

**RISK FACTORS ASSOCIATED WITH SILICOSIS IN ZAMBIAN  
FORMER MINEWORKERS**

**By**

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**A dissertation submitted to the University of Zambia in partial fulfilment of  
the requirements for the degree of Master of Public Health**

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## DECLARATION

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I hereby declare that works presented in this study for the Master of Public Health has not been presented whether wholly or in part for any other study programme and is not being submitted for any other Masters programme. The result is entirely the result of my own independent investigation. The various resources to which I am indebted have been acknowledged.

Signed .....

William Sitembo (Candidate)

I have read this dissertation and approve it for examination

Supervisor: Dr. Rosemary Likwa-Ndonyo

Signed:.....

Date:.....

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**CERTIFICATE OF APPROVAL FORM**

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The dissertation by William Sitembo has been approved as fulfilling the requirements for the award of the Master Degree in Public Health by the University of Zambia.

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## ABSTRACT

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The risk of silicosis depends on a number of factors which include among others; the nature of the dust, the intensity and duration of exposure as well as individual susceptibility. The association of these factors with silicosis vary from country to country and between regions being influenced mainly by work culture, environmental and safety conditions prevailing at worksites. This study aimed to determine the risk factors of silicosis in Zambian former copper mineworkers.

A retrospective cross-sectional study involving the review of 476 randomly selected records of all Zambian former copper mineworkers who attended medical examinations at Occupational Health Management Board in Kitwe, between the periods 1<sup>st</sup> January 2004 and 31<sup>st</sup> December 2008. Data was analysed using Epi Info version 3.3.2 statistical package. Data was described for silicosis by; current age, dates of certification and discharge, sex, service in various mining divisions, work-sites, job categories, and mean percent silica concentration.

The results showed a silicosis prevalence of 8.8percent (CI = 6.27 to 11.38). The study established an average age of 66 years in silicotics, as compared to 56 years in non-silicotics ( $p$ -value  $<0.001$ ). The silicotics were found to have worked for a median 26 years while the non-silicotics' median service stood at 21 years ( $p$ -value  $<0.001$ ). For each additional year spent working for Mufulira or Chibuluma divisions, miners were 16percent more likely to develop silicosis (OR = 1.16; CI = 1.06 to 1.26 and OR = 1.16; CI = 1.04 to 1.30 respectively). On each additional year spent working in the underground production areas, miners were 14percent (OR = 1.14; CI = 1.06 to 1.24) more likely to develop silicosis. Each year spent working as a lasher increased miners' chances of developing silicosis by 31percent (OR = 1.31; CI = 1.12 to 1.54). Silicotics were exposed to 825percent silica-years as compared to 507percent silica-years in non-silicotics ( $p$ -value  $< 0.001$ ).

Long service, working in Mufulira or Chibuluma division, working in the production area, working as a lasher and exposure to dust with high percent silica concentration are associated with silicosis in Zambian former miners. Efforts to reduce the silicosis burden among the former miners should address the above identified risk factors. These include reducing years of service and providing personal protective equipment for workers in work-areas with high silica content.

## **DEDICATIONS**

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This research work is dedicated to my wife Chisenga, my daughters Mbikwa and Mwitwa for their unfailing love, endurance, patience and immense support during my post graduate studies.

To the former Zambian miner whose contributions to the country's economy necessitated his/her exposure to debilitating silica dust.

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# TABLE OF CONTENTS

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DECLARATION .....	ii
CERTIFICATE OF APPROVAL FORM .....	iii
ABSTRACT.....	iv
DEDICATIONS.....	vi
ACKNOWLEDGEMENTS.....	vi
TABLE OF CONTENTS.....	vii
LIST OF FIGURES .....	x
LIST OF TABLES.....	xi
LIST OF ABBREVIATIONS.....	xiii
CHAPTER 1: GENERAL INTRODUCTION .....	1
1.1. INTRODUCTION.....	1
1.2. STATEMENT OF THE PROBLEM .....	2
1.3. RESEARCH QUESTIONS.....	4
1.4. PROBLEM ANALYSIS .....	5
1.4.1. Interpretation of the Problem Analysis Chart .....	6
1.5. JUSTIFICATION OF THE STUDY .....	7
1.6. TERMS AND DEFINITIONS.....	7
CHAPTER 2: LITERATURE REVIEW AND RESEARCH OBJECTIVES .....	11
2.1. LITERATURE REVIEW.....	11
2.1.1. Introduction.....	11
2.1.2. Global Perspectives of Silicosis.....	11
2.1.3. Regional Perspectives of Silicosis .....	13
2.1.4. National Perspectives of Silicosis.....	14
2.1.5. Risk Factors Associated with Silicosis .....	15
2.1.6. Silicosis and HIV infection.....	17
2.2. OBJECTIVES .....	19
2.2.1. General Objective .....	19

2.2.2. Specific Objectives .....	19
CHAPTER 3: METHODOLOGY .....	20
3.1. INTRODUCTION.....	20
3.2. CONCEPTUAL FRAMEWORK .....	20
3.3. STUDY DESIGN.....	22
3.4. STUDY SITE .....	22
3.4.1. The Occupational Health Management Board (OHMB).....	23
3.4.2. Diagnosis of Silicosis at OHMB.....	23
3.5. STUDY POPULATION .....	23
3.6. SAMPE SIZE DETERMINATION.....	24
3.7. SAMPLING METHODS .....	25
3.8. ELIGIBILITY CRITERIA.....	25
3.8.1. Inclusion Criteria .....	25
3.8.2. Exclusion Criteria .....	25
3.9. DATA COLLECTION TECHNIQUES AND TOOLS.....	25
3.10. ETHICAL CONSIDERATION.....	26
3.11. DATA PROCESSING AND QUALITY CONTROL .....	26
3.12. LIST OF VARIABLES .....	27
3.13. DATA ANALYSIS .....	27
3.14. STUDY LIMITATIONS .....	27
3.15. PROJECT ADMINISTRATION AND MONITORING .....	28
CHAPTER 4: RESULTS .....	29
4.1. INRODUCTION .....	29
4.2. UNI-VARIATE ANALYSIS .....	29
4.2.1. Distribution of miners by years of service in individual mine division:.....	29
4.2.2. Distribution of miners by Mining Sites .....	31
4.2.3. Distribution of miners by Job Categories .....	31
4.2.4. Mean silica content in dust samples.....	32
4.2.5. Prevalence of silicosis in Zambian former copper miners.....	33
4.3. BI-VARIATE ANALYSIS .....	34

4.3.1.	Silicosis according to age of miners .....	34
4.3.2.	Silicosis according to years of service .....	34
4.3.3.	Silicosis according to year of certification and discharge .....	35
4.3.4	Silicosis according to individual mining divisions .....	35
4.3.5.	Silicosis according to service in major work sites .....	37
4.3.6.	Silicosis according to service in different job categories.....	38
4.3.7.	Silicosis according to cumulative silica exposure .....	39
4.3.8.	Incubation period of silicosis in Zambian former copper miners .....	39
CHAPTER 5: DISCUSSION.....		40
5.1.	INTRODUCTION.....	40
5.2.	PREVALENCE OF SILICOSIS AMONG FORMER MINERS .....	40
5.3.	DURATION OF SERVICE IN MINING INDUSTRY .....	41
5.4.	INTRINSIC FACTORS AT DIFFERENT MINING DIVISIONS .....	41
5.5.	SERVICE IN MAJOR WORK-SITES .....	42
5.6.	SERVICE IN DIFFERENT JOB-CATEGORIES .....	42
5.7.	CUMULATIVE SILICA EXPOSURE.....	42
CHAPTER 6:CONCLUSION AND RECOMMENDATIONS .....		43
6.1.	CONCLUSION .....	43
6.2.	RECOMMENDATIONS .....	44
REFERENCES CITED.....		46
APPENDIX A: Data Collection Checklist .....		53
APPENDIX B: Letter; requesting permission to use medical records at the Bureau .....		55
APPENDIX C: Approval from Graduate Proporsal Presentation Forum.....		56
APPENDIX D: Ethics Committee’s permission to conduct research .....		57
APPENDIX E: Bureau management’s authorisation to use medical records.....		58
APPENDIX F: Details of supervisors .....		59

## LIST OF FIGURES

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	<b>Page</b>
Figure 1.1: The problem analysis chart of silicosis.....	5
Figure 4.1: Year of certification in relation to year of discharge.....	35
Figure 4.2: Silicosis cases according to mine divisions.....	36
Figure 4.3: Silicosis prevalence by major work-sites.....	37

## LIST OF TABLES

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	<b>Page</b>
Table 2.1: Silicosis in Northern Rhodesia.....	14
Table 3.1: Operational indicators of the dependent and independent variables.....	20
Table 4.1: Characteristics of the Zambian former miners.....	29
Table 4.2: Duration of service in specific mining divisions in years.....	30
Table 4.3: Duration of service in specific mining sites in years.....	31
Table 4.4: Duration of service in specific job categories in years.....	32
Table 4.5: Mean silica content (%) in dust samples from different operation sites in individual mine divisions.....	33
Table 4.6: Prevalence of silicosis in the Zambian former copper miners.....	33
Table 4.7: Mean age among silicotics and non-silicotics.....	34
Table 4.8: Median years of service among silicotics and non-silicotics.....	34
Table 4.9: Age-adjusted odds of developing silicosis after working in individual mine divisions.....	36
Table 4.10: Age-adjusted odds of developing silicosis afterwork in different major work-sites in mining.....	38
Table 4.11: Age-adjusted odds of developing silicosis after work in different job-categories in mining.....	38
Table 4.12: Means of cumulative exposure to silica over years among silicotics and non-silicotics (percent silica-years).....	39

## LIST OF ABBREVIATIONS

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AIDS	Acquired Immunodeficiency Syndrome
ATT	Anti Tuberculosis Treatment
CDC	(United States) Centres for Disease Control and Prevention
CI	95% Confidence Interval
COSHH	Control of Substances Hazardous to Health
FEV	Forced Expiratory Volume
FVC	Forced Vital Capacity
HIV	Human Immunodeficiency Virus
HSE	(United Kingdom) Health and Safety Executive
ILO	International Labour Organisation
IQR	Interquartile Range
KCM	Konkola Copper Mines
MCM	Mopani Copper Mines
NIOSH	(United States) National Institute for Occupational Safety and Health
OHMB	Occupational Health Management Board
PPE	Personal Protective Equipment
Q <sub>1</sub>	First quartile
Q <sub>3</sub>	Third quartile
SD	Standard Deviation
USAID	United States Agency for International Development
VB	Village Benefit
WHO	World Health Organisation
ZCCM	Zambia Consolidated Copper Mines

# CHAPTER 1: GENERAL INTRODUCTION

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## 1.1. INTRODUCTION

Occupational inhalation of crystalline silica (silica or silicon dioxide) dust as happens in various mining and other rock abrasive works is the cause of silicosis. However, the risk of silicosis depends on a number of factors, including the nature of the dust, the intensity and duration of exposure as well as individual susceptibility (Danilaet *al*, 2009).

