An Assessment of Risk Factors Associated with developing Silicosis among Konkola Copper Mine Workers in Zambia

By

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'Thesis Submitted in partial fulfillment of the requirements towards the awarding of Master of Science Degree in Epidemiology'

The University of Zambia

Lusaka

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DECLARATION

I hereby declare that works presented in this study for the Master of Science in Epidemiology 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: ………………………

Japhet Zimba (Candidate)

CERTIFICATE OF APPROVAL FORM

The University of Zambia has approved the dissertation by Japhet Zimba as fulfilling the requirements for the award of the Master of Science in Epidemiology.

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ABSTRACT

Silicosis is the most important occupational disease worldwide and is regarded as a major public health challenge in developing countries. The disease is mainly related to exposure to crystalline silica dust, and once the disease has been established, no present treatment exists. There is less focus on other factors that are related to one acquiring the disease among the people at greater risk of developing silicosis. The main aim of this study was to assess the risk factors associated with developing silicosis among Konkola Copper Mine workers in Zambia. A retrospective case review study was used, consisting of 168 Konkola Copper Mine Workers. A data extraction checklist was used to collect data on miners from the occupational hygiene silicosis registers. Data was analyzed using STATA version 12.0; a quantile-quantile plot was used to test for normality of continuous variables such as age and a chi-squared test was used to ascertain association with development of silicosis. Adjustment for the effect of other factors was computed using an investigator led stepwise multivariate logistic regression method. For each year increase in length of service, Konkola Copper Miners are 1.95 times more likely to develop silicosis adjusting for other factors such as business unit, job category (95% CI 1.92-1.99, p=0.033). Miners working in the production areas were highly susceptible to developing silicosis compared to those working in other areas. Within the production area, miners working underground represented 38% of silicotics, while those working at open pit only had 10%. Miners belonging to konkola and nchanga business unit were 5.42 and 5.96 times more likely to develop silicosis compared to those working in other units respectively. As a result of the statistical analysis, the researchers determined that the factors considered best predictors of silicosis were length of service, business unit and the job category to which the miners belonged to (P-values 0.033, 0.001, <0.001 respectively). There is need to strengthen control measures regarding utilization of personal protective equipment, health education programs, frequent job rotations (for unskilled labour) and adherence to periodical medical examinations. These predictors need to be tested in other mines as they cannot be generalized. There is need to do more prospective research to investigate why some sections are more prone to silicosis than others.

DEDICATIONS

I wish to dedicate this research to my wife Luyando, my daughter Taonga for their unfailing love, endurance, patience and immense support during my post graduate studies. I also dedicate this work to my parents for their continual support and encouragement.

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And finally, many thanks to numerous other people and friends who endured this long process with me and offered their support. Prominent among these are Mr. Milimo Sikoobwe and family; Pastor Isaac Chiyokoma and family, whose home during my postgraduate studies was "home away from home"; Ms Milimo Kapombe of the Department of Public Health at the University of Zambia; and finally the MPH/MSc class of 2016 for their support and encouragement.

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LIST OF ABBREVIATIONS

AIDS	Acquired Immuno-deficiency Syndrome
CCM	Chambishi Copper Mine
CS	Case-control Study
COPD	Chronic Obstructive Pulmonary Disease
HIV	Human Immuno-deficiency Virus
ID	Identity Number
KCM	Konkola Copper Mine
MCM	Mufulira Copper Mine
MOH	Ministry of Health
NCM	Nchanga Copper Mine
NkCM	Nkana Copper Mine
OHMB	Occupational Health Management Bureau

SD	Standard Deviation
TB	Tuberculosis
UNZA	University of Zambia
UNZA BREC	University of Zambia Biomedical Research Ethics Committee
WHO	World Health Organization

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Introduction

Silicosis is one of the oldest occupational health diseases. It is one of the most important occupational disease worldwide and it is regarded as a major public health challenge in developing countries such as Southern African Countries (Leung, 2012). The World Health Organization/WHO (2000) ranked China to have the largest cases of silicosis worldwide with 24,000 deaths annually.

The risk of disease is mainly related to the amount of crystalline silica dust one inhales during the time they work in areas prone to this dust. Silica has been known to cause silicosis for centuries (Gómez-Puerta *et al*., 2013; Steenland and Ward, 2014) and plays a significant role in autoimmune diseases (Pollard and Kono, 2013). Once the disease has been established, no effective treatment presently exists (Li *et al*., 2013). However, patients are provided with supportive care and are considered for lung transplantation if needed (Bang *et al*., 2015).

According to WHO (2005) estimates, 65 million people have moderate to severe chronic obstructive pulmonary disease (COPD) and more than three million people died from COPD in 2005, which corresponds to five percent of all deaths globally. Most of the information available on COPD prevalence, morbidity and mortality comes from high-income countries and even in those countries, accurate epidemiologic data on COPD are difficult and expensive to collect. It is known that almost 90 percent of deaths related to COPD occur in low- and middle-income countries (WHO, 2005).

In 2002 COPD was the fifth leading cause of death. Total deaths from COPD are projected to increase by more than 30 percent in the next 10 years unless urgent intervention measures are taken to reduce the underlying risk factors, especially tobacco usage. Estimates show that COPD becomes in 2030 the third leading cause of death worldwide (WHO, 2005). Silica dust and other occupational exposures such as chemicals (vapours, irritants and fumes) are among the factors which can cause COPD (WHO, 2010).

