PREVALENCE OF SILICOSIS AMONG THE IN-SERVICE ZAMBIAN COPPER MINERS.

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Declaration: The work in this research report is my own work. It has not been used for other degrees or diplomas in the past.

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DECLARATION

"I declare that the research report, which I hereby submit for the degree masters in Public Health at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at another university."

DEDICATION

This research report is dedicated to the Zambian miner who gets closer to silicosis any time he breathes.

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I owe deep gratitude to so many people for their help with the research project that more than a page would be required simply to list them all.

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ABRIVIATIONS AND DEFINITIONATIONS OF TERMS

AAFB	Acid Alcohol Fast Bacilli
ILO	International Labour Organisation
ppcc	particles per cubic centimetre
RCM	Roan Consolidated Copper Mine
NCCM	Nchanga Consolidated Copper Mine
TF	Temporally File
ZCCM	Zambia Consolidated Copper Mines

DEFINITIONS OF TERMS

Initial: refers to one who comes to be examined for the first time at the bureau.

Periodical: refers to a person who comes for examination after initial examination and is still in employment.

Village benefit: refers to one who has retired and is coming for annual medical examination.

Scheduled area: refers to a place in the mining area affected by free silica.

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ABSTRACT: Prevalence of silicosis among the in-service Zambian copper miners.

Objectives To determine the prevalence of silicosis among the in-service Zambian copper miners and identify which areas of operations and mines are mostly affected by silicosis.

Design: Cross-sectional point prevalence.

Setting: Medical records of miners from Occupational Health Research Bureau Kitwe-Zambia.

Subjects and methods: 1122 miners who had worked for more than ten years in the scheduled area were randomly selected for the study from the Bureau records. Data was analyzed in Stata for descriptive summaries associations of silicosis with and independent variables.

Results: The prevalence of silicosis was 8 per 1000 miners with Chibuluma mine recording the highest prevalence2.2%(1 out of 27) and with the dust producing areas recording the highest prevalence 6 out of the 9 cases (66.6%). All the cases were from underground miners and were above 40 years of age. Silicosis was strongly associated with years of service, age of the miners and area of operations ($p < 0.05$). Association was shown between silicosis and dust particles in chi-square test of association, but when put in binary logistic regression there was no association (p 0.7) probably because dust particle levels was used instead of respirable free silica and the different mines contain different silica levels in their virgin rocks. If respirable free silica levels were used the association could have been there. This can be confirmed by the high prevalence in dust producing areas.

Conclusion: The prevalence of silicosis among the in-service Zambia copper mines is low compared to other mining countries. There is a possibility of high prevalence among the retirees since all of them are more than 40years of age and there is strong association between years of service age, and areas of operation with silicosis.

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Silicosis is well-known fibrotic lung disease and is the most common pneumoconiosis" worldwide. Despite all efforts to prevent it, this ancient disease still affects thousands of miners and millions of other workers engaged in hazardous dust occupations in many countries. With its potential to cause physical disability silicosis continues to be one of the most important health problems in the world.[1, 2]

Silicosis is caused by exposure to dust containing free silica and usually develops gradually over a period of at least ten years. However the extent of disease depends on a number of factors including the nature of dust, its concentration and duration of exposure as well as individual susceptibility.[1, 3,4] The well-known Zambian copper belt is one of the great metallogenic provinces in the world. Its' eight operating mines produced in 1974 above 750000 metric tones of copper, to place the country in the fourth position on the world producing table.[3, 4, 5]

Zambia situated in Southern Africa, covers an area of 752610 km^2. Despite the large size, Zambia has about 10.3 million people of whom 65% live in the urban areas and 45% in rural areas.[3, 6]

The miners on the Zambian copper mines are full time workers. Once one is employed he is likely to be there until he retires unless something happens.[3]

Miners in copper mines are exposed to a lot of dust. In Nchanga Open Pit, for example, nearly ten million tones of 'overburden' had to be drilled, blasted, stripped, transported and dumped before reaching bearing rocks. At the mine plant the subsequent crushing of rocks containing say 3% copper oxide or copper sulphide, produces further dust. Waste dumps and tailing too, contributes to dust polluted air.[3, 10]

The bureau, a government institution is tasked by the act to examine miners, would- be miners, and ex-miners. It is staffed with full time medical doctors and it is equipped to carry out all chest and auxiliary diagnostic procedures.[6] The Pneumoconiosis act demands every person must hold a valid certificate of fitness issued by the Bureau before he is permitted to work in the occupation with a pneumoconiosis hazard. The issue of certificate for engagement (initial certificate) is dependent upon the prospective employee passing a clinical examination and radiological examination of his chest on a full size film. These examinations are repeated annually in order to obtain the required periodical certificate. After leaving employment those who have worked for more than five years are permitted to undergo annual examination (village benefit examination).[7]

Dust sampling in the mines is a joint responsibility of the Government mine department and the Ventilation departments of each mine. The mines departments use thermal precipitators, and the ventilation department of the mines employs Rand Konometer for "snap sampling." The agreed minimum permissive limit in the 50's of dust particles between o.4 microns and 7.0

microns was 350 per cc. The free silica content of this fine atmospheric is determined the x-ray diffraction method using the Geiger counter technique, and the average silica content of the atmospheric dust in the above range in the six mines varies from 19% to 43%. [6]The rocks in different mines contain different levels of crystalline silica.

The mines have changed hand since inception in the early 1900's. In the 70's the government nationalized the mines until the early 1990's when they were privatized.[3] The new owners demanded for down sizing of the work force, which led to redundancies in the mining industry.

