YES
Performance reports	Yes - frequency determined by regulator	YES	Yes	YES

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