Mine related respiratory diseases have been an international concern, with silicosis at the forefront, leading to the Global Programme for the Elimination of Silicosis (Lehtinen and Goldstein, 2002). It is estimated that pneumoconiosis accounts for 30 000 deaths annually, with approximately 1.3 disability-adjusted life years (Lehtinen and Goldstein, 2002). The prevalence rates in Zambia are equally of concern: the studies of ex-miners from Botswana, Transkei, and Lesotho, suggested prevalence rates of pneumoconiosis ranged from 26 percent to 36 percent of former mineworkers (Girdler-Brown *et al.*, 2008).

Adverse health outcomes associated with occupational exposure to crystalline silica include silicosis, tuberculosis, chronic obstructive pulmonary disease (COPD) and lung cancer. Silicosis is a debilitating and often fatal lung disease of continuing worldwide importance whose cumulative estimates exceed one million cases in developing countries (WHO, 2007).

Silicosis is a progressive disease that belongs to a group of lung disorders called pneumoconiosis. Silicosis is marked by the formation of lumps (nodules) and fibrous scar tissue in the lungs. It is the oldest known occupational lung disease, and is caused by exposure to inhaled particles of silica, mostly from quartz in rocks, sand, and similar substances. People at high risk of developing silicosis include miners, foundry workers, stonecutters, potters and ceramics workers, sandblasters, tunnel workers, and rock drillers. Silicosis is mostly found in adults over 40 years. It has four forms: (a) Chronic - Chronic silicosis may take 15 or more years of exposure to develop. There is only mild impairment of lung functioning. Chronic silicosis may progress to more advanced forms; (b) Complicated - Patients with complicated silicosis have noticeable shortness of breath**,** weight loss, and extensive formation of fibrous tissue (fibrosis) in the lungs. These patients are at risk for developing tuberculosis (TB); (c) Accelerated - This form of silicosis appears after five to ten years of intense exposure. The symptoms are similar to those of complicated silicosis. Patients in this group often develop rheumatoid arthritis and other autoimmune disorders. (d) Acute - Acute silicosis develops within six months to two years of intense exposure to silica. The patient loses a great deal of weight and is constantly short of breath. These patients are at severe risk of TB (Haggerty, 2006).

1.2 Problem Statement

In Zambia, the silica exposure hazard and silicosis morbidity levels have been poorly studied among nearly half a million miners that have been employed in the copper mining industry. This is because control of silicosis, as implemented in Zambia, using the two methods of monitoring dust in mines and annual pneumoconiosis screening of miners has notable gaps (Hayumbu *et al*., 2008). For example, Zambian dust control regulations used over the past 50 years have only utilized total dust occupational exposure limits (reported as konimeter measured count data) that do not take account of the quantitative silica content in dust to which miners are exposed.

Experimental studies suggest that the toxic and fibrogenic potentials of silica dusts differ depending on the innate characteristics of the silica dust (Donaldson and Borm, 1998). This means that people exposed to different environments containing silica dust have different levels of developing silicosis. Miners are among the people at greater risk of developing silicosis hence this study was conducted to assess risk factors associated with developing silicosis among Konkola Copper Mine Workers in Zambia.

1.3 Justification

Results of this study compared the number of silicosis cases among different work environments (departments) of the mine. This will provide information to the company owner on who is at greater risk of developing silicosis, leading to policy change in relation to silica exposure controls. While the general risk factors of silicosis among mine workers are well elaborated and evaluated worldwide, no study has been conducted to establish the specific risk factors associated with silicosis with a comparison to two different copper mining types in Zambia (open pit and underground).

1.4 Objectives

1.4.1 General Objective

To determine the risk factors associated with developing silicosis among copper mine workers at Konkola Copper Mines of Zambia

1.4.2 Specific Objectives:

1. To determine miners at which work sites are at greater risk of developing silicosis at Konkola Copper Mine Plc

2. To determine miners at which business unit are more likely to develop silicosis at Konkola Copper Mine Plc
3. To assess the major risk factors associated with developing silicosis among copper mine workers at Konkola Copper Mine Plc

1.5 Hypothesis

Null Hypothesis (H_o): There is no association between risk factors for silicosis and development of silicosis among miners working at Konkola Copper mines.