Silicosis, the oldest known occupational lung disease and most common pneumoconiosis, still kills thousands of people every year, everywhere in the world (ILO/WHO, 2003). It is an incurable and irreversible fibrotic lung disease which continues to progress even after exposure has stopped. Extremely high exposures are associated with much shorter latency and more rapid disease progression (Danilaet *al*, 2009; Buchanan *et al*, 2003). However, long and steady service works in mines, quarries, foundries, construction sites, glass manufacture, ceramics, abrasive powders, and masonry workshops are particularly risky and associated with the majority of disease manifesting late in life (WHO, 2000).

Copper mining, the main economic activity in Zambia, necessitates exposure of miners to dust with a high content of free crystalline silica. The industry has, since 1926 when large-scale copper production began, been the largest single employer in this country (Paul, 1961). About 40,000 people are currently employed by the mining sector, while a lot more, now retired or retrenched, have worked in the mines before (OHMB, 2006). These people are all at risk of being permanently disabled by the effects of silicosis.

Despite the public health importance of silicosis in the Zambian mining industry and the Zambian economy at large, little is known about the associated predisposing factors and the risk of this disease among Zambian former miners.

This retrospective cross-sectional study gathered and evaluated data on silica exposures among Zambian former mineworkers. In this report, information about the prevalence and risk factors of silicosis among Zambian former copper mineworkers has been presented.

## **1.2. STATEMENT OF THE PROBLEM**

Zambia's economy is highly dependent on copper mining. Unfortunately, mining activities expose mineworkers to many adverse public health problems which include silicosis and pulmonary tuberculosis.

Silicosis, an incurable fibrotic lung disease, usually has a long induction period between exposure to risk factors in the mines and the eventual development of disease; as a result, mineworkers often manifest with this disease long after they have left active employment, a period during which they do not have any reasonable income to pay for medical fees. Furthermore, these mineworkers often retire to the rural communities where medical facilities are not as good as those found in the urban communities hence, externalizing the cost of this occupational lung disease to rural communities. More than 40,000 people, whose occupational productivity contributes more than half of Zambia's gross domestic product, are at risk of being chronically debilitated by silicosis.

A couple of available researches conducted in Southern Africa suggest that the burden of silicosis in rural communities is considerable. A prevalence study of former mineworkers resident in the Kweneng district of Botswana found an overall prevalence of pneumoconiosis [Silicosis] of 26percent to 31percent (Steen *et al*, 1997). Another study of former gold

mineworkers resident in the Libode district of South Africa found a prevalence of pneumoconiosis of 22percent to 37percent (Trapido *et al*, 1998).

Such high prevalence as demonstrated by these two studies clearly illustrates the impact of mining activities on public health. They also impact severely on the socio-economic status of the rural communities as they affect the family bread winners.

A number of factors have been implicated in the causation of silicosis; the mean crystalline silica exposure ( $\text{mg}/\text{m}^3$ ), cumulative crystalline silica exposure ( $(\text{mg}/\text{m}^3)\text{-years}$ ), duration of exposure to silica (years), work area, job description and cigarette smoking (Rosenman *et al*, 1996). Poor ergonomics in mining work sites usually facilitate complex interactions between these factors and mineworkers to cause silicosis.

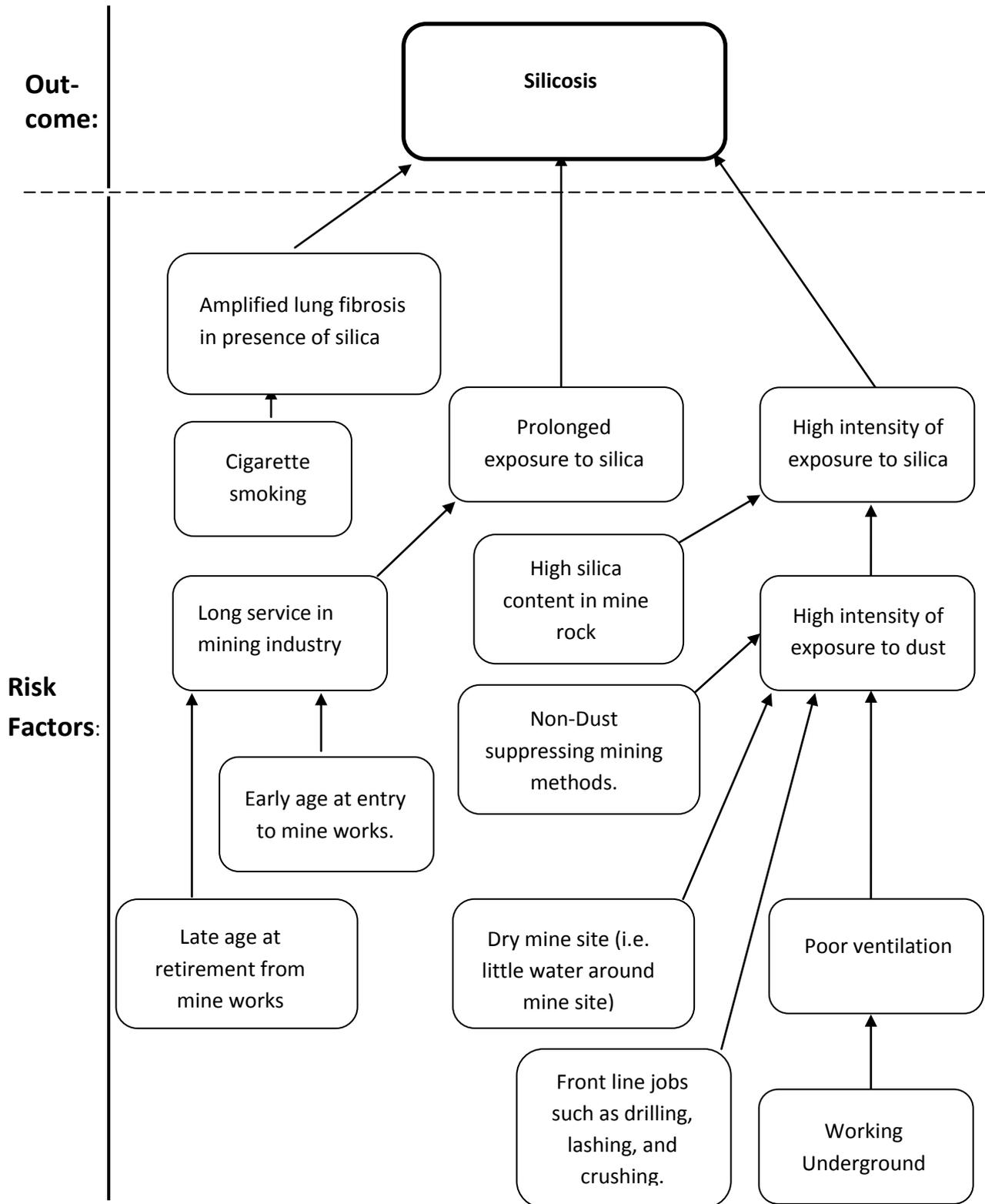
In Zambia, no study has been done to establish the risk of silicosis and its associated risk factors in the older community of former mineworkers. In fact, only two studies since the 1950s have been conducted to establish the prevalence of silicosis in in-service Zambian copper mineworkers. Mulenga *et al* (2005) established a silicosis case proportion of 28.6percent, among all certified miners, during the period 1960 to 1970 and 12.4percent during the years 1992 to 2002, while Mwansa (2004) established a silicosis prevalence of 8 per 1,000 among Zambian in-service copper mineworkers in the year 2002. A study done by Robert Paul (1961) established the annual incidences of silicosis from 1950 to 1959 in the then Northern Rhodesia copper mineworkers. While it might be difficult to deduce the prevalence of silicosis among miners in the later study, the former shows a relatively low prevalence of silicosis among Zambian in-service miners as compared to most other studies done elsewhere in the world. With the fact that silicosis can develop and continue to progress years after retirement from silica abrasive jobs, its prevalence is expected to be higher among the retired miners than among those still in employment (Chen *et al*, 2001).

Given the public health importance and socio-economical problems created by silicosis on rural communities to which the former miners retire, it is imperative that the risk factors and the levels of this disease are determined. This is especially important as part of monitoring of silica dust control measures implemented by the mining industry, and as part of improvement in the ascertainment of cases. Controlling dust in the worksite is fundamental to preventing silicosis. Methods of controlling dust in the mining industry include effective ventilation systems and a combined process of wet drilling, wet transportation and wet crushing of rock materials (Mantle, 2008; HSE, 2004). These methods are supplemented by workers wearing personal respiratory protective equipment which clean external air; and total worker isolation in enclosed control rooms (Kortum and Bozsoki, 2007). In order to detect silicosis early enough, mineworkers in Zambia undertake annual health surveillance which includes elicitation of occupational history, a methodical clinical examination, and a regular chest radiograph. This study took advantage of the later, to collect data about the former mineworkers.

### **1.3. RESEARCH QUESTIONS**

- What is the current prevalence of silicosis among the Zambian former copper mineworkers?
- What is the association between demographic, occupational and social factors; and silicosis among the former miners?

## 1.4. PROBLEM ANALYSIS



**Figure 1.1:** The problem analysis chart of silicosis among former miners in Zambia

#### **1.4.1. Interpretation of the Problem Analysis Chart**

Figure 1 shows the interaction between factors as they pre-dispose miners to silicosis. Silicosis development is influenced mainly by ‘prolonged exposure to silica’ and/ or ‘high intensity of exposure to silica’.