1.2. LITERATURE REVIEW

1.2.1. EPIDEMIOLOGY

Silicosis refers to a spectrum of pulmonary disease attributed to inhalation of various forms of silicon dioxide. Silicon dioxide is the most abundant mineral on earth. It is formed from elements of silicon and oxygen under condition of increased heat and pressure. Silica exists in crystalline and amorphous forms. Examples of crystalline silica are quartz, cristobalite, and tridymite. The most common is quartz a typical component of the rock. Amorphous silica is non-crystalline and has relatively non-toxic pulmonary properties.[5]

There are several types of silicosis, viz, classic, accelerated and acute, which are distinguished by the degree of air borne concentration and length of exposure to the crystalline silica to induce them and replace lung tissue with fibrotic nodules.[5]

The link between silica and lung fibrosis was described more than 100 years ago by the German pathologist Friedrich von Zenker who coined the term pneumoconiosis or 'lung dust' to describe silicosis or other lung disease.[8] The first use of the word silicosis is attributed to Visconti (1870). [9]

Crystalline silica is referred as "free silica", when combined with other minerals it is called combined. It is the free silica, which is more dangerous to the miners. The presentation of and severity of silicosis are influenced by multiple factors, principally the concentration of free silica in the work place, the duration of exposure and physical characterization and innate fibrogenic properties of repairable dust. Genetic factors, cigarette smoking and additional complicating pulmonary diseases are among the host factors that interact with environment in complex and poorly understood fashion resulting in spectrum of disease presentation.[4]

Diagnosis of silicosis is based on medical and occupational history, clinical examination and radiology. In establishing the worker's occupational history, it is important to ascertain as accurately as possible the duration and the degree of exposure to dust, the probable proportion of quartz or other forms of crystalline silica in the dust. The clinical examination is helpful in detecting other diseases other than silicosis, because of the latter's scanty symptomatology.

The radiographic examination must be carried out using a suitable technique, since otherwise it can be misleading, i.e. silicosis may be diagnosed when it is not there or may be overlooked when it does exist.
There are more than 40 diseases, which may give an x-ray, picture similar to silicosis. The commonest ones are tuberculosis, endogenous haemosiderosis, and Boeck's sarcoidosis, some form of pulmonary metastasis of carcinoma, idiopathic interstitial pulmonary fibrosis, and some collagen diseases.[11]

Silicosis is associated with increased susceptibility to mycobacterium infection especially tuberculosis. Two recent studies amongst Danish foundry workers, (and the other in South African gold mines have shown that workers with chronic silicosis have three-fold increase in incidence of pulmonary tuberculosis when compared with a group without silicosis matched for exposure and age.[17]

Silicosis dust exposure can also lead to airflow obstruction in the absence of radiological signs of silicosis and the association between cumulative silica dust exposure and airflow obstruction can be interdependent of silicosis. It is therefore likely that certain properties of silica dust are capable of causing Chronic Obstructive Pulmonary Disease.[12]

In 1987, a working group of International Agency for Research on Cancer (IARC) reviewed the relevant scientific literature and concluded that there was "sufficient" evidence for carcinogenicity of silica in experimental animals and "limited" evidence on human. But the study of Hessel et al demonstrated a lack of association between lung cancer and exposure to crystalline silica in human studies.[13]

A recent study (Corbeltt et al, 200) of effect of infection on silicosis and tuberculosis incidence in black South African gold miners, found that HIV infection increased the incidence of tuberculosis by five times and silicosis increased the incidence of tuberculosis by three times. The presence of both HIV and silicosis increased the incidence of tuberculosis fifteen times, so called multiplicative interaction.[17]

1.2.2. PREVALENCE

Prevalence is the proportion of any given population with silicosis at any time of the survey. It gives the indication of the burden of disease in the population [whether in service or out of service] and the burden of likely complications e.g. silicosis related tuberculosis that might be expected. It can also be used to assess exposure response relationships.[17]

Zambian copper miners are normally employed on permanent basis. Once employed the miner can work for 32 years or when he reaches 55 years old. The exceptions are those brought in by the contractors or when one is dismissed. This means that, one is likely to be employment for longer period a situation that can help in prevalence studies unlike in old South Africa gold mines where employment was not stable for blacks.[8, 17]

There was a reduction in incidences of silicosis in Zambia from the early 1950s up to the late 50s', which coincided with improvement of ventilation and dust suppression.

This had been a triumph for ventilation engineers, and the importance of there achievement was emphasized by the fact that there was no case of silicosis in any employee whose dust exposure in Northern Rhodesia copper mines were subsequent to 1950.[7]

The figurers on silicosis in Zambian copper mines have been in most cases crude figures from annual reports. Between 1950 and 1959, out of a total of 313,651 copper belt miners examined by the bureau, at Kitwe, 810 were diagnosed with silicosis. In the same period 47 miners were diagnosed with silico-tuberculosis[6]. In 1993, Mufurila division alone had 73 cases out of the total number that attended the medical examination. Remarkably, there is very little information available on prevalence of silicosis in both in service and ex-miners in Zambia copper mines.[7]

In South Africa gold mines Cowie and Van Schalkwyk provided evidence that prevalence of silicosis in black mine workers working in gold mines of the Orange Free State is not less 134 per 10,000.[13] Murry et al. analyzed statutory autopsy data over 16000 black gold miners who had died of non-natural causes while in service of between 1975 and 1991. Though it was done in an average young group, an average overall of 9.7% of histological silicosis was found.

Steen et al. undertook a prevalence survey of occupational lung disease amongst random sample of former gold miners in Kweneng district in

Botswana. The researchers demonstrated a significant burden of pneumoconiosis and found an overall prevalence of pneumoconiosis [> or = 1/0 on international labour organization (ILO) scale of 25.7% in the random arm of the study.[15]

Trapidol et al. carried out a prevalence of occupational lung disease in a random sample of former mine workers in the Libonde district of the Eastern Cape Province and found an overall prevalence of 22% to 36% depending on the readers.[14]

In other parts of the world silicosis prevalence is still high especially in developing countries for example in Colombia the government estimates that 1.8 million workers in the country are at risk of developing the disease.[2]

1.2.3. PREVENTIVE MEASURES

Prevention is very important in the case of silicosis because ones the disease starts there is no cure.

I. Many techniques and wide range of equipment have been devised to suppress dust at working places and keep dust concentrations below recommended maximum permissible levels.

II. Medical prevention consists of medical examination and posterior/anterior x-ray pictures taken at various intervals according to magnitude of the risk.

III. The length of time during which miners work in hazardous dust should be restricted.

IV. Use of dust respirators that have been much improved as regards to efficiency and comfort may be used as temporal measure.

V. Dust measurements to know whether permissible levels are being exceeded

CHAPTER 2: OBJECTIVES OF STUDY

2.1. RESEARCH QUESTION:

What is the prevalence of silicosis among the in-service Zambian copper miners?