1.6 Conceptual Framework

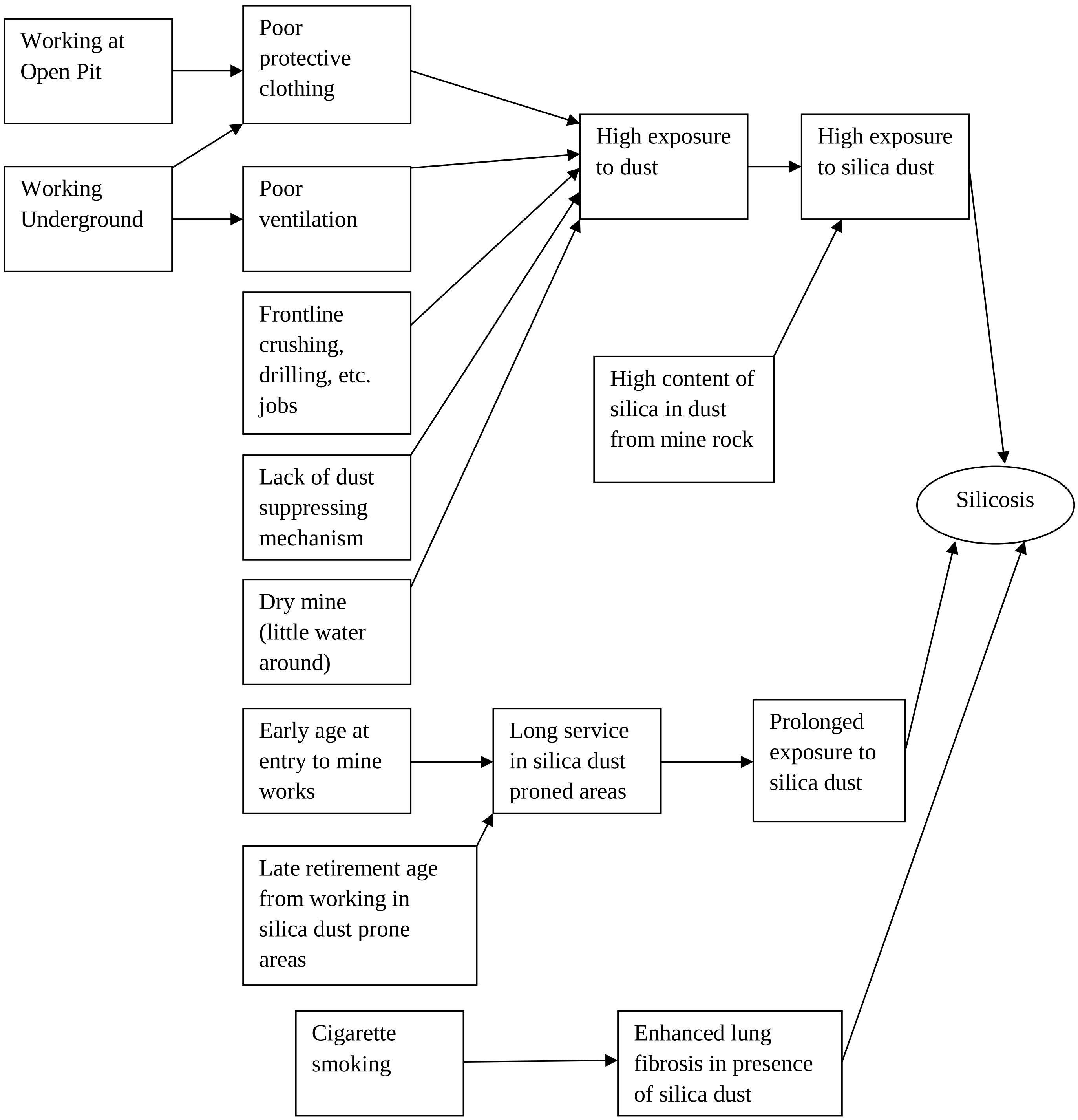

Figure 1: Conceptual framework of the causes of silicosis among copper mine workers Modified from (Sitembo, 2012)

CHAPTER 2: LITERATURE REVIEW AND RESEARCH OBJECTIVES

This chapter discusses the literature from the global, continental and Zambian perspective regarding the prevalence of risk factors associated with silicosis among copper mine workers. Risk factors associated with silicosis among underground and open pit copper mine workers are also discussed. Objectives (general and specific) of the study are also stated.

2.1 Global Prevalence of Silicosis

According to studies done in China between 1991 and 1995, more than 500 000 cases of silicosis were recorded, with around 6000 new cases and more than 24,000 deaths occurring each year, mostly among older workers (Chen *et al*., 1992, Hua *et al*., 1994, Chen *et al*., 2001, Leung *et al*., 2012) . In India, a prevalence of 55 per cent was found in one group of workers – many of them very young – engaged in the quarrying of shale sedimentary rock and subsequent work in small, poorly ventilated sheds (Ugbogu *et al*., 2009). In Brazil, in the state of Minas Gerais alone, more than 4500 workers have been 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 (97 percent), an activity that generates great quantities of dust in confined spaces, resulted in a prevalence of 26 percent of silicosis, with many cases of accelerated forms (Chiavegatto *et al*., 2010). The state of Rio de Janeiro banned sandblasting after a quarter of shipyard workers were found to have silicosis (WHO, 2000).

The global perspective of silicosis review that the disease is rampant among employees working in silica dust associated areas as reviewed from different studies conducted in different parts of the world. Numbers of cases escalate the most among the aged population.

2.2 Regional Prevalence of Silicosis

Results from an International Social Security Association survey (2003) show that the main challenge in Rwanda with regard to occupational diseases is silicosis. This has been confirmed by other studies done in South Africa among gold miners by (Churchyard *et al*., 1999, Nelson *et al*., 2010, Wilson, 2011), who found the prevalence of silicosis to be 19.9 percent with significant trends related to length of service, mean intensity of exposure and cumulative exposure; a disease burden increase in developing countries. The study found that the mean length of service to be 21.8 years (range 6.3 – 34.5) and the mean intensity of respirable dust exposure was 0.37mg/ m^3 (range 0 – 0.70). Results confirmed that a large burden of silicosis was among the older black workers in South Africa.

2.3 National Prevalence of Silicosis

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 (Mwansa, 2004). 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.

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 silicotics 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 (Mulenga *et al.,* 2005).

2.4 Risk Factors Associated with Silicosis

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 33.7 percent. 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 67.4 percent of the silicotics developed the disease on average 3.7 years after they had retired from tin mining. Cumulative exposure to silica ((mg/m^3-years) was established as a strong predictor of the risk of silicosis (Chen *et al*., 2001).

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 (Lee *et al*., 2001). In his commentary, (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.

2.4.1 Silicosis and Age

An evaluation conducted by (Bang *et al*., 2015) found that silicosis deaths are mostly among people aged between 15 and 44 years old.

2.4.2 Silicosis and length of Service

Studies conducted by Danpaiboon et al., (2015) found a statistic significant ($p<0.005$) correlation between silicosis and length of service (duration of work). They found that the increasing of work time every one year risked to silicosis 1.117 fold (Danpaiboon *et al*., 2015).