Prolonged exposure to silica could result from ‘long service in mining industry’. In turn, long service is influenced by two factors; ‘early age at entry to mine works’ and ‘late age at retirement from mine works’.

High intensity of exposure to silica is thought to result from two main factors; ‘high silica content in mine rock’ and ‘high intensity of exposure to dust’ at work place. The later is in turn influenced by four factors; ‘non-dust suppressing mining methods’, ‘dry mine site (i.e. little water around mine site)’, ‘poor ventilation’, and working in ‘front line jobs such as drilling, lashing and crushing’ which generate large quantities of dust. Poor ventilation is thought to be influenced by ‘working underground’ and ‘lack of proper ventilation machinery’ at mine sites.

The collective effect of the above factors on the prevalence of silicosis varies from one mining division to another and is highly dependent on the ergonomic conditions at each one of these mining divisions.

‘Cigarette smoking’ has been known to cause small opacities in the lungs, hence in presence of silica dust, it may accelerate or exaggerate the development of silicosis.

These are the main factors responsible for the causation and progression of silicosis among miners and silica abrasive works workers. Which one of these is ranked first, varies according to type of industry, type of job, site of work and ergonomic factors at place of work. This

might also vary within a similar industry or job from country to country. This study will aim to isolate and quantify those factors that affect Zambian copper miners.

### **1.5. JUSTIFICATION OF THE STUDY**

While the general risk factors of silicosis among mine workers are well known worldwide, no study has ever been conducted to establish the specific risk factors and the overall risk of the disease in Zambian former copper mineworkers. The study sought to determine the factors influencing the levels of silicosis in the Zambian former miners. It also sought to establish the prevalence of silicosis among former copper mineworkers. The findings of the study will be imperative in the prevention of this public health conditions.

### **1.6. TERMS AND DEFINITIONS**

#### **Act**

The Workers, Compensation Act, number 10 of 1999;

#### **Certification**

The issuance, by the OHMB, of a report that there is or are present in any person pneumoconiosis or tuberculosis or both these diseases;

#### **Concentrator**

A plant in the mining industry where rock (copper ore) is crushed/grinded, the final autogenous micro particles are there after subjected to the floatation process which separates metal from rock;

#### **Crusher**

A mineworker operating from the rock (ore) crushing/ grinding plant;

**Driller**

A mineworker, whose main job description involves drilling of holes in rocks;

**Initial examinee**

A candidate for pre-employment examinations;

**Lasher**

A mineworker, whose main job description involves loading, transportation or offloading of rock materials;

**Mineworker (Miner)**

Any person employed or who has been employed at a scheduled mine and the nature of the employment necessitates working below the surface of the ground or in any scheduled place.

**In-service** miner refers to a mineworker who is currently working in the mines, as opposed to a former miner;

**Multiplicatively**

Term used by many occupational health researchers to forward an idea that the relations between silica and tuberculosis are compounded by HIV. The risks of silicosis and HIV infection combine multiplicatively for tuberculosis, so that tuberculosis remains as much a silica-related occupational disease in HIV-positive as in HIV-negative miners (Churchyard *et al*, 1999; Rees, 2005).

**Occupational lung disease**

Work related lung disease. Some of the diseases under this category include pneumoconiosis, byssinosis, coal miner's lung, asthma and pulmonary tuberculosis;

**OHMB (Bureau)**

The Occupational Health Management Board also known as the Occupational Health Safety and Research Bureau established under section twenty of the Pneumoconiosis Act of 1955;

**Periodical examinee**

A candidate for intra-employment examinations;

**Pneumoconiosis**

Any form of lung disease due to the inhalation of dust. Examples include silicosis, asbestosis, byssinosis and coal miners' lung. Some cited articles in this study use the word "pneumoconiosis" synonymously with the word "silicosis";

**Service**

The period a person spent working in the mining industry;

**Silicosis**

A fibrotic lung disease caused by inhalation of silica (crystalline silica) dust particles. It affects workers in hard-rock mining and tunnelling, quarrying, stone dressing, sand blasting, and boiler scaling (Martin, 2003).

**Silicotic**

A person certified as having silicosis or a person diagnosed with silicosis;

**Surface**

Mining worksites situated above the surface of the ground, and immediately surrounding any silica-bearing rock crushing plant, silica-bearing rock screening plant or belt conveyor plant wholly within and forming an integral part of such rock crushing or rock screening plant;

**Underground**

Mining worksites situated below the natural surface of the ground, and immediately surrounding any silica-bearing rock crushing plant, silica-bearing rock screening plant or belt conveyor plant wholly within and forming an integral part of such rock crushing or rock screening plant;

**Village-Benefit Examination (Benefit Examination)**

Medical examination carried out at OHMB on any person who was formerly but is no longer employed as a miner.

## CHAPTER 2: LITERATURE REVIEW AND RESEARCH OBJECTIVES

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### 2.1. LITERATURE REVIEW

#### 2.1.1. Introduction

The risks of silicosis among mineworkers exposed to silica have been well documented the world over (ILO/WHO, 2003; Mannetje *et al*, 2002; Oxman *et al*, 1993; Snider *et al*, 1978; Paul, 1961).

The risk factors and prevalence of this disease vary from country to country and are highly dependent on the environmental and safety conditions at work sites, and to some extent the nation's social economic status.

In Zambia, the prevalence of silicosis in in-service mineworkers was documented as 8 per 1,000 in 2002 (Mwansa, 2004). No data exists for former mineworkers.

#### 2.1.2. Global Perspectives of Silicosis

According to the World Health Organisation (WHO) Fact sheet number 238 of May 2000, during the period 1991 to 1995, China recorded more than 500,000 cases of silicosis, with around 6,000 new cases and more than 24,000 deaths occurring each year mostly among older workers. In Vietnam the number of silicotics reached 9,000. This represented 90percent of all occupationally compensable diseases. In India, a prevalence of 55percent was found in one group of workers, many of them very young, engaged in the quarrying of sedimentary rock and subsequent work in small, poorly ventilated sheds. Studies on silicotic pencil workers in Central India demonstrated high mortality rates; the mean age at death was 35 years and the mean duration of the exposure was 12 years. In Brazil, in the state of Minas

Gerais alone, more than 4,500 workers were diagnosed with silicosis. In drought-affected regions in the north-east of the country the hand-digging of wells through layers of rock with very high quartz content (97percent), an activity that generates great quantities of dust in confined spaces, resulted in a prevalence of 26percent of silicosis, with many cases of accelerated forms. The state of Rio de Janeiro banned sandblasting after a quarter of shipyard workers were found to have silicosis. In the United States of America (USA), it is estimated that more than one million workers are occupationally exposed to free crystalline silica dusts (more than 100,000 of these workers are sandblasters), of whom some 59,000 will eventually develop silicosis. It was reported that each year in the USA about 300 people die from it, but the true number is not known. Abrasive blasting with silica sand, often used to prepare surfaces for painting, was associated with exposures 200 times greater than the level recommended by the United States National Institute for Occupational Safety and Health (NIOSH). This agency recommended that silica sand be prohibited as an abrasive blasting agent. In Quebec, Canada, in the years 1988-1994, 40 newly diagnosed workers were compensated (12 were less than 40 years old). The Colombian Government estimated that 1.8 million workers in the country were at risk of developing the disease.

The global perspectives on silicosis illustrate the world-spread nature of the disease sparing neither the developed nor under-developed countries. It is highly associated with some of the high income generating activities such as mining, quarrying, foundry and sandblasting. Silicosis afflicts both the young and the old leading to reduced productive age and life expectancy. Its prevalence the world over is high with ranges of about 26 to 55percent among respective workers.

### **2.1.3. Regional Perspectives of Silicosis**

Trapido *et al* (1998), with the objective of determining the prevalence of occupational lung disease and the previous compensation history in migrant mineworkers, undertook a study among a random sample of men living in Libode, a rural district of Eastern Cape province, South Africa. They examined two hundred thirty-eight ex-mineworkers according to a protocol that included chest radiography and spirometry. The radiographs were read by two independent readers. The mean age of the participants was 52.8 years, and the mean length of service was 12.15 years. The prevalence of pneumoconiosis was 22percent and 36percent (variation by reader). For both readers, a significant association between length of service and pneumoconiosis and between pneumoconiosis and reduction in FVC, and FEV at one second was found.

In trying to determine whether previous health experiences affected the prevalence of occupational lung disease in a semi-rural Botswanan community where there was a long history of labour recruitment to South African mines, Steen *et al* (1997) established an overall pneumoconiosis prevalence of 26.6percent to 31.0percent among the former miners. Progressive massive fibrosis was present in 6.8percent of the miners. The progressive massive fibrosis was associated with mining service of 15 or more years. Pneumoconiosis was found to be associated with airflow limitation. In their study, the mean age among the former miners was 56.7 (range: 28-93) years, while the mean duration of service was 15.5 (range: 2-42) years.

Murray *et al.* (1996) analysed autopsy data for 16,454 black South African gold miners who died from unnatural causes from 1975 to 1991 inclusive. They collected information on age at death, duration of service in mine works, year of autopsy examination, and the prevalence of silicosis and tuberculosis. The study established that there was an increase in the

prevalence of silicosis from 9.3percent in 1975 to 12.8percent in 1991. The study team also established that prevalence of both silicosis and tuberculosis increased with age and duration of service.

Hnizdo and Sluis-Cremer (1993) examined the risk of silicosis in a cohort of white South African gold miners. The team established a silicosis prevalence of 14percent and the average age of the silicotics was found to be 55.9 years. Fifty seven percent of the silicotics developed silicosis an average 7.4 years after mining exposure ceased. Hnizdo and Sluis-Cremer concluded that the risk of silicosis was strongly dose-dependent, and that latency period for silicosis was independent of dose.

#### 2.1.4. National Perspectives of Silicosis

Table 2.1 by Robert Paul (1961), shows the incidences of silicosis in the last column. It illustrates the trends of silicosis among Northern Rhodesian copper miners in the years between 1950 and 1959.