2.2. OVERALL OBJECTIVE:

The overall objective is to determine the prevalence of silicosis among in-service Zambian copper miners.

2.3. SPECIFIC OBJECTIVES OF STUDY:

1. To determine the current level of silicosis and silico-tuberculosis, in the Zambian copper mines.

2.To determine the type of occupation mostly affected by silicosis.

3.To determine which of the six mines is mostly affected by silicosis.

4. To determine the latent period for silicosis in Zambian copper miners.

5. To relate silica levels with silicosis.

2.4. RELEVANCE OF THE STUDY:

No similar study has been done before in Zambian copper mines since the1950s'. Silicosis and pulmonary tuberculosis are two compassable occupational diseases in the Zambian copper mines.[17] The compensation given to the affected miners cannot be compared to the health they lose when they develop silicosis. The best one can do is to prevent or minimize the chances of one getting in contact with free silica. Study of this nature will be able to tell whether the dust control measures are working by knowing the prevalence.

The study will provide information, which will be useful to both the Bureau and the mining companies in protecting miners' health.

CHAPTER 3: METHODOLOGY

3.2. TYPE OF DESIGN AND SETTING:

The study design was a point prevalence cross- sectional study.

This study was conducted in December 2003 to January 2004 from medical records of copper miners from Occupational Health Research Bureau in Kitwe Zambia.

3.3. SOURCE POPULATION:

The source population was taken from Zambian copper miners' records in from the Bureau in Kitwe, and from these, a target population of copper miners attending annual medical examination at Bureau in 2002, was chosen.

Out of 46906 in service miners who were examined at the bureau in 2002, 18824 were identified as periodicals that had worked for 10 years and more. Researches have shown that one is more likely to develop silicosis after working for ten years and more.[3,4] The six mines were taken as strata, total of 18824, Nchanga had 7,595, Nkana 3,953, Mufulira had 3237 periodicals Konkola had 2804, Chibuluma 470, and Chambishi 752 periodicals who have worked for ten years and more. It was from this study population that the sample of 1137 was selected. It means that Nchanga with the biggest number of miners had a biggest sample and Chibuluma with the smallest number had smallest sample. In short a stratified proportional sampling was done at first and then a systemic sampling was done to get the required number from each mine after calculating the interval, see sampling technique.

Bureau series-numbers given to the miners at the time of first engagement, were used for random sampling. Radiographic reports were taken from the file records. The x-ray films have already been read by the panel of doctors who at times included the pulmologist, the occupational health physician, radiologist, pathologist and general medical doctors. The minimum number of doctors to form a quorum is 5 when reading x-ray films. Results are recorded in the miners' personal files .It was from these files records were taken.

The records contain the demographic information like age at the time of recruitment, service years, sex, name of the mine, job category, history of smoking area of operation, and occupational history. The information collected from the personal files of sampled population was entered in the data sheet.

The miners were assigned with different identity numbers on the data sheet different from mine numbers for the sake of confidentiality. The free silica levels of the mining divisions and individual areas of operations could not be taken because the x-ray diffraction which uses Geiger counter technique to record free silica, is out of order and we tried to avoid converting the dusting particles to estimate the free silica content because of different levels of silica in different mine rocks to avoid introducing a bias. So instead dust particles per cubic centimeters (ppcc) were taken from the mine safety records and entered in the data sheets.

3.4. INCLUSION CRITERIA.

1.All those who have been working in the scheduled copper mine areas or had worked in the scheduled copper mine area up to 2002 and still in employment.

3.5. EXCLUSION CRITERIA

1. All those who have worked in other mines other than Zambia copper mines before, were excluded.

2.All European mine workers as nearly all of them have worked in the mines before coming to Zambia.

It is important here to mention here that any body whose chest x-ray shows any sign of increased bronchial vascular markings and let alone nodulations is disqualified at initial examination.

3.All ex-miners and initials (those who are being examined for the first time) were excluded.

4. Those who have worked for less than 10 years in copper mining industries were also excluded.

3.6. SAMPLE SIZE OF STUDY:

According to the Occupational and Health Research Bureau of Zambia, 46906 miners were eligible for medical examination. In 1954, the prevalence rate of silicosis for Zambia was 4 per thousand miners. The selection criterion was periodicals that attended the annual medical examination at the Occupational and Health Research Bureau in 2002. All those who come to the bureau for medical examination work in scheduled areas.

The initial sample size of study is denoted by n_0, and is determined using the formula shown below in Equation (1):

$$n_0 = \frac{Z^2_{1-\frac{\alpha}{2}} \times P(1-P)}{d^2} \quad \text{------ Equation (1)}$$

In Equation (1), the following values of α, P, and d will be used:

α = 0.05 = level of significance

$Z_{1-\frac{\alpha}{2}} = Z_{1-\frac{0.05}{2}} = Z_{1-0.025} = Z_{0.975}$ = 1.96 = value of standard normal random variable at the α = 0.05 level of significance

P = 0.004 (the prevalence of silicosis per thousand miners)

1- P = 0.996

d is the margin of error = 0.004

Equation (1) gives an initial sample size of 956 miners.

The final sample size of study is denoted by n, and is given by

The formula shown below in Equation (2):

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \quad \text{------ Equation (2)}$$

In Equation (2),

n_0 is the initial sample size of study = 956

N is the total population size of study = 18824

Equation (2) gives a final sample size of n = 909 miners.

Making a 20% adjustment for dropouts, the actual sample size of study becomes equal to $\frac{909}{1-0.20}$ = 1137.

3.7. SAMPLING TECHNIQUE:

A systematic random sample of 1137 miners were selected for the study based on records belonging to the Occupational and Health Research Bureau of Zambia. The sampling interval was equal to $\frac{N}{n}=\frac{18824}{1137}$ = 16. The first eligible miner will be selected at random. From then on, every 16th miner on the list was selected for the study.

3.8. LIST OF VARIABLES OF STUDY:

The variables of study are several socio-economic, demographic and health-related variables such as age, duration of service, job description, silicosis, silico- tuberculosis, pulmonary tuberculosis, overall health condition, etc.