CHAPTER 3: METHODOLOGY

The purpose of this study was to assess the risk factors associated with developing silicosis among copper mine workers at Konkola Copper Mine, Zambia. This section focuses on research methods which were used and they include; study design, study site, study population, sample size determination, sampling methods, eligibility criteria, data collection procedures, ethical considerations and data management procedures.

3.1 Study Design

A retrospective case record review study design was used in this study. Konkola Copper Mine workers with silicosis were followed up retrospectively to assess whether length of service and other risk factors (potential confounders) are associated with developing silicosis.

3.2 Study Setting

Zambia is a land-locked country in sub-Saharan Africa that borders the Democratic Republic of Congo (DRC) to the north, Malawi and Mozambique to the east, Tanzania to the northeast, Namibia to the southwest, Zimbabwe and Botswana to the south, and Angola to the west. Zambia covers a total land area of 752,612 square kilometres. The country is divided into 10 provinces and 74 districts administratively. Two of the provinces are predominantly urban, namely Lusaka and Copperbelt. The remaining provinces are predominantly rural. Lusaka is the capital city, in the south-central part of the country. Zambia lies between eight and 18 degrees south latitude and between 20 and 35 degrees east longitude. It has a tropical climate and vegetation with three distinct seasons: the cool dry winter from May to August, a hot dry season during September and October, and a warm wet season from November to April (ZDHS, 2013-14).

The country has a mixed economy consisting of a rural agricultural sector and a modern urban sector that, geographically, follows the rail line. Currently, construction sector contributes 14 percent of the gross domestic product (GDP), agriculture contributes nine percent of the GDP, manufacturing sector and mining each contribute eight percent of the GDP (CSO, 2014).

Nchanga, Konkola, Nkana and Nampundwe business units were included in this study and these have been in existence for more than 15 years (long induction period of silicosis diseases criteria met). These mines are owned by Vedanta Resources PLC and operate under the company name called Konkola Copper Mine (KCM) in Zambia. The major product produced is copper with pyrite, cobalt, anode slimes and acid as by - products. The figure below shows the asset related operations of the company:

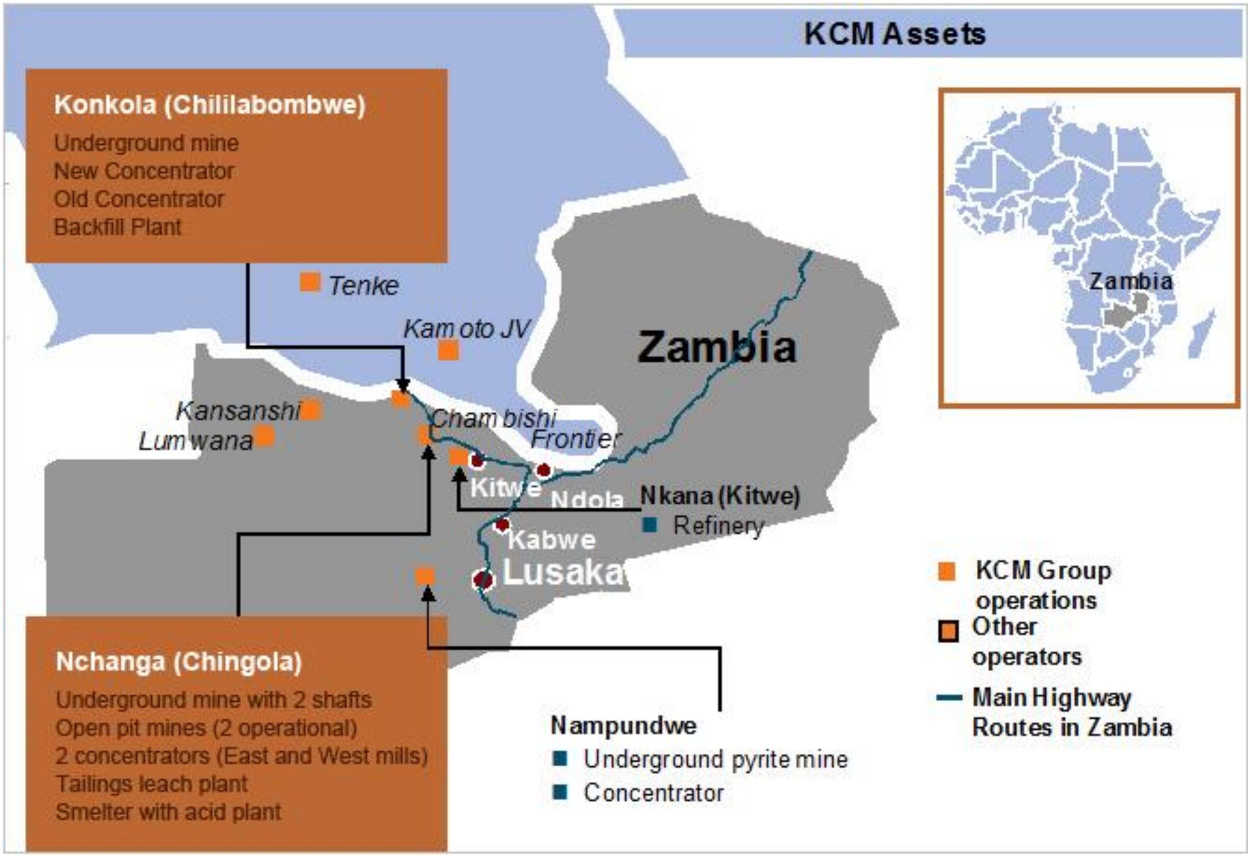

Figure 2: KCM Asset Map

3.3 Study Population

The study population included all Konkola Copper Mines workers diagnosed with silicosis from 2000 to 2015. These should have attended medical examination from OHMB on a yearly basis.