**Table 2.1:** Silicosis in Northern Rhodesia

Year	Miners examined	Total silicosis	Silicosis per 1,000	Total silico-tuberculosis	Silico-tuberculosis per 1,000	Total all silicosis	All silicosis per 1,000
1950	25,812	97	3.8	7	0.3	104	4.0
1951	26,884	44	1.6	3	0.1	47	1.7
1952	26,852	26	1.0	6	0.2	32	1.2
1953	28,455	85	3.0	4	0.1	89	3.1
1954	29,791	119	4.0	6	0.2	125	4.2
1955	31,086	106	3.4	6	0.2	112	3.6
1956	35,272	123	3.5	8	0.2	131	3.7
1957	39,178	80	2.0	6	0.2	86	2.2
1958	31,448	46	1.5	6	0.2	52	1.7
1959	38,873	24	0.6	8	0.2	32	0.8

(Adapted from Paul, 1961: 11)

Mulenga *et al* (2005) examined annual cases of silicosis and tuberculosis in Zambian miners, and went further to compare the patterns of these diseases in the pre-HIV/AIDS era (1960-1970) to the HIV/AIDS era (1992-2002). In this study, they established that the proportion of silicosis among all the certified miners decreased from 28.6 percent to 12.4 percent with the arrival of HIV/AIDS, while tuberculosis cases rose from 37.1 percent to 86.1 percent during the same period.

In his study, Mwansa (2004) reviewed 1,122 miners' files from OHMB with the objective of determining the prevalence of silicosis among in-service Zambian mineworkers and identifying the areas of operation and divisions mostly affected by silicosis in the year 2002. The prevalence of silicosis was found to be 8 per 1,000 miners, with Chibuluma mine recording the highest prevalence at 2.2 percent. All the cases of silicosis were from underground miners. Silicosis was strongly associated with years of service, age of the miners and area of operation. Association was also demonstrated between silicosis and dust particles.

#### **2.1.5. Risk Factors Associated with Silicosis**

Buchanan *et al* (2003) illustrated an "exposure-response relation between exposure to quartz in coal mine dust and silicosis." From their reanalysed data of a Scottish colliery, they established that dose of exposure to silica dust was as important as prolonged (cumulative) exposure. They concluded that exposure to relatively high silica concentrations at short durations of even a few months can lead to silicosis. Buchanan *et al* thus showed that concentration of silica as well as duration of exposure to silica were important risk factors of silicosis.

According to Mallett *et al* (2002), "the relation between exposure to crystalline silica and silicosis mortality" is predictive. Mortality due to silicosis was noted to increase steadily with

increase in either length of exposure to silica bearing rock or percentage concentration of silica in the surrounding rock. They observed that “those who died of silicosis had a median duration of exposure of 28 years and a median cumulative exposure of 7.15 mg/m<sup>3</sup>-years (compared to respectively 10 years and 0.62 mg/m<sup>3</sup>-years for the whole cohort).”

Chen *et al.* (2001), during the period 1960 to 1965, examined 3010 miners employed by four Chinese tin mines. The study team established a silicosis prevalence of 33.7percent. The silicotics had a mean age of 48.3 years with an average elapsed time of 21.3 years since their first exposure to silica. The team also established that 67.4percent of the silicotics developed the disease an average 3.7 years after they had retired from tin mining. Cumulative exposure to silica ((mg/m<sup>3</sup>)-years) was established as a strong predictor of the risk of silicosis.

Lee *et al* (2001) reported that silicosis continues to progress from simple forms to more advanced and complex forms. They established a positive association between the period of follow up and the radiological progression to more advanced forms of silicosis. They also established that an early cessation to “silica exposure was associated with a less progression” to more advanced forms of silicosis.

In his commentary, Ian Greaves (2000) states that four parameters were needed for proper assessment of individual’s risk of silicosis;the intensity of exposure (measured by the airborne level of respirable silica), the duration of exposure, the time from first exposure (latency), and the crystalline form of silica (quartz, tridymite, or cristobalite). He stated that tridymite and cristobalite, though less common, were more toxic than quartz.

Rosenman *et al.* (1996) evaluated medical records and silica exposure data for 1,072 retired and in-service workers of an iron foundry, which produced engine blocks for the automotive industry. They established that the risk of silicosis increased with years of service,

quantitative and cumulative silica exposure ((mg/m<sup>3</sup>)-years), work area, and cigarette smoking.

In an attempt to establish the exposure-response relationships for silicosis Kreiss and Zhen (1996) investigated 134 male miners aged 40 years and more in Leadville, Colorado. They concluded that the risk of silicosis was best predicted by elapsed time since last exposure together with either; cumulative silica exposure ((mg/m<sup>3</sup>)-years), or a combination average intensity of silica exposure (mg/m<sup>3</sup>) and duration of exposure (years).

Steenland and Brown (1995) evaluated male gold miners in South Dakota, who had worked in underground mine work-sites in the period 1940 to 1965. The percentage of silica in the mine dust averaged 13percent. The study established that cumulative silica exposure ((mg/m<sup>3</sup>)-years), duration of exposure (years) and intensity of exposure (mg/m<sup>3</sup>) were important predictors of silicosis.

Thus, the studies reviewed in this section illustrate that the risk factors associated with silicosis can be collapsed into four main factors; intensity of silica exposure measured in mg/m<sup>3</sup>, duration of exposure (or duration of service in silica abrasive works) to silica measured in years, cumulative silica exposure measured in (mg/m<sup>3</sup>)-years, and crystalline form of silica.

#### **2.1.6. Silicosis and HIV infection**

Although currently, the impact of HIV/AIDS has lead to a global change in the way most diseases present, no study has ever showed an association between silicosis and HIV infection. However, the risks of the two conditions have been shown to combine multiplicatively, so that TB remains as much a silica-related occupational disease in HIV-

positive as in HIV-negative miners, and HIV-positive silicotics have considerably higher TB incidence rates than those reported from other HIV-positive miners (Churchyard *et al*, 1999).

## **2.2. OBJECTIVES**

### **2.2.1. General Objective**

To determine the risk factors associated with silicosis among Zambian former mineworkers.

### **2.2.2. Specific Objectives**

- To determine the proportion of silicosis among former miners;
- To determine the association between silicosis in former miners and;different forms of exposure to silica, long service and cigarette smoking;
- To determine the association between silicosis and the length of service in various mining divisions, length of service in major work-sites and length of service in various job categories.

## CHAPTER 3: METHODOLOGY

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### 3.1. INTRODUCTION

The purpose of this study was to determine the factors assumed to influence the prevalence of silicosis in the Zambian former miners. The discussion in this section focuses on research methods which were used and they include among others; conceptual framework, study design, study site, study population, sample size determination, sampling methods, eligibility criteria, data collection procedures, study limitations, ethical considerations and data management procedures.

### 3.2. CONCEPTUAL FRAMEWORK

Table 3.1 shows how operational indicators were used to illustrate the relationship between the dependent and independent variables. The dependent variable is a measure of the problem under study, while the independent variables illustrate the assumed causal factors.

**Table 3.1:** Operational indicators of the dependent and independent variables

VARIABLES	OPERATIONAL DEFINITION	INDICATORS	SCALE OF MEASUREMENT
<b>Dependent Variable:</b>			
• Silicosis	State of being diagnosed with silicosis	Total number of silicotics among the participants.	Proportion (Prevalence rate)
<b>Independent Variables:</b>			
• Demographic Characteristics;			
- Age at employment	Actual number of years from birth the participant had at first employment to mine works.	Age as stated at date of first employment; 18 – 99 years old.	Time in years

**Table 3.1:** Continued.

- Age at certification	Actual number of years from birth the participant had at time of certification	Age as stated at date of certification; 18-99 years old.	Time in years
- Age at retirement	Actual number of years from birth the participant had at time of retirement from employment as a miner.	Age as started at date of retirement from mine works; 18-99 years old.	Time in years
- Gender	State of being male or female.	Ratio of males to females among participants.	Ratio
• Smoking	State of being a cigarette smoker.	Total number of smokers among participants.	Percent
• Duration of Service in mines	State and duration of having worked in one of the major mining work places.	Total number of participants who worked in each of the mining companies' work places.	Percent
		Total number of years of mining exposure at one or more of the mining companies' work places.	Time in years
• Mining work-site	State and duration of having worked in one of the major mining work sites.	Proportion of participants who worked in one of the major mining work-sites.	Percent
		Number of years of mining at one or more of the mining worksites.	Time in years

**Table 3.1:** Continued.

• Mining job-category	State and duration of having worked in one of the major mining job categories.	Proportion of participants who worked in one of the mining job categories.	Percent
		Number of years of mining in one or more of the mining job-categories.	Time in years
• Silica levels	Silica content in dust samples from different mining sites.	Proportion of silica in dust samples from different mining sites at individual mines.	Percent

### **3.3. STUDY DESIGN**

This was a retrospective cross-sectional study design involving a review of records of former copper mineworkers from different geographical settings in Zambia, who attended medical examinations at the OHMB from January 2004 to December, 2008. The former miners are expected to attend medical examination once a year, but unfortunately, due to their personal reasons, some attend medical examinations once in two or three years. For this reason alone, the retrospective cross-sectional study was preferred over the point prevalence study as it was expected to capture a larger and more representative study population.

### **3.4. STUDY SITE**

The study was conducted at the Occupational Health Management Board in Kitwe, Zambia.

### **3.4.1. Occupational Health Management Board (OHMB)**

Occupational Health Management Board is located along the Kitwe-Chingola road, about half a kilometre from the Kitwe main post office. This is the only institution in Zambia mandated by law to conduct initial, periodical and benefit medical examinations for scheduled area mineworkers. It is mandatory by law for any person wishing to work, working or retired from work in the scheduled mining areas to attend medical examinations at OHMB. “No employment [in a scheduled area] without, or in breach of, certificate of fitness [from OHMB]” (The Workers’ Compensation Act, 1999). The study involved the review of files of benefit examinees’ who attended medical examinations at the OHMB during the period 1<sup>st</sup> January 2004 to 31<sup>st</sup> December 2008 stored in the records hall at this institution.

### **3.4.2. Diagnosis of Silicosis at OHMB**

The diagnosis of silicosis at OHMB is made by a panel of not less than six doctors. This panel consists of an occupational health physician, an epidemiologist and general medical officers.