3.9. STATISTICAL METHODS OF DATA ANALYSIS:

Primary data was entered in Epi-data. Analysis was in STATA version 8 and SPSS version11[18, 19]. Data for a total of 1122 miners was used to analyse the silicosis and silico-tuberculosis dependent variables. A descriptive analysis of the records with the help of frequency tables and bar charts for all the variables of interest was performed. Pearson's chi-square tests of association between selected variables of interest were conducted to first determine which of the twelve possible explanatory variables are significantly associated with silicosis prior to binary logistic regression analysis. In addition Prevalence rates of silicosis and silico-tuberculosis were obtained.

Following Pearson's chi-square test of association, a binary logistic regression analysis was used to estimate the effect of covariates on silicosis since the dependent variable was dichotomous. Variables that were found to be significantly associated with silicosis after performing a chi-square test were included into the final logistic regression model.

If P is the probability of a miner acquiring silicosis, the

$$P(Y = 1) \frac{1}{1+e^{\beta x}}$$

is logistic function, where β is a vector of unknown coefficient, Y is the dependent variable (acquiring silicosis) and X is vector of covariates that are associated with acquiring silicosis.

The general logistic regression model is of the form;

$$\text{Loge}\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots + \beta_K X_K$$

This expresses the log odds of acquiring silicosis as a linear function of the covariates.

3.10. QUALITY ASSUARANCE

X ray films of those who were found with silicosis were counter checked to make sure that I was dealing with the same person and laboratory results of those who were found with tuberculosis were also counter checked to make sure the laboratory record had the same information.

A team of experienced and qualified doctors of which five form the quorum had read the x-rays and had agreed on the findings and reported according to

(0\1 ILO classification). Adequate training was given to officers who were getting the data from files. Data was entered in double entry system for accuracy and all case report forms was reviewed daily for completeness and accuracy.

In case that the study subject was examined and died with in the year the post mortem results was supposed to be asked as well. In case of silico-tuberculosis sputum results for AAFB, was checked.

3.11. ETHICAL CONSIDERATIONS

The protocol was submitted to Academic Programme Committee of the University of Pretoria School of Health Systems and Public Health for approval. Faculty of Health Sciences Research Ethics Committee of the University of Pretoria further reviewed the protocol. The Executive Director of Occupational Health and Research Bureau in Kitwe gave a letter for permission to use miners' records. See appendix 1 and 2. On confidentiality every effort was done to ensure that only numbers were used and not names of the study subjects. The numbers that were used were those that were assigned to data sheets and not the mine series numbers.

3.12 Data processing.

All data were coded using Epi-data for subsequent statistical analysis using Stata and SPSS. Data was crossed checked to detect and correct coding errors. The variables were summarized for statistical purpose as follows:

3.12 .1 Dependent variables.

The dependent variables in this research were silicosis and silico-tuberculosis and in the final stage pulmonary tuberberculosis was used since the study was looking at the prevalence of silico-tuberculosis as well.

Silicosis {1 if one has silicosis (9)

{2 if other wise (1113)

Silico-Tb {1 if has silico-Tb (1)

{2 if otherwise (1122)

Tb. {1 if has tuberculosis (18)

{2 other wise (1104)

3.12.2 Independent variables

The independent variables used in the study if they were associated with silicosis were; years of service, age of the miner at the time of the study, the mine the mine was working in, sex of the mine whether the miner smokes, the type of job, the area of operation and the annual average dust particles in the area of operation.

a) Service {1 if service years > 15 years (863)

{2 if service years < = 15 years (259)

b) Sex {1 if male (1113)

c) Smoking {1 if smokes (3)

{2 if other wise (1119)

d) Profession {1 if general worker (582)

{2 if professional (419)

{3 if supervisor of general workers (121)

e) Area of operation {1 if working under ground (763)

{2 both surface and underground (10)

{3 works on the surface (350)

f) Job categories {1 if drilling (147)

{2 if crushing (111)

{3 if lashing (106)

{4 if in any other apart from above categories (758)

g) Mine {1if works Nchanga (452)

{2 if works in Nkana (235)

{3 if works in Mufulira (193)

{4 if works in Konkola (169)

{5 if works in Chambishi (44)

{6 if works in Chibuluma (27)

h) Stage {1 if stage 1 (9)

{2 if stage 2 (0)

{3 if stage 3 (0)

3.13. LIMITATIONS CONFOUDERS AND BIASES.

The silica levels were measured in form of dust particles instead of resipirable free- silica this made it difficult to relate silica levels with silicosis accurately.

The results cannot be extrapolated to other miners like those in foundry and quarries because the copper mining industry has a well-established dust-control system. Age was dealt with at design stage by restricting the study only to those who had worked for more than 10 years and above, this means all the mines had workers who were 30 years of age and above. Smoking and gender was supposed to be dealt with at analysis stage using logistic regression analysis but they were very few of them and none of them had silicosis making the procedure unnecessary.

CHAPTER 4: RESULTS

Of the 1137 files in the original random sample, 7 were reported as missing and 8 were temporally files (TF) making a total of 15 (1.3%) unavailable for entry leaving 1122(98.6) as final available sample size. So even the calculation and analysis is based on 1122 miners examined in 2002.

4.1: DISCRITIVE STATISTICS.

4.1.1: Age distribution of miners

The average age of the miners was 43.6 years minimum 30years maximum 64 years and Std 6.56.

4.1.2: Distribution of respondents by sex

The study sample comprised of 99.2% (1113) male and 0.8% (9) was female.

4.1.3: Distribution of respondents by professional job category

The professional compositions were as follows: professionals accounted for 37.34%, the supervisors of general workers 10.78% and general workers 51.87%.

4.1.4: Percentage of smokers

The percentage of smokers according to the surveys was 0.3

4.1.5: Years of service

The minimum service years was 10 years, this was as a result of the 10 years cut off-point, maximum was 37 years and the mean was 20.3779 and Std 6.61.

4.2: Levels of dust particles

For the dust particles the minimum was 41ppcc, and maximum 170ppcc and the mean was 75.03ppcc with 20.53ppcc as Std. Most of the mines produce below the maximum permissible level of 350ppcc though at times producing as high as 500ppcc in some operations.[7, 21]

4.3: Distribution of miners by mines

The sample was proportionately distributed with the biggest mine having the highest number of records 452 (40.29) as shown in table 4.1.