3.4 Sample Size Determination

The sample size was determined using the 95 percent confidence interval by the formula for comparison of proportion given as:

$$n = \left(\frac{r+1}{1}\right)\frac{(Z_1 + Z_2)^2 . P(1-P)}{(P_2 - P_1)^2}$$

Where

n = sample size

r = Ratio of controls to cases (2)

Z_1 = 1.96 for 95 percent confidence level

Z_2 = 0.84 for 80 percent power

P = Average of P_1 and P_2 (0.405)

P_1 = proportion exposed in control group (0.31)

P_2 = proportion exposed in case group (0.5):

where $P_2 = \frac{ORP_1}{P_1(OR-1)+1}$, where OR = 3.5

$P_2 - P_1$ = Minimum meaningful difference in proportions (0.19)

The assumptions of sample size determination were based on a similar study conducted in South Africa (Churchyard *et al*., 1999). 168 participants were included in the study (56 silicotics and 112 non-silicotics). For each silicotic, two non-silicotics were selected.

3.5 Sampling Methods

The researchers used a simple random sampling (probability sampling method), to select the participating copper mine employees from the study population. This procedure was used because it gives equal chance to every participant from the population to be selected. The participants were drawn from records of employees at KCM occupational health section; and who attended medical examinations at the OHMB in the period from 1st January, 2000 to 2015.

3.5.1 Sampling Scheme

Incidence density sampling scheme was used to select silicotics and non-silicotics. This means that the two groups were picked simultaneously to ensure that the odds ratio measured will be an estimate of rate ratio on the population base.

3.6 Eligibility Criteria

The eligibility criteria outlined below applied for both silicotics and non-silicotics.

3.6.1 Inclusion Criteria

The study included participants who had valid silicosis certificates and attended silicosis medical examinations annually.

3.6.2 Exclusion Criteria

Participants diagnosed with silicosis and had no valid certificates.

3.7 Selection of Participants

3.7.1 Definition of Silicotics

Silicotics included a sample of Konkola Copper Miners diagnosed (both clinically and radiological examination) with silicosis. These had valid medical certificates.

3.7.2 Definition of Non-silicotics

Non-silicotics included a sample of workers with similar characteristics as the silicotics, except they did not have the outcome of interest (clinically and radiological diagnosed silicosis).

3.8 Data Collection techniques and Tools

Data collection was done through the review of Konkola Copper Mine PLC mineworkers' files (records) at the corporate occupational health office. A data extraction checklist was used to collect data which was later entered directly into STATA for data cleaning (checking for completeness, coding, etc).

3.9 Ethical Consideration

This study received ethical approval from the University of Zambia Biomedical Research Ethics Committee. Permission to use the miners' records was sought from Konkola Copper Mine Plc.

Participants' data (name, silicosis status, etc) was de-identified using IDs. The results of the study will only be circulated to affected mine to uphold confidentiality and minimize risk to company.

3.10 Data Processing and Quality Control

Data from the data collection checklist was entered directly onto the computer in coded form using STATA. However, before proceeding with the analysis, raw data was checked for completeness and accuracy.

3.11 List of Variables

The table below shows the relationship between the dependent variable (the problem under study) and the independent variables (the factors supposed to be causing the problem).

Table 1: List of variables

VARIABLES	OPERATIONAL DEFINITION	INDICATOR	SCALE OF MEASUREMENT
Response Variable			
Silicosis	State of having confirmed silicosis	Total number of silicotics among participants in at that particular time	Dichotomous
Potential Confounders			
Length of service	Number of years worked in copper mines		Categorical
Demographic characteristics:			
▪ Age	Actual number of years of participant	Stated age	Continuous
▪ Gender	State of being male or female	Ratio males to female participants	Categorical

▪ Education Status	State level of education	Proportion of participants who attained either primary, secondary or tertiary education	Categorical
Mining related job section/category	State of working in any of the mine related job sections	Proportion of participants working in a particular job category	Categorical

3.12 Data Analysis

All analyses were performed using STATA software, version 12.0 SE (Stata Corporation, College Station, TX, USA). The distributions of continuous variables were not symmetric. To test for normality, the q-q plot was used to investigate normality graphically (results not shown). There was no evidence to suggest that data were normally distributed, hence in the descriptive statistics for continuous variables, we report median and inter-quartile range.

To avoid inflating the type-I error rate, loss of power, residual confounding, and bias, continuous predictor variables (age and length of service) were not categorised (Del Priore et al, 1997; Austin and Brunner, 2004; Royston et al, 2006). To test any differences in age and length of service, a non-parametric Wilcoxon rank sum (Mann–Whitney) test was used as opposed to a two sample T-test as these continuous variables were not symmetric.

Categorical variables such as sex, are first reported as numbers, percentages; Chi-squared test was used to ascertain association with development of silicosis.

An investigator led step wise multiple regression best model selection approach was used to select the best predictors of developing silicosis in the multiple logistic regression model as opposed to machine-led step-wise regression, which is not advisable (Hurvichand Tsai, 1990; Derksen and Keselman, 1992). Adding of variables in the model was influenced by literature review. Selection of predictor variables was performed by using the likelihood ratio test after estimation of the nested models by adding and eliminating variables one at a time.