The diagnosis is made based on the International Labour Organisation (ILO) classification of radiographs of pneumoconiosis. A radiographic reading of 1/0 or more (rounded opacities) defined mineworkers with a diagnosis of silicosis.

## **3.5. STUDY POPULATION**

The study population was made up of non-duplicate records of all Zambian former copper mineworkers who reported for medical examinations in the period 1<sup>st</sup> January 2004 to 31<sup>st</sup> December 2008. Thus, the study unit was a Zambian former copper mineworker’s file updated at the OHMB during the period 1<sup>st</sup> January 2004 to 31<sup>st</sup> December 2008.

### 3.6. SAMPLE SIZE DETERMINATION

The sample size was determined using the 95percentconfidence interval by the formula;

$$n = \frac{z^2 p(100-p)}{d^2}$$

Where:  $n$  = Sample size;

$z$  = 1.96 at 95% Confidence Level;

$p$ =The estimate of prevalence or estimated percentage of former miners with silicosis. No such study has been carried out in Zambian former miners; therefore, 50% was used as  $p$ ;

$d$  = 5%, the desired width of confidence interval.

Therefore;

$$n = \frac{1.96^2 * 50(100-50)}{5^2} = \underline{384.2}$$

Adjusting for a 20percent misplaced or mutilated files;

$$\text{Sample size} = 384.2/0.8$$

$$= 480.25$$

Rounding off this figure to the nearest 100, sample size was determined as;

$$\text{Sample size} = 500 \text{ records.}$$

Therefore, 500 records were expected to allow estimation of the prevalence of silicosis and the risk factors associated with silicosis in Zambian former mineworkers to within fivepercent width of the 95percent confidence interval.

### **3.7. SAMPLING METHODS**

This research employed simple random sampling, a probability sampling method, to select the participating former miners' files from the study population. The file numbers of all former miners who attended medical examinations during the study period were entered into the computer, screened for duplicating file numbers and then simple random sampling done using Epi6 software. Each selected file was reviewed for required data. This procedure was used because it gave equal chance for anyone file in the target population to be selected.

### **3.8. ELIGIBILITY CRITERIA**

#### **3.8.1. Inclusion Criteria**

The participants were drawn from records of all Zambian former copper mineworkers who attended medical examinations at the OHMB in the period spanning between 1<sup>st</sup> January 2004 and 31<sup>st</sup> December 2008.

#### **3.8.2. Exclusion Criteria**

The study excluded all initial and periodical examinees, all benefit examinees who did not report for medical examination during the study period. It also excluded workers of non-copper mining companies. Non-copper mining companies include Chilanga cement, Ndola Lime, Stone quarry industries, Albidon mine, Nampundwe mine and Maamba collieries. Employees of Kansanshi and Lumwana mines were also excluded from participation as the two mines were yet to record a former miner legible for participation in this study.

### **3.9. DATA COLLECTIONTECHNIQUES AND TOOLS**

Data collection was done through the review of former copper miners' files. The information collected was recorded in a questionnaire. The questionnaire is appropriate because it allowed

data entry helpers record only the necessary information about risk factors and prevalence of silicosis among former copper miners. The questionnaire was designed using EpiData software, and this same software was used for data entry (Lauritsen and Bruus, 2004).

### **3.10. ETHICAL CONSIDERATION**

This study involved the review of Zambian former copper miners' records which belong to those who came for medical examination at the OHMB in the period 1<sup>st</sup> January 2004 to 31<sup>st</sup> December 2008, therefore not involving any direct bodily invasion, the protocol sought for an ethics waiver for the research to proceed. Nevertheless, the protocol assured the University of Zambia Research Ethics Committee that identities of the miners as recorded in their files would not form part of the study, except for the file numbers which were used in the establishment of the sampling frame to help identify the participating files. The sampling procedure was done by the principal researcher and his team of research assistants, therefore no other people had access to the file numbers that formed the study population. After the study population was determined and participating files were identified, the file numbers were discarded in a secure manner. Collected data was stored on a computer to which only the principal researcher and his team had access.

Permission to use the miners' files at Occupational HealthManagement Board was sought from the Director's office at OHMB in Kitwe.

### **3.11. DATA PROCESSING AND QUALITY CONTROL**

Data from the data collection form was entered directly onto the computer in coded form using an EpiData created questionnaire. However, before proceeding with the analysis, raw data was checked for completeness and accuracy by the principal investigator.

### **3.12. LIST OF VARIABLES**

The list of variables and their operational definitions are as illustrated in table 3.1 on page 20.

### **3.13. DATA ANALYSIS**

Data was further processed and analysed using Epi Info Version 3.3.2 software (CDC, 2008).

Data was used to determine the frequency of silicosis and confidence intervals were determined to quantify the closeness of the frequency of silicosis in the study population to that unobserved in the target population.

In order to determine the risk factors of silicosis in the former miners, data was described for silicosis by; age at employment, current age, date of certification, sex, smoking status, duration of service in mining companies (i.e. Chambishi, Chibuluma, Konkola, Luanshya, Mufulira, Nchanga and Nkana mines), duration of service in major work sites (i.e. underground, surface mining and other surface sites), duration of service in individual job categories (i.e. drilling, lashing, crushing and other categories) and the mean percent crystalline silica content of the rock around individual mining companies.

The t test, and logistic regression analysis were used to determine the importance of age at discharge and at certification, sex, duration of service, mining divisions, major work sites, individual job categories, and dust percent crystalline silica content, as predictors of silicosis. Kruskal-Wallis was used to determine the difference in median duration of service between the silicotics and the non-silicotics.

### **3.14. STUDY LIMITATIONS**

This was a cross section study, as such, it only included those miners who reported for medical examination during the study period, and excluded all those miners who could not

report for examination due to various reasons which probably included advanced silicosis, the condition most relevant to the study itself.

This study involved the review of Zambian former mine workers' records (i.e. exposure reconstruction). This method has some drawbacks in that some required records for the study were not available or were incomplete. Of particular importance to this study, was the missing data on smoking status, and that of missing files.

Silica level exposure was calculated based on fixed point dust samples. This does not represent personal respirable silica dust exposure which would be more representative of the intensity of exposure.

### **3.15. PROJECT ADMINISTRATION AND MONITORING**

Project administration and monitoring was done by the principal researcher with the help of research assistants. The principal researcher did daily supervisions and monitoring of the project.

A lot of assistance was sort from the supervisors during the course of the study.

## CHAPTER 4: RESULTS

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### 4.1. INTRODUCTION

Of the 500 former miners records included in the original random sample, 22 (4.4percent) could not be located for inclusion in the study. In total, 478 records were available for this study. During data processing and cleaning, two individuals with unknown age at employment were not considered in further analysis. Therefore, a total of 476 (95.2percent) records formed the final sample size for this study.

### 4.2. UNI-VARIATE ANALYSIS

Table 4.1 shows the demographic characteristics and duration of service of the Zambian former miners.

**Table 4.1:** Characteristics of the Zambian former miners

Character	Value
Number ( <i>n</i> )	476
Mean age (SD) in years	56 (SD = 9.1) years
Gender	99.6% males, 0.4% females
Service in mines (median (Q <sub>1</sub> , Q <sub>3</sub> ) years)	21 (Q <sub>1</sub> = 13.8, Q <sub>3</sub> = 27.1) years

\* Data on smoking status was missing.

Data concerning the smoking status of the former miners was missing from the files. Apparently, this characteristic was not being recorded in the years before 2000, a period to which nearly all the participants in this study belong.

#### 4.2.1. Distribution of miners by years of service in individual mine division

When the mines were owned by the Zambia Consolidated Copper Mines (ZCCM), it was common for miners to be transferred from one division to another. Thus a number of miners in the sample served in more than one mining division.

**Table 4.2:** Duration of service in specific mining divisions in years.

Mine division	Frequency	Duration of Service		
		Median	Q <sub>1</sub>	Q <sub>3</sub>
Nkana: Overall	124	20	12	26
Nkana division only	110	21	13	26
Nkana and other divisions	14	8	5	15
Nchanga: Overall	161	20	12	26
Nchanga division only	142	21	12	27
Nchanga and other divisions	19	11	5	16
Konkola: Overall	41	18	10	29
Konkola division only	29	23	13	30
Konkola and other divisions	12	11	5	22
Mufulira: Overall	112	21	11	27
Mufulira division only	83	23	17	28
Mufulira and other divisions	29	9	4	13
Chibuluma: Overall	26	9	3	19
Chibuluma division only	8	20	14	25
Chibuluma and other divisions	18	5	1	9
Chambishi: Overall	43	11	6	18
Chambishi division only	17	19	12	24
Chambishi and other divisions	26	8	3	10
Luanshya: Overall	37	12	5	15
Luanshya division only	15	16	14	25
Luanshya and other divisions	22	6	1	10
Other divisions*: Overall	19	7	2	12

\* Other divisions include miners employed under mines like Mpelembe drilling company, Tamrock and Sandvic Zambia. These were in most cases seconded to big divisions.

Table 4.2 shows the proportionate distribution of miners with Nchanga, Nkana, Mufulira and Konkola divisions having had employed a large number of miners. This distribution shows the same trend as that described by Mwansa(2004).Table 4.2 also shows the median duration of service that former miners served in each of the divisions. Konkola, Mufulira, Nchanga and Nkana divisions recorded the highest overall durations of greater than 17 years. Chibuluma, Chambishi and Luanshya divisions recorded overall durations which were less than 13 years.

#### 4.2.2. Distribution of miners by Mining Sites

Table 4.3 shows a median duration of service of nine ( $Q_1 = 4$ ,  $Q_3 = 16$ ) years among the 332 former miners who once worked in production section underground. The median duration of service for those who worked in other areas underground was five ( $Q_1 = 2$ ,  $Q_3 = 11$ ) years.