Table 4.1: Composition of miners by mines

Division	Frequency	Percent
Nkana	235	20.94
Nchanga	452	40.29
Konkola	169	15.06
Chambishi	45	4.01
Chibuluma	28	2.50
Mufulira	193	17.20
Total	1122	100.00

4.4 Years of diagnosis

The minimum years for diagnosis of silicosis was 9 years and maximum was 26 years with 19.7 as the mean. Std was 4.863698.

Based on the table below, working as drillers accounted for 13% as lashers for 9.45%, as crushers for 9.45, other areas accounted for 67.56%.

Table 4.2: Distribution of miners' composition by areas of operation

Area of operation	Frequency	Percentage
Drilling	147	13.10
Crushing	111	9.89
Lashing	106	9.45
Other areas	758	67.56
Total	1122	100.00

Table 4.3: Distribution of miners according to site.

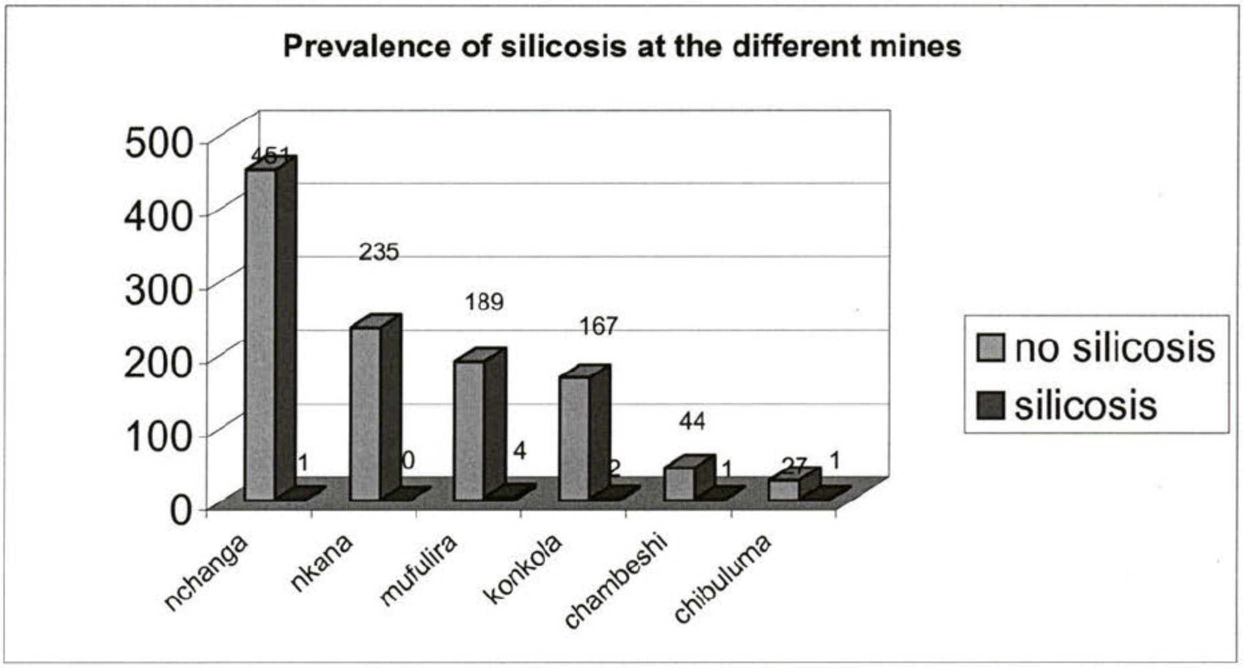
The table below shows the distribution of miners according to the areas of operation. Being under ground mines except for Nchanga, which is both underground and surface, more miners were found in underground section.

Site	Freq.	Percent	Cum.
Surface	350	31.17	31.17
Surface u/g	10	0.89	32.06
U/g	763	67.94	100.00
Total	1,122	100.00	

4.5 Prevalence of silicosis by mines.

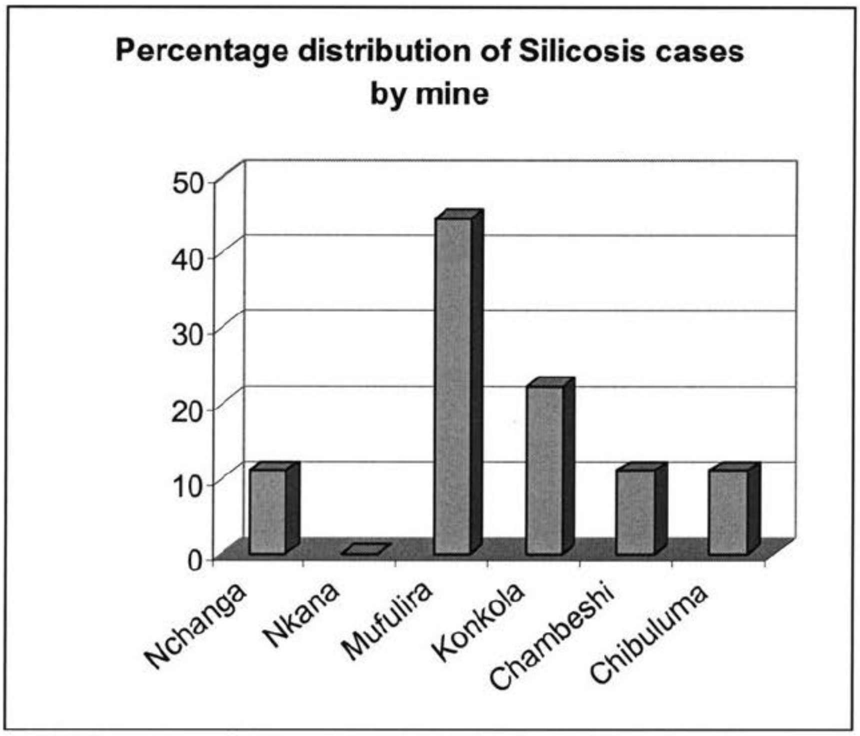
The figure below shows the number of cases in each mine against the total sample of the mine. Mufulira had more cases followed by Konkola with no case reported in Nkana.

Figure 4.1: Distribution of cases and non-cases by mines



The figure below shows distribution of cases as in the above figure but showing clearly which mine had more cases and which had least number of cases.