3.13 Project Administration and Monitoring

Project administration and monitoring was done by the principal researcher. Assistance was sought from the supervisors.

3.14 Dissemination Plan

The results of the study will be summarized and sent to the mine where the study was conducted. A copy will be put in the UNZA Library and arrangements will be made to share the findings at Provincial and national epidemic preparedness meetings.

CHAPTER 4: RESULTS

4.1 Socio-demographic characteristics

The population of the study comprised only miners working at konkola copper mine. During the 15 year period, 168 miners were investigated for risk factors associated with developing silicosis. Table 4.1 shows the demographic characteristics of the participants. Age distribution ranged from 40 to 51 with a median of 46 years and 34 to 53 with a median of 48 among the silicotics and non-silicotics respectively. A total of 29 (17% of total) were females and 139 (83% of total) were males. Only one (3% of total) female was a silicotic and 28 (97% of total) were non-silicotics and 55(40% of total) males were silicotics and 85(60% of total) were non-silicotics. There was a significant difference between females and males who were silicotics ($P<0.001$). However, there was no significant difference in marital status and education status between the silicotics and non-silicotics ($P=0.081$ and 0.925 respectively).

4.2 Risk factors

The results of univariate analysis to assess for correlation between individual risk factors and development of silicosis are given in table 4.1. There was no significant difference in age between Konkola Copper miners in the silicotic and non-silicotic group (median age of 46 versus 48, $P=0.7463$) and no difference in the period they have worked in mine or length of service (median period of 11 versus 19 years, $P=0.1813$). There was a significant difference between the silicotics and non-silicotics in relation to the business unit and job category they belonged ($P<0.001$).

Table 4.1: Demographic Characteristics of Konkola Copper Mine workers

Factors	**Silicotics, n=56**	**Non-silicotics, n=112**	**P-Value**
Age (years)	46(40-51)	48(34-53)	0.7463}[a]
Length of service(years)	11(8-27)	19(8-31)	0.1813}[a]
Sex:			
Female	1(3%)	28(97%)	<0.001}[b]
Male	55(40%)	84(60%)	
Marital status:			
Married	52(36%)	93(64%)	0.081}[b]
Single	4(17%)	19(83%)	
Divorced	0	0	
Education Status:			
Primary	4(29%)	10(71%)	0.925}[b]
Secondary	29(34%)	57(66%)	
Tertiary	23(34%)	45(66%)	
Business Unit:			
Corporate	7(11%)	55(89%)	<0.001}[b]
Konkola	12(48%)	13(52%)	
Nchanga	35(47%)	39(53%)	
Nchanga smelter	1(33%)	2(67%)	
Nkana	1(25%)	3(75%)	
Job category:			
Technical services	29(63%)	17(37%)	<0.001}[b]

Support services	7(54%)	6(46%)
Production	8(12%)	61(88%)
Engineering services	12(30%)	28(70%)

[a]Two-sample Wilcoxon rank sum test (Mann –Whitney test). [b]Chi-square-Test.

4.3 Distribution of silicotics according to job category

The figure 3 below shows the distribution of silicotics according to job categories, while figure 4 shows the distribution of silicotics according to the production areas:

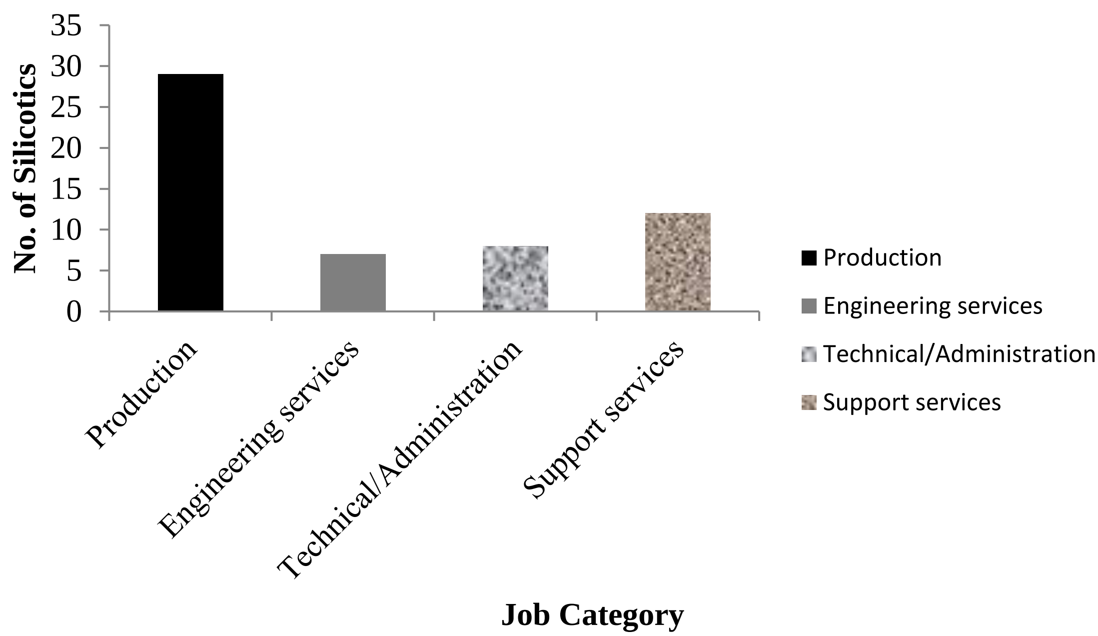

Figure 3: Distribution of silicotics

The figure above shows that a majority of silicotics belonged to the production unit and there was a significant difference between the job categories (P<0.001).