**Table 4.3:** Duration of service in specific mining sites in years.

Work-site	Frequency	Duration of Service		
		Median	$Q_1$	$Q_3$
Underground Work-sites:				
Production; Overall	332	9	4	16
Production only	12	11	7	14
Production & other sites	320	9	3	16
Other underground sites; Overall	328	5	2	11
Other underground sites only	5	17	11	17
Other underground sites & other sites	323	5	2	10
Surface Work-sites:				
Concentrator; Overall	160	6	2	13
Concentrator only	12	12	11	25
Concentrator & other sites	148	5	1	12
Other surface sites; Overall	276	6	2	12
Other surface sites only	41	14	10	18
Other surface sites & other sites	235	5	1	9

-The total number of miners does not add up to 476 because some miners served in more than one mining sites.

Among the workers who worked on surface sites, 160 worked for a median duration of six ( $Q_1 = 2$ ,  $Q_3 = 13$ ) years in the concentrator, while 276 worked in other areas on surface for a median six ( $Q_1 = 2$ ,  $Q_3 = 12$ ) years. A comparison of the four major work sites show that service in production areas was the longest at a median of nine ( $Q_1 = 4$ ,  $Q_3 = 16$ ) years, while service in other underground sites was shortest at five ( $Q_1 = 2$ ,  $Q_3 = 11$ ) years.

#### 4.2.3. Distribution of miners by Job Categories

Table 4.4 shows the characteristics of the sample in respect of average duration of service the former miners worked as a driller, lasher, crusher or other jobs. It should be emphasised that

some miners worked in more than one work category. This is why the frequency does not add up to 476.

**Table 4.4:** Duration of service in specific job categories in years.

Job Category	Frequency ( <i>n</i> )	Duration of Service		
		Median	Q <sub>1</sub>	Q <sub>3</sub>
Drilling	61	3	2	7
Lashing	68	2	1	5
Crushing	20	5	2	8
Other job categories	472	19	12	26

Sixty one miners worked for a median of three( $Q_1 = 2, Q_3 = 7$ ) years as drillers, 68 former miners worked a median two( $Q_1 = 1, Q_3 = 5$ ) years as lashers, while 20 miners worked as crushers for a median five( $Q_1 = 2, Q_3 = 8$ ) years. Ninety nine percent of former miners once worked in other job categories for a median 19 ( $Q_1 = 12, Q_3 = 26$ ) years.

#### 4.2.4. Mean silica content in dust samples

Table 4.5 shows mean silica content in dust from major dust generating job sites in individual mine divisions. On average, lashing generates dust with a high silica content at 37.3 (SD=17.97)percent followed by crushing at 32.2(SD=21.11)percent.

**Table 4.5:** Mean percent silica content in dust samples from different operation sites in individual mine divisions.

Mine division	Drilling	Lashing	Crushing	Average	(SD)
Nkana	16.70	6.58	3.50	8.93	( 6.91)
Nchanga	17.50	45.10	16.99	26.53	(16.08)
Konkola	15.68	51.57	44.95	37.40	(19.10)
Mufulira	33.28	24.50	41.10	32.96	( 8.30)
Chambishi	---	---	---	---	( ---)
Chibuluma	28.73	45.53	54.25	42.84	(12.97)
Luanshya	73.88	50.50	---	62.19	(16.53)
<b>Average</b>	30.96	37.30	32.16		
<b>(SD)</b>	(22.23)	(17.97)	(21.11)		

(Adopted from Kalowa, 1996)

Drilling on average generates dust with least silica content at 31.0(SD=22.23)percent. A combination of the high dust generating work sites show that Luanshya division has on average a high silica content at 62.2(SD=16.53)percent in its dust, while Nkana division has the least silica content in its dust at 8.9(SD=6.91)percent.

#### 4.2.5. Prevalence of silicosis in Zambian former copper miners

The prevalence of silicosis in Zambian former copper miners is as shown in Table 4.6.

**Table 4.6:** Prevalence of silicosis in the Zambian former copper miners

Status of Silicosis	Frequency	Percentage	95% Conf. Interval
Absent	434	91.2%	
Present	42	8.8%	6.27 – 11.38
Total	476	100.0%	

The table shows the prevalence of silicosis at 8.8(CI: 6.27 - 11.38)percent among former miners during the period 1<sup>st</sup>January 2004 to 31<sup>st</sup>December 2008.

### 4.3. BI-VARIATE ANALYSIS

#### 4.3.1. Silicosis according to age of miners

Table 4.7 shows the relationship between silicosis and average age of the former miners.

**Table 4.7:** Mean age among silicotics and non-silicotics

	Silicotics	Non-silicotics	<i>p</i> -Value
Frequency	42	434	
Means	66	56	<0.001
95% Conf. Interval	63 - 68	55 - 57	

The silicotics mean age was 66 (SD = 8.9) years, while the non-silicotics' was 56 (SD = 7.2) years. This shows a significant difference in age between the two groups with *p*-Value at less than 0.001.

#### 4.3.2. Silicosis according to years of service

For each additional year of service in the mines, the miners were 10 percent more likely to develop silicosis (OR = 1.10; CI = 1.05 to 1.15).

The relationship between silicosis and median years of service in the mining industry is as shown in table 4.8.

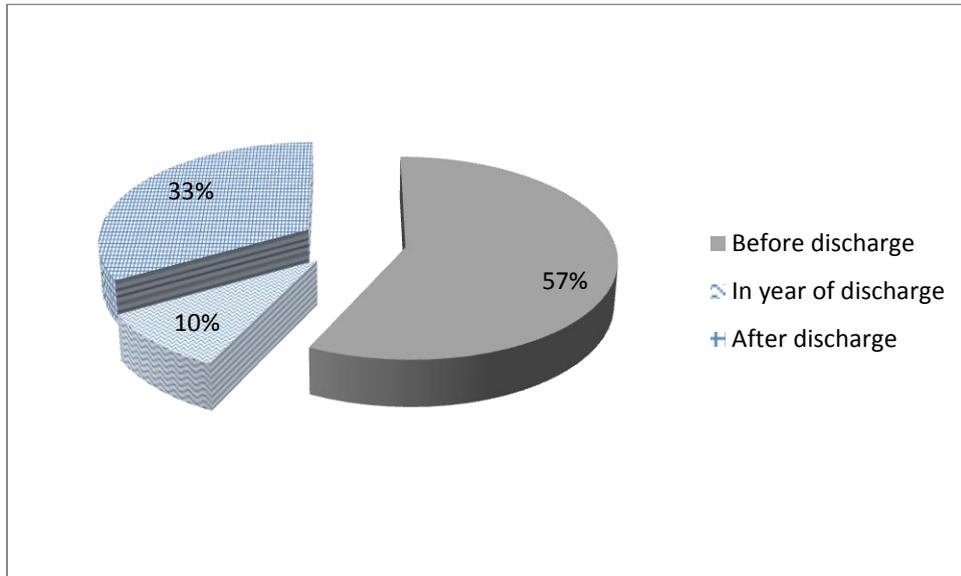
**Table 4.8:** Median years of service among silicotics and non-silicotics

Parameter	Silicotics	Non-silicotics	Chi-Square	<i>p</i> -Value
Frequency	42	434		
Median (years)	26	21	15.10	<0.001
Q <sub>1</sub> – Q <sub>3</sub>	21 - 30	13 - 27		

The median years of service among the silicotics were 26 years, while the non-silicotics median years of service were 21 years (*p*-value < 0.001).

### 4.3.3. Silicosis according to year of certification and discharge

Figure 4.1 shows the relationship between the year of certification and year of discharge for the 42 silicotics.

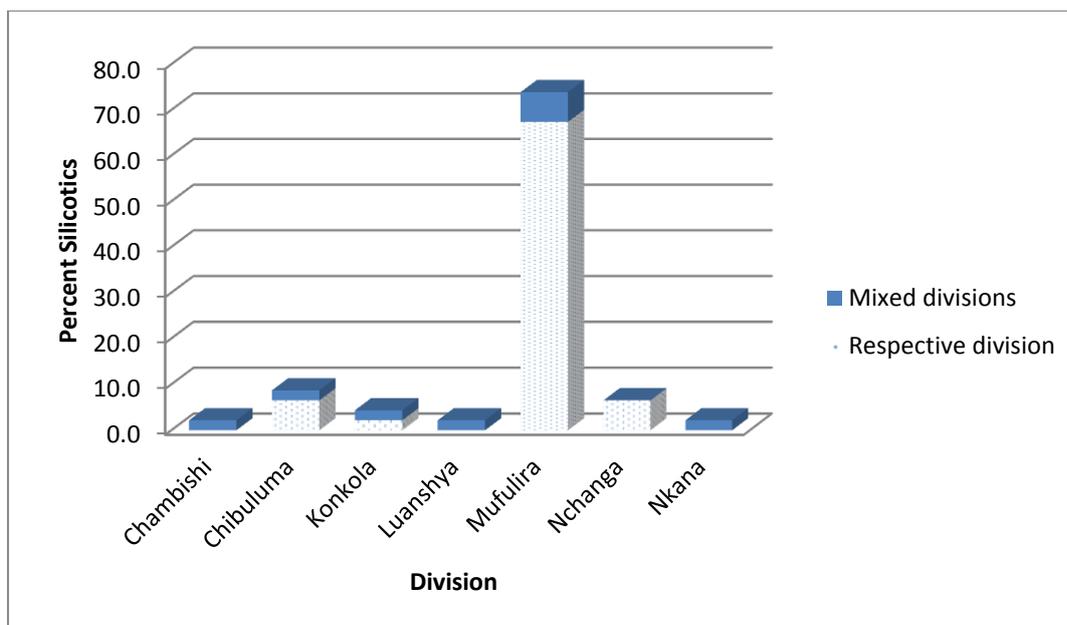


**Figure 4.1:** Year of certification in relation to year of discharge.

While the majority of miners were diagnosed of silicosis before being discharged, figure 4.1 shows that 33percent developed silicosis years after they were discharged from mining works.

### 4.3.4 Silicosis according to individual mining divisions

The work history of silicotics through the different mine divisions is as illustrated in figure 4.2. The figure shows that 74percentof the 42 silicotics worked exclusively for Mufulira division.



**Figure 4.2:** Silicosis cases according to mine divisions ( $n = 42$ )

All the silicotics registered under Nkana, Chambishi and Luanshya had service in other divisions as well, while silicotics from Nchanga had exclusive service in Nchanga division.

Table 4.9 shows the likelihood of miners suffering from silicosis after work in individual mine divisions.