Figure 4.2: Distribution of silicosis cases by mine

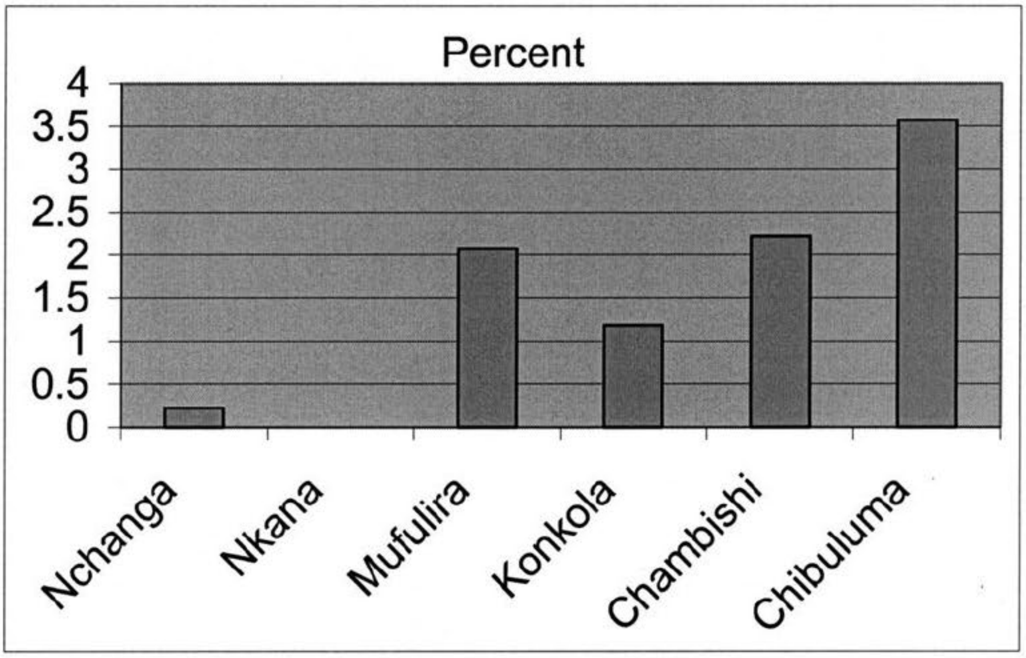


4.6 Proportional distribution of cases

The figure below now give the proportional prevalence with Chibuluma this time having the highest prevalence and Mufulira coming distant third.

Chibuluma had 3.5% 0f its sampled population with silicosis followed by Chambishi 2.3% and Mufulira 2.2% of their sampled population.

Figure 4.3: Proportional distribution of prevalence of silicosis in the individual mines.



4.8: Prevalence of silicosis between sexes

All cases were found among male though female formed a small percentage .8% (9 out of 1122) in most cases they are allocated in non-dust producing areas.

4.9: Prevalence of silicosis in relation to smokers

Cases were found among the "non-smokers". There were only 3 out of 1122 as smoker. It was not even worth it including them in the analysis but since smoking is confounder they were included to see if any had silicosis.

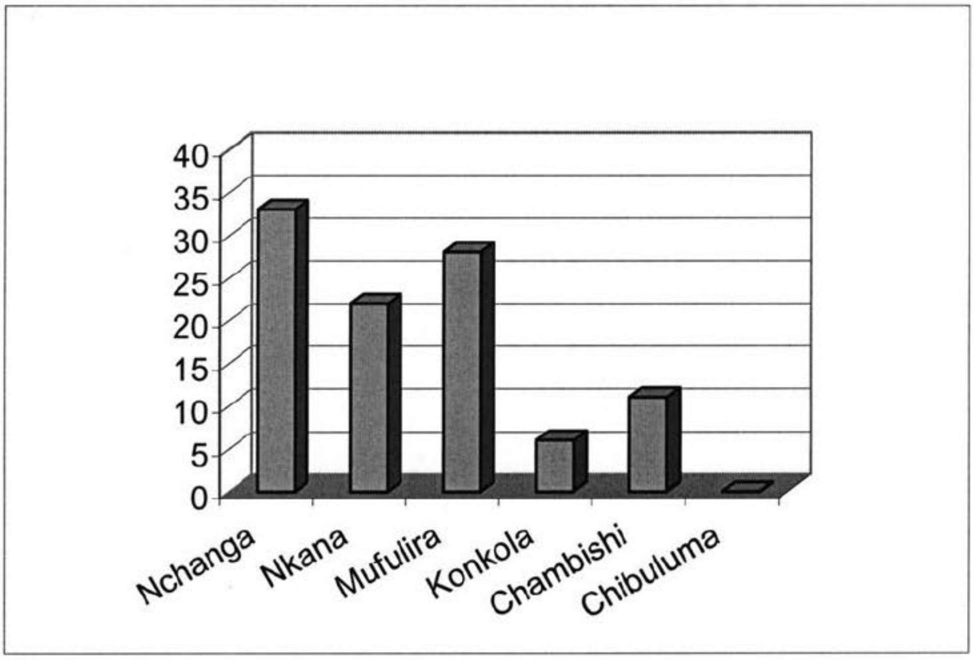
4.10: Prevalence of silico-tuberculosis.

The prevalence of silico- tuberculosis was 0.1%. (1 out of 1122)

4.11: Prevalence of Pulmonary tuberculosis

The prevalence of pulmonary tuberculosis in individual mines was looked at since the study included silico-tuberculosis. It was found at 1.6%(18 out of1122). Below were the cases in individual mines. Nchanga had more case and was followed by Mufulira with Chibuluma recording no case. Scale 10 units per case.

Figure 4.4 Prevalence of Pulmonary Tuberculosis.



4.9: Bivariate analysis –Chi-square tests of association

The Chi-square test of association was performed, and the following factors were perceived to have been associated with silicosis, years one has worked in scheduled area (service) (x^2 =16, p-value =0.001), age (x^2 =5.74, p-value 0.02), site of operation (x^2 =8.51, p-value =0.037), mine (x^2 =11.87, p-value =0.036) and dust particles (x^2 = 5.74, p- value =0.02).

The results below indicate that service, site of operation, dust particles, age and type of mine are associated with silicosis. They have the p-value at 5% level of significance less than 0.05, which is statistically significant.