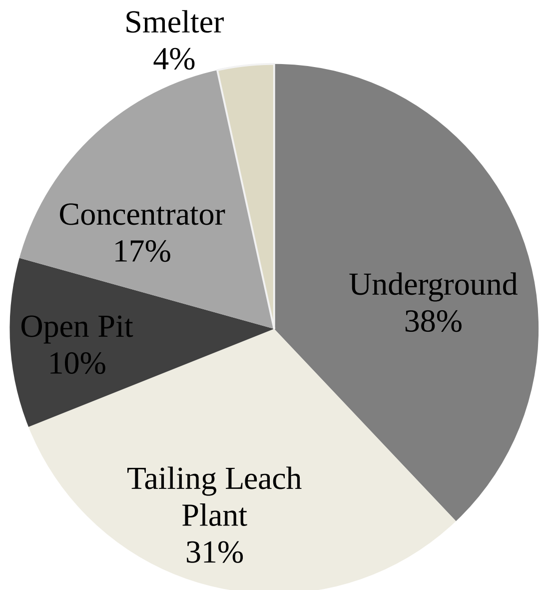

Figure 4: Distribution of silicotics according to production areas

As shown in figure 4 above, within the production unit, most silicotics where from underground section and the least were from smelter.

4.4 Risk Factors Associated with Silicosis

Table 4.2 below shows how each predictor variable related with the outcome variable (bivariate analysis) and how all the predictor variables interacted with the outcome variable (multivariate analysis). As a result of statistical analysis, the investigators determined that the factors considered best predictors of silicosis from this study were length of service or the period worked in the mining industry, business unit and job category to which the copper miners belonged to (P-values 0.033, 0.001 and <0.001 respectively) as shown in table 4.3.

Table 4.2: Bi-variate and multivariate analysis of predictor variables

Variable	**Unadjusted OR(95% CI)**	**P-value**	**Adjusted OR(95% CI)**	**P-value**
Sex:				
Female	1		1	
Male	18.33(2.42-138.68)	0.05	*16.83(1.93-146.87)	0.011
Age		0.561	1.02(0.94-1.12)	0.622
	1.01(0.98-1.05)			
Marital status:				
Married			1	
Single	1	0.090	0.16(0.03-0.02)	0.022
	0.38(0.12-1.67)			
Education status:				
Primary			1	
Secondary	1		1.50(0.34-6.71)	
Tertiary	1.27(0.37-4.41)	0.704	1.39(0.28-6.80)	0.595
	1.28(0.36-4.52)	0.704		0.686
Length of service			0.93(0.86-0.90)	
	0.99(0.96-1.10)	0.347		0.041
Business unit:				
Corporate			1	
Konkola	1		2.97(0.71-12.35)	
Nchanga	7.25(2.39-22.03)	<0.001	4.68(1.51-14.48)	0.135
Nchanga smelter	7.05(2.84-17.51)	<0.001	3.54(0.19-67.21)	0.007
Nkana	3.93(0.31-49.12)	0.288	1.12(0.07-19.14)	0.399
	2.62(0.23-28.75)	0.431		0.935
Job category:				
Technical/Admin			1	
Support services	1		0.48(0.12-1.89)	
Production	0.68(0.20-2.37)	0.549	0.71(0.02-0.23)	0.295
Engineering	0.77(0.03-0.20)	<0.001	0.19(0.06-0.58)	<0.001
	0.25(0.10-0.62)	0.003		0.003

*Males were 16.8 times more likely to develop silicosis compared to females and this was statistically significant (95% CI 1.93-146.87, P=0.011).

Table 4.3: Adjusted Predictors of Silicosis from the best model that fits the data well

Variable	**OR(95% CI)**	**P-value**
Length of service	*1.95(1.92-1.99)	0.033
Business unit		
Corporate	1	
Konkola	5.42(1.48-19.84)	0.011
Nchanga	5.96(2.11-16.79)	0.001
Nchanga smelter	4.23(0.29-61.21)	0.290
Nkana	1.15(0.08-16.48)	0.920
Job category:		
Technical/Admin	1	
Support services	1.65(0.18-2.41)	0.522
Production	1.09(1.03-1.26)	<0.001
Engineering	1.21(1.08-1.58)	0.002

*For each year increase in length of service, konkola copper miners are 1.95 times more likely to develop silicosis.

CHAPTER 5: DISCUSSION

The findings of this study showed that the risk factors associated with silicosis were length of service, the business unit and job category to which mineworkers belonged to. Length of service was defined as the number of years one has been working in the mining sector. The longer one works, the more they are exposed to crystalline silica dust and hence increasing the chances of developing silicosis. Length of service was statistically significant in relation to mineworkers developing silicosis. This is consistent with the study done by (Churchyard *et al*., 1999), who found that for each year increase working in the mining industry, miners were 11 percent more likely to develop silicosis adjusting for other factors such as cumulative exposure to respirable dust; and for every five years increase in working in the mining sector, miners were 1.69 times more likely to develop silicosis (ibid).

Konkola Copper Mine has six business units and these include, Corporate, Nchanga, Konkola, Nchanga Smelter, Nkana and Nampundwe. The investigators found that mineworkers at Nchanga and Konkola were more likely to develop silicosis compared to those working in other business units and this was statistically significant. Nchanga and Konkola house many business operations of this company (where many mining activities take place from). Hence they have a large number of workforce exposed to crystalline silica dust compared to the other business units. Nampundwe business unit is mainly associated with pyrite mining than copper mining. No silicotic was present in Nampundwe during the study period. This may suggest that pyrite mining is less likely to cause silicosis compared to copper mining. However, there is need for further study on this.