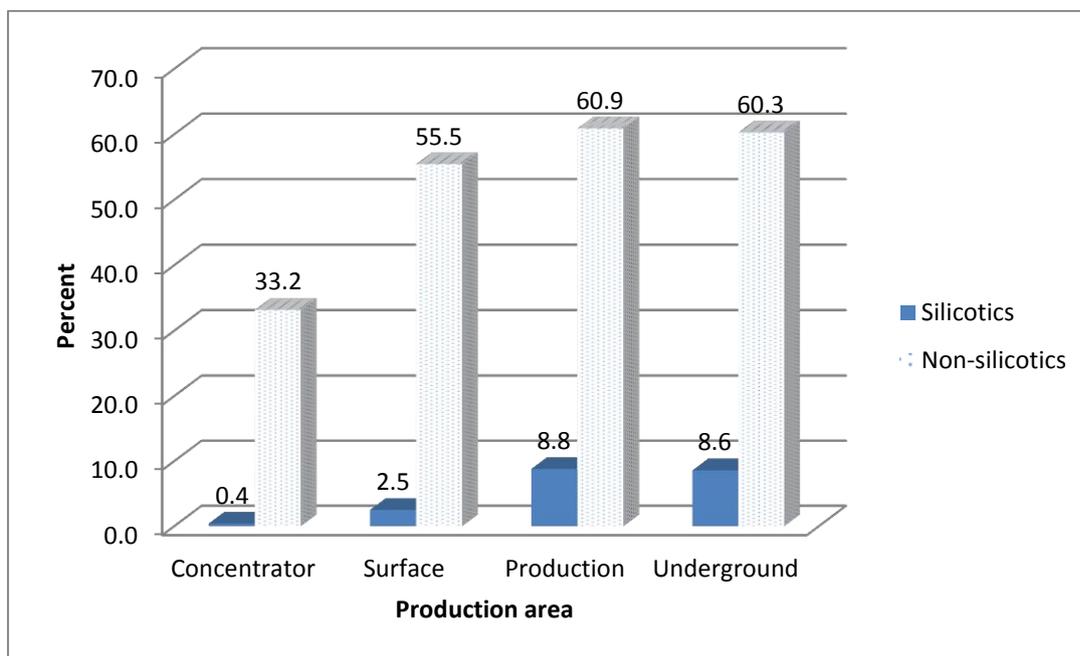
**Table 4.9:** Age-adjusted odds of developing silicosis by mine divisions.

Mine division	Odds Ratio	95% Conf. Interval	P-Value
Nkana	0.90	0.74 – 1.10	0.327
Nchanga	1.01	0.94 – 1.08	0.739
Konkola	1.03	0.98 – 1.09	0.251
Mufulira	1.16	1.06 – 1.26	0.001
Chibuluma	1.16	1.04 – 1.30	0.009
Chambishi	0.87	0.61 – 1.24	0.437
Luanshya	0.47	0.13 – 1.70	0.249
Others	1.12	0.89 – 1.40	0.327

On each additional year spent working in Mufulira and Chibuluma divisions, miners were 16percent more likely to have developed silicosis, length of service in other mining divisions was not significantly associated with the development of silicosis.

#### 4.3.5. Silicosis according to service in major work sites

The distribution of silicotics and the non-silicotics by service in major mining work-sites is illustrated in figure 4.3.



**Figure 4.3:** Silicosis prevalence by major work-sites (n=476).

The figure shows that all the silicotics (8.8percent) once worked in the production area, while a subset of silicotics (8.6percent of the silicotic miners) had service in other areas underground.

Table 4.10 shows the likelihood of developing silicosis after service in the different major work sites in the mining industry.

**Table 4.10:** Age-adjusted odds of developing silicosis by major work-sites in mining

Major Work-site	Odds Ratio	95% Conf. Interval	<i>p</i> -Value
Surface:			
- Concentrator	0.97	0.85 – 1.10	0.603
- Other sites	0.97	0.87 – 1.06	0.444
Underground:			
- Production	1.14	1.06 – 1.24	0.001
- Others	1.05	0.95 – 1.16	0.370

On each additional year spent working in the underground production areas, miners were 14percent more likely to have developed silicosis, length of service in other major work-sites was not significantly associated with development of silicosis among former miners as table 4.10 illustrates.

#### 4.3.6. Silicosis according to service in different job categories

The association between service in different job categories of mining, and developing silicosis is illustrated in table 4.11.

**Table 4.11:** Age-adjusted odds of developing silicosis by job-categories in mining

Job Category	Odds Ratio	95% Conf. Interval	<i>p</i> -Value
Drilling	1.03	0.89 – 1.18	0.721
Lashing	1.31	1.12 – 1.54	0.001
Crushing	1.16	1.00 – 1.34	0.054
Others	1.09	1.00 – 1.18	0.042

As table 4.11 shows, for each additional year spent working as a lasher, miners were 31percent more likely to have developed silicosis, length of service in other job categories was not significantly associated with the development of silicosis among the former miners.

#### 4.3.7. Silicosis according to cumulative silica exposure

Table 4.12 shows the association between cumulative silica exposure in percent silica-years and silicosis. The cumulative silica exposure (CSE) was calculated using the formula below:

$$CSE = \sum [\text{Silica content (\%)} * \text{Duration (years)}]$$

Where: Silica content = average percentage silica content in dust at mine division as shown in table 4.5 on page 33.

Duration = Period of service in years a miner worked at mine division.

This was a sort of time weighting as most of the miners had worked in different mining divisions. Since it was a multiplication of percent silica content and years of service, the units are given in percent silica-years (%Silica-years).

**Table 4.12:** Means of cumulative percent silica exposure by silicosis status

Parameter	Silicotics	Non-silicotics	<i>p</i> -Value
Frequency*	42	413	
Means (% silica-years)	825.1	506.7	<0.001
95% Conf. Interval	754.12 – 896.12	473.79 – 539.51	

\* The total frequency does not add up to 476 because the miners who worked exclusively in Chambishi and other divisions such as Mpelembe drilling were excluded from this analysis as data on silica content for these was missing.

Table 4.12 illustrates that the silicotics did on average work in environments that had a higher percent silica (825.1 percent silica-years) content over years than that among non-silicotics (506.7 percent silica-years).

#### 4.3.8. Incubation period of silicosis in Zambian former copper miners

Among the silicotics, the average years of service (years of exposure) it took for a miner to be diagnosed with silicosis was 26 (SD = 6.32) years.

## CHAPTER 5: DISCUSSION

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### 5.1. INTRODUCTION

This research study aimed to determine the risk factors associated with silicosis among Zambian former copper mine workers for the period January 2004 to December 2008. To identify the risk factors, exposure factors were compared between the silicotic and the non-silicotic former miners.

The study established a significant difference in mean age of silicotics from that of non-silicotics. The silicotics were on average 10 years older than the non-silicotics.

### 5.2. PREVALENCE OF SILICOSIS AMONG FORMER MINERS

In the course of determining the risk factors associated with silicosis, the prevalence of silicosis among the Zambian former miners, for the period January 2004 to December 2008 was determined as 8.8percent. Although 10 fold higher than the prevalence established by Mwansa (2004), among the in service miners, a prevalence of 8.8percent is relatively lower than average prevalence obtaining worldwide and in the region (WHO, 2000; Trapido *et al* 1998; Steen *et al* 1997).

Thirty three percent of the silicotics among the former miners developed silicosis an average 4.7 years after retirement from mining jobs as illustrated in figure 4.1. The later exemplify the fact that silicosis can continue to progress or can develop years after cessation of exposure from silica (ILO/WHO, 2003; Lee *et al*, 2001).

### **5.3. DURATION OF SERVICE IN MINING INDUSTRY**

Duration of service which was the period from date of employment to date of discharge was significantly associated with silicosis. Each additional year of service in the mines increased the likelihood of miners developing silicosis by 10 percent. There was a significant difference in average years of service with the silicotics having worked an extra 5 years on average than the non-silicotics. Mannetjeet *al* (2002) established a similar predictive association between duration of exposure to crystalline silica and eventual development of silicosis. Duration of exposure to silica as a predictor of silicosis is very important as it is inextricably associated with cumulative exposure to silica, itself an important risk factor in silicosis causation (Buchanan *et al*, 2003).

### **5.4. INTRINSIC FACTORS AT DIFFERENT MINING DIVISIONS**

Some intrinsic factors, beyond the scope of this study, necessitated increased risks of developing silicosis at certain mining divisions as compared to others. For instance, 73.8 percent of silicotics worked exclusively in Mufulira division. Working for Mufulira or Chibuluma divisions carried a high risk of developing silicosis as the results of the logistic model in table 4.9 shows. Intrinsic factors which could justify such differences in the prevalence might range from differences in work cultures, including institutional support for silicosis prevention procedures, to structural and geological difference at individual mines (Green *et al*; 1989). One such prominent difference is that some workers, not all, from Nchanga division might have worked in the open pit mining area, while the remaining 6 divisions are entirely underground mines.

## **5.5. SERVICE IN MAJOR WORK-SITES**

All the 42 silicotics once worked in the underground productive work site. Of the 42 silicotics, 97.6percent had an extra service underground working in non-production jobs. The results of a logistic model in Table 4.10, show a very strong association between developing silicosis and having worked in the underground production areas. This relationship between service in underground works and silicosis was also established by Green *et al* (1989).

## **5.6. SERVICE IN DIFFERENT JOB-CATEGORIES**

Service in certain job categories, especially mining face works, are associated with high risk of silicosis. In this study, there was a strong association between former miners who once worked as lashers and silicosis. However, no significant association between a former miner developing silicosis and the drilling, crushing, or other job types was shown.

## **5.7. CUMULATIVE SILICA EXPOSURE**

Cumulative exposure to crystalline silica was also found to be associated with the development of silicosis. The t-test results as illustrated in table 4.11 shows that the silicotics were on average more exposed to dust with a highpercent silica concentration by 318.47percent silica-years. Similar findings, of association between cumulative exposure and silicosis, have been noted in other studies (Buchanan *et al*, 2003; Mannetje *et al*, 2002).

## CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

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### 6.1. CONCLUSION

The study provided answers to nearly all the specific objectives, except one. It showed unequivocally that occupational exposure to crystalline silica was associated with silicosis in Zambian former copper mine workers. Silicosis was established to continue developing and progressing despite withdrawal of a miner from exposure to silica dust.

Although the prevalence of silicosis in the Zambian former miners was relatively lower as compared to that obtaining in many other countries worldwide, the risk factors associated with the disease in the former mineworkers were relatively similar.

Silicosis was well associated with long years of service in the copper mining industry. Long years of service usually influence other factors such as cumulative exposure to silica. The longer the years of service, the higher the cumulative exposure to crystalline silica was. This study showed a high risk of silicosis among miners with a large mean cumulative exposure to dust that had a high percentage concentration of silica.

Having worked for Mufulira or Chibuluma division carried a higher risk of silicosis for the former miners. The reason for this risk factor could not be determined by this study.

The risk of silicosis in former miners who worked in underground work station was higher than that of those who worked in surface workstations. Working as a lasher posed a higher risk for silicosis among miners than working in the other job categories.

Unfortunately, this study could not determine the influence of cigarette smoking on silicosis. This was so, because the data about cigarette smoking was missing from the files.

## 6.2. RECOMMENDATIONS

A prevalence of 8.8percentfor an incurable debilitating disease is a significant public health problem which calls for concerted effort from both the health sector and the mining industry. Based on the findings in this study, long service, work in Mufulira or Chibuluma divisions, work in the production area, work as a lasher, and exposure to dust with high percent silica concentration are associated with silicosis among Zambian former miners. Thus, efforts to reduce the incidence of silicosis among former miners should address the above identified risk factors. The following recommendations,to help reduce the disease burden and its debilitating effects on those who work in the mines, have been suggested:

- 6.2.1. The Ministry of Health should take note that silicosis can occur many years after miners have been retired from their work. It therefore, should educate health workers on the methods of diagnosing silicosis. In this instance, an occupation history, often ignored by many clinicians, makes a difference between a former miner being diagnosed with “sputum negative – drug resistant PTB”only to be complicated by the side effects of anti-tuberculosis drugs; and a diagnosis of silicosis that does not require drug therapy except when complicated by chest infection, occupational asthma or cor-pulmonale.
- 6.2.2. The Occupational Health Management Boardshould extend its data base so as to capture other relevant information such as cigarette smoking and other social activities among miners. It is also important for the bureau to start surveillance programs aimed at visiting the former miners at home, as most of them do not attend medical examinations after they have retired. Thebureau should educate the miners, mine owners, and the unions on the debilitating effects of silicosis, and hence the importance of its eradication.

- 6.2.3. The mining companies should implement stringent silica exposure control measures. The fact that some mining divisions had higher prevalence of silicosis than others simply shows that there is diversity in the manner that each division perceives and implements the control of silica exposure. Mining companies should institutionalise the control of silicosis by educating their employees about the dangers of silicosis, and therefore the need to prevent it. They should institute administrative controls that enable frequent job rotations, and reduced years of service in high dust areas and underground work sites (HSE, 2009; Aw *et al*, 2007). The mines should also encourage wet operations in the drilling, lashing and crushing of the copper ore. The ventilation systems, especially in high dust areas, should be adequate and well maintained. In areas where the above control measures cannot be achieved, a supplementation with PPE should be provided.
- 6.2.4. The Mine Safety Department should monitor the work culture at the mine divisions which had high prevalence of silicosis. They should also evaluate silicosis preventive measures put in place in the lashing job category. This could help illustrate the reason why there was such difference in the prevalence across the mining divisions.
- 6.2.5. There is need for further research in this area to determine the reason why some mine divisions have high prevalence of silicosis, and also to determine the influence of cigarette smoking on silicosis. Additional evidence based information will help both the health and mining sector combat the risk factors of silicosis, channelling more resources to more obvious factors and hence avoiding wastage of scanty resource that the country already experiences.

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7. Duration of service in individual job categories (months):
- a. Drilling.....;
- b. Lashing.....;
- c. Crushing.....;
- d. Others, specify;( );

8. Duration of service in major work-sites (months):
- a. Underground (production).....;
- b. Underground (others).....;
- c. Surface (concentrator).....;
- d. Surface (Others);( );

9. Date of first appointment to mining works.....;     
Day Month Year

10. Presence of Silicosis:
- a. Silicosis absent.....;
- b. Silicosis present.....;

11. If silicosis is present, enter date of certification.....;     
Day Month Year

END.

## APPENDIX B

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### Sample letter requesting permission to use medical records at the Bureau;

C/O Department of Community Medicine  
The University of Zambia  
School of Medicine  
P.O. Box 50110  
**LUSAKA**

20<sup>th</sup> July 2009

The Executive Director  
Occupational Health Management Board  
P.O. Box 20205  
**KITWE.**

Dear Sir,

#### **REQUEST FOR PERMISSION TO USE MEDICAL RECORDS AT THE BUREAU**

As a pre-requisite for my studies in Master of Public health at the University of Zambia, I am carrying out a research; “**Risk factors associated with silicosis in Zambian former mine workers**”. The study will involve the review of Zambian former mine workers’ records who attended silicosis examination at the Bureau from 2004 to 2008.

I would like to request your permission to use the medical records at your institution exclusively for the above stated purpose. I would like to assure you that the study protocol was approved by the University of Zambia Biomedical Research Ethics Committee and that no personal identifiers for the medical records will be used in the study, therefore confidentiality will be maintained.

Enclosed herewith is a copy of study approval from the University of Zambia Biomedical Research Ethics Committee.

I will be very grateful if my request is granted.

Yours sincerely,

**Dr. William Sitembo**  
MPH Student (UNZA)

## APPENDIX C:

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**THE UNIVERSITY OF ZAMBIA**  
SCHOOL OF MEDICINE

Telephone: 252641  
Telegram: UNZA, Lusaka  
Telex: UNZALU ZA 44370  
Email: kbowa@yashoo.com

P.O. Box 50110  
Lusaka, Zambia

-----  
19<sup>th</sup> November, 2008

Dr. W. Sitembo  
Department of Community Medicine  
LUSAKA

Dear Dr. Sitembo,

**Re: GRADUATE PROPOSAL PRESENTATION FORUM**

Following the Graduate Proposal Presentation Forum (GPPF) which was held on Thursday, 13<sup>th</sup> November, 2008 in the Main Lecture Theatre (UTH) at 14:00 hours; we wish to inform you that your research proposal titled: **"Risk factors associated with silicosis and occupational PTB in former miners in Zambia "** was approved by the Board of Graduate Studies of the School of Medicine. The assessors gave you a mark of 75%.

The overall comments were that:

1. Remove TB from the study focus on silicosis.
2. Discuss weakness of retrospective study.
3. How will you deal with confounding variable of HIV.
4. Reduce the objectives they are too many.
5. List variable, discuss how you will analyse the data .

The study is judged as a pass subject to the above adjustments.

  
Mr. K. Bowa, MSc, M.Med , FRCS, FACS  
**ASSISTANT DEAN, POSTGRADUATE**

CC: Director, Graduate studies  
Dean, School of Medicine  
Head of Department – Community Medicine

## APPENDIX D:

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### THE UNIVERSITY OF ZAMBIA

#### BIOMEDICAL RESEARCH ETHICS COMMITTEE

Telephone: 260-1-256067  
Telegrams: UNZA, LUSAKA  
Telex: UNZALU ZA 44370  
Fax: + 260-1-250753  
E-mail: unzarec@zamtel.zm

**Assurance No. FWA00000338**  
**IRB00001131 of IORG0000774**

Ridgeway Campus  
P.O. Box 50110  
Lusaka, Zambia

28 August, 2009  
Ref.: 006-06-09

Dr William Sitembo  
C/O Department of Community Medicine  
UNZA School of Medicine  
P.O. Box 50110  
LUSAKA

Dear Dr Sitemba,

RE: SUBMITTED RESEARCH PROPOSAL: "RISK FACTORS ASSOCIATED WITH SILICOSIS IN ZAMBIAN FORMER MINE WORKERS"

The above-mentioned research proposal was presented to the Biomedical Research Ethics Committee on 24 June, 2009 where changes were recommended. We would like to acknowledge receipt of the corrected version with clarifications. The proposal is now approved.

#### CONDITIONS:

- This approval is based strictly on your submitted proposal. Should there be need for you to modify or change the study design or methodology, you will need to seek clearance from the Research Ethics Committee.
- If you have need for further clarification please consult this office. Please note that it is mandatory that you submit a detailed progress report of your study to this Committee every six months and a final copy of your report at the end of the study.
- Any serious adverse events must be reported at once to this Committee.
- Please note that when your approval expires you may need to request for renewal. The request should be accompanied by a Progress Report (Progress Report Forms can be obtained from the Secretariat).
- Ensure that a report on the findings is submitted to this Committee.
- **Ensure that you submit the final report of the study to this Committee**

Yours sincerely,

Dr E. Munalula-Nkandu, BSc (Hons), MSc, PgD R/Ethics, PhD  
CHAIRPERSON

Date of approval: 28 August, 2009

Date of expiry: 27 August, 2010

## APPENDIX E:

ALL COMMUNICATIONS SHOULD BE ADDRESSED TO  
THE EXECUTIVE DIRECTOR  
TELEPHONE 03-228977, 02-228948  
FAX 03-228927, E-Mail: ohsmb@zambia.gov.zm

In reply please quote

No. \_\_\_\_\_



### OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT BOARD

OCCUPATIONAL HEALTH SAFETY AND RESEARCH BUREAU  
P O BOX 20205,  
KITWE, ZAMBIA.

MH/MO/5599

17 August 2009

Dr. William Sitembo  
OHMB  
P.O. Box 20205  
**KITWE**

Dear Dr. Sitembo

**RE: AUTHORITY TO USE MEDICAL RECORDS**

This serves to confirm that authority has been granted for you to use medical records at the Bureau as you would be conducting your research.

Thanking you.

Yours sincerely  
**OCCUPATIONAL HEALTH MANAGEMENT BOARD**

  
Dr. C.M. Musowe  
**EXECUTIVE DIRECTOR**

## APPENDIX F:

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### Study Supervisors

Below are the details and addresses of the supervisors for this study;

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