Table 4.4 Association of silicosis and eight independent variables

Variable	Chi-square value	p-value
Service category	16.21	0.001
Site of operation	8.52	0.037
Dust particles	5.74	0.02
Age category	5.7	0.017
Mine	11.87	0.036
Smoking	0.02	0.87
Sex	0.07	0.78
Occupation	1.43	0.44

4.10: Binary logistic regression analysis

All variables that were identified in the Pearson chi-square test of association were considered for inclusion in the binary logistic regression model. The estimated parameter values (odds ratios), the p-values together with the confident intervals of the variables are presented in the table.

Table 4.5. Results of binary logistic regression on the independent variables for developing silicosis

Variable	odds ratio	Std	p-value	95% confident interval	
Service	3.25		0.033	1.02	10.34
Dust part	0 .72		0.70	0.63	8.20
Site 1	3.34		0.2	0 .44	25.04
Site 2	5.24		0.037	1.15	23.7
Mine 1	45550		0.00	1997	$1.04e^{+}$
Mine 2	$2.89e^{+}$		0.00	20067	$4.05e^{+}$
Mine 3	1.04		0.00	$1.4e^{+}$	$7.7e^{+}$
Mine 4	6.76				
Mine 5	2.8		0.00	1.66	$4.8e^{+}$
Age	1.15		0.012	1.032	1.293

The independent variables strongly associated with silicosis, as the table above shows were; service years age and site. Those worked for more than 15 years 3.25 chances of developing silicosis than those who have worked less than 15 years. The chi-square is more than 3.84 and the odds ratio is away from 1 with p-value less than 0.05 and the 95% confident interval does not contain 1. This shows a statistical significance at the level of 5%. One is 1.15 likely to develop silicosis if he is more 40 years old in the mining industry. The p-value for the two variables is less than 0.05 and their 95% c0nfident intervals do not contain 1.

The analysis also shows that working underground one has 5.2 chances of developing silicosis than working on the surface. The strength of association between dust particles and silicosis in the binary logistic regression did not show any statistical significance as the table shows.

Table 4.6 Model Validation for silicosis, goodness-of-fit test

Number of observations = 334

Number of covariate patterns = 49

Pearson chi2 (39) = 47.29

Prob > chi2 = 0.1701

The p-value of the logistic model for silicosis, goodness-of fit test was 0.17 which is greater than Alfa (0.05), so we accept the null hypothesis and conclude that the estimated model is reliable.

4.11: Classification model

The classification table shows that the overall percentage of accurate prediction for the model is 97.6%. This means only few cases are classified incorrectly indicating the adequacy of the predicted power of the model. The specificity is high compared to the sensitivity because of the low prevalence.[19, 27]

Table 4.7. Classification model

Sensitivity	Pr (+| D) 11.11%
Specificity	Pr (-|~D) 100.00%
Positive predictive value	Pr (D| +) 100.00%
Negative predictive value	Pr (~D| -) 97.60%
False + rate for true ~D	Pr (+|~D) 0.00%
False - rate for true D	Pr (-| D) 88.89%
False + rate for classified +	Pr (~D| +) 0.00%
False - rate for classified -	Pr (D| -) 2.40%
Correctly classified	97.60%

4.12: The sensitivity model

When a perpendicular line is drawn from the point of interception of the two graphs down wards, it is very close to zero, which shows that the fitted model is reliable.

Figure 4.5

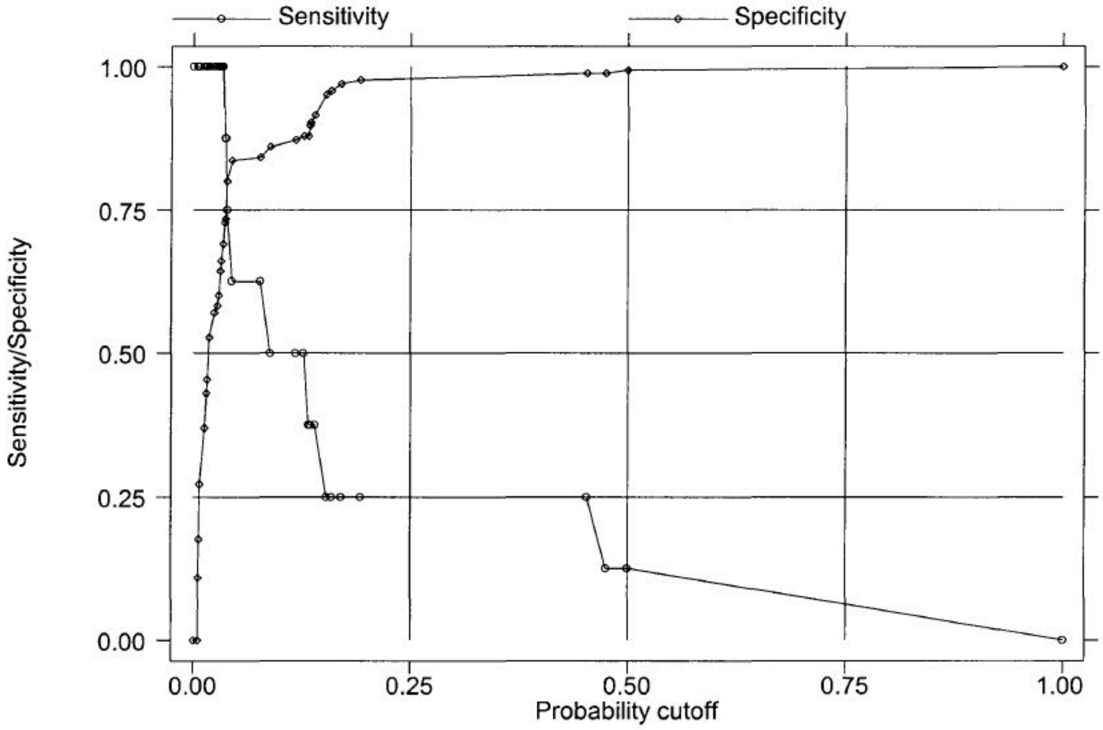
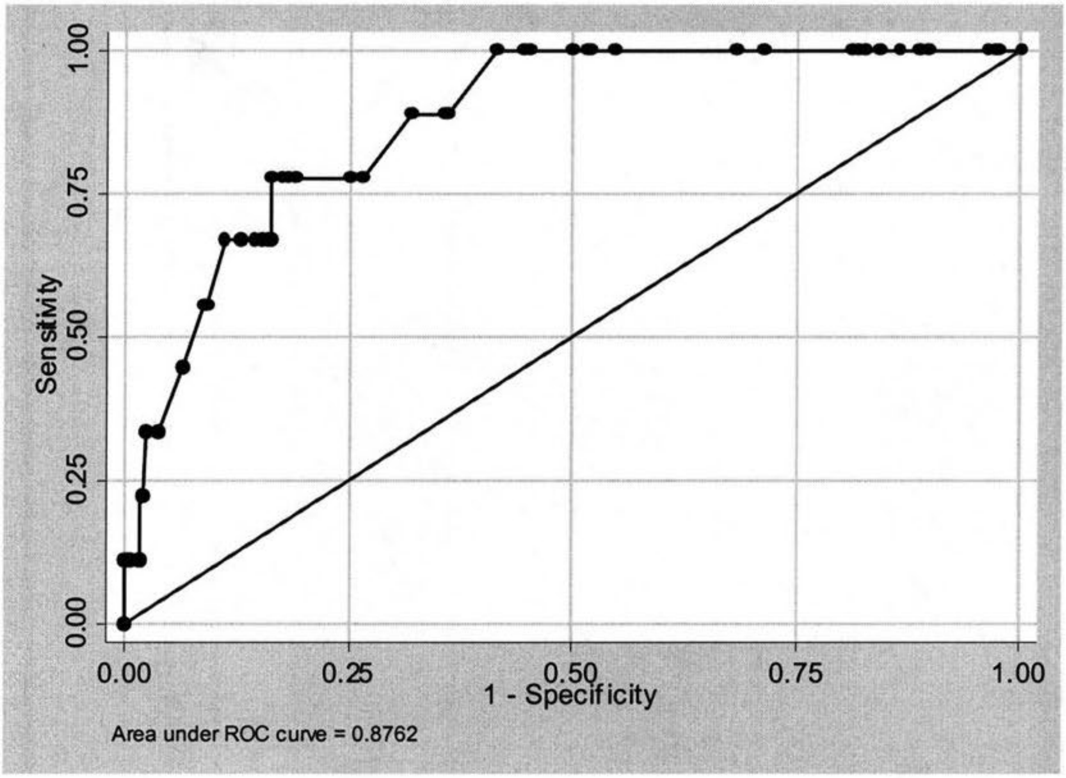

Sensitivity
Specificity
1.00
0.75
0.50
0.25
0.00
Sensitivity/Specificity
0.00
0.25
0.50
0.75
1.00
Probability cutoff

Figure4.6 Roc curve for the estimate of logistic model for association of silicosis and independent variables.



This represents a fairly good fit with the area under the roc curve being 0.87.

The fitted model accounts for 87% of the variable in the outcome variable.

CHAPTER 5: DISCUSSION

The primary objective of this study was to determine the prevalence of silicosis among the in service Zambian copper miners.

The prevalence of silicosis for year 2002 was 8 per 1000. The findings were almost similar to the ones found by Cowie and friends in white South African in-service gold miners study.[13] Prevalence of silico-tuberculosis was 1 per 1000. When one looks at the attack rate, the prevalence of silico-tuberculosis is on the higher side. This is higher than the findings of Paul in his study in Zambia in 1959.[7]

The prevalence of pulmonary tuberculosis was also looked at since the study involved determining the level of silico-tuberculosis. The prevalence for PTB was 16 per 1000, giving an attack rate of tuberculosis on silicotics and non-silicotics of 111per 1000 and 16 per 1000 respectively.[7, 24]

Crushing had the highest prevalence of silicosis in comparison to other areas of operation followed by other dust producing areas. One would expect drilling to have the highest prevalence than crushing like some of studies have found. (Paul in 1959 and Hnizdo in 1994). I suspect in this case that since the dust is coming directly in their faces they are more likely to use the masks (ventilation respirators) than their colloquies who prefer to use mutton clothes because of the discomfort of the masks.[4, 7,14] In total the most dust producing areas had 6 cases out of the total 9 cases. The results for chi squire test of association was statistically significant at 5% level of significance, p-value was 0.037 and when tested for strength of association. Site had odds ratio of 5.24 with a p-value of 0.032 CI 1.156, 23.71. This is in line with most of the fidings.[21, 22]

Generally the nature of occupation determines the rate of development and prevalence of silicosis. In other words, dust and its silica content and duration of exposure correlates with resultant silicosis cases. As a result more cases were found among the general workers who are mostly in dust- producing areas like crushing and lashing in comparison to non- dust producing areas.

1.03% of general workers had silicosis and only 0.72% of professional had silicosis, but when a Chi-square Test of association was performed between silicosis and profession, the results were not statistically significant $x^2 = 1.43$ with a p-value of 0.44. This can be explained by the fact that the categorizing of professionals included those with craft certificates; some of them could have worked as general workers before they did some courses in craftsmanship.

There was no female with silicosis as the results show. Though the number was small, the findings are in line with those by Francesco and colloquies that did not find the pulmonary risks for female workers to have been charecterised.[25] The women are mostly engaged in non-dust producing areas. Proportionally Chibuluma had the highest prevalence with 3.57% of its work force, followed by Chambishi 2.2% and Mufulira 2.07%. Of the four big mines Mufulira had the highest prevalence with 2.075% followed by Konkola 1.18% and the least was Nkana with 0%. Mufulira could have the higher prevalence than the other 3 big mines probably due to its high content of sio2 in the crystalline form of quartz[3]. It is for this reason that the government mine safety department has advised them (Mufulira) to maintain lower level of dust compared to other mines. They also have the second highest prevalence of pulmonary tuberculosis. The reason for Chibuluma mine having the highest prevalence and Nkana the least of them all is not very clear to me at the moment, I can only speculate the reason can be due to differences in content of quartz in respirable dust. Another research will be required to look into it.

The X^2 test of association of silicosis and the mines was 11.87 with a p-value of 0.036, which was statistically significant, an indication that one is at more risk of developing silicosis by belonging to Mufulira Chambishi and Chibuluma