Our aim was to determine the risk factors associated with developing silicosis among Konkola Copper Mine workers. We also evaluated which work site and business unit is more associated with developing silicosis. We found that the average age range for one to develop silicosis was between 46 and 48 which is close to 44 years and 48 which Bang *et al*., (2015) and Chen *et al*., (2001) respectively found in their studies.

Furthermore, we found that males are more likely to develop silicosis compared to female counterparts and this was statistically significant. However, this would also be attributed to the nature of the population under study. There are more males employed in the mining sector than females. Varkey *et al*., (2015) attested to the fact that silicosis mainly affects male workers, reflecting the occupations at risk. Selection of occupations is highly influenced by societal norms regarding gender roles. Manual work is more associated to males than females.

Miners working in the production areas were highly susceptible to developing silicosis compared to those working in other areas. Within the production area, miners working underground represented 38% of the total silicotics and were more likely to develop silicosis compared to those working at open pit and other areas. This is consistent with other studies which showed that miners working as lashers (production area) are more likely to develop silicosis (Sitembo, 2012).

Mineworkers belonging to Konkola and Nchanga business unit were more likely to develop silicosis compared to those working in other units respectively. A study conducted by Sitembo (2012), equally showed that the percentage of silicotics at Nchanga is higher than those at Konkola. Unlike other business units, Nchanga has most mining operations, for instance, smelting, underground, tailing leach plant, to mention but a few.

As a result of the statistical analysis, the researchers determined that the factors considered best predictors of silicosis were length of service, business unit and the job category to which the miners belonged to (P-values 0.033, 0.001, <0.001 respectively). Length of service was defined as the period one has worked in the mining industry. Mannetje*et al* (2002) established a similar predictive association between duration of exposure to crystalline silica and eventual development of silicosis which is also in consistent with Varkey et al., (2015) also confirmed that the risk of developing silicosis increased as the duration of exposure increased. The longer one works in the mining industry, the more they are exposed to crystalline silica dust hence increasing the chances of developing silicosis.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Silicosis was well associated with long years of service in the mining industry, the business unit and the job category to which the participants belonged to besides other hypothesized factors. Males are more likely to develop silicosis compared to females as most mining operations are associated to male counterparts as opposed to females. Long years of service usually influence other factors such as cumulative exposure to crystalline silica dust. Different business units and job categories have varying operations and hence differences to exposure levels. The findings are consistent with other studies which have tried to look at risk factors associated with developing silicosis.

6.2 Recommendation

There is need for more prospective studies to investigate why other departments are at greater risk of developing silicosis. Such findings indicate the importance of educating at-risk workers and their employers regarding the dangers of exposure to respirable crystalline silica in the workplace. Comprehensive silicosis prevention programs include substituting less hazardous noncrystalline silica alternatives when possible, implementing engineering controls local exhaust ventilation, not using compressed air for cleaning surfaces, using water sprays to control airborne dust, and using surface wetting to prevent dust from becoming airborne when cutting, drilling, grinding, etc.), administrative and work practice controls, personal respiratory protective equipment, medical monitoring of exposed workers, and worker training. Because of the serious health and socioeconomic consequences of silicosis, new operations and tasks placing workers at risk for silicosis, and the continuing occurrence of silicosis deaths among young workers, effective primary prevention through elimination of exposure to respirable crystalline silica is critical.

At the same time, because of the sometimes long latency of silicosis, with cases diagnosed years after exposure and often in retirement, ongoing silicosis surveillance is needed to track its prevalence in all risk areas. There is need to rotate employees across different job categories and business units.

6.3 Limitations

Results of this study may not be generalized to other mines as it was a case review study. However, they provide a baseline for further research and measures which can be applied in the affected mining industry. We started off with a case control study but because of lack of information, we ended up doing a case review which has also provided much needed knowledge on the risk factors associated with silicosis. Data on smoking status was not available on records, as a result the investigators did not measure this variable.

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8.0 APPENDICES

APPENDIX I - DATA EXTRACTION CHECKLIST

Data Collection Instrument

Site: Konkola Copper Mines Plc

Data Extractor (1) :Principal Investigator 2) Research Assistant

Study ID #: _____________Date/Month/Year/ of Enrolment in the study:_________________

Indicator	**Answer**	**Instruction**	**Column for Coding**
1. Age of participant	Indicate in Numbers _____		
2. Sex	1. Male 2. Female	Tick the correct range	
3. Marital status	1. Single 2. Married 3. Divorced 4. Widowed	Tick the correct range	

	5. Other (specify) ______________________		
4. Education status	1. No education 2. Primary education 3. Secondary education 4. Tertiary education	Tick the correct range	
5. Name of the mine	1. Nchanga Copper Mine 2. Konkola Copper Mine 3. Nkana Copper Mine 4. Mufulira Copper Mine 5. Chambishi Copper Mine		
6. Length of service	1. 0 – 15.0 2. 15.1 – 20.0 3. 20.1 – 25.0 4. 25.1 – 30.0 5. 30.0+	Tick the correct range	

11. Job category: a. underground – operations b. underground – productions c. open pit – operations d. open pit – production e. concentrator f. smelter g. acid plant h. Leach plant (TLP)	 1. ……………… 2. ……………… 3. ……………… 4. ……………… 5. ……………… 6. ……………… 7. ……………… 8. ………………	Indicate number of years in each space provided	
14. Silicosis status	1. silicosis present 2. silicosis absent 3. unknown		
15. If silicosis present, state date of certification	…………………………………	Indicate day, month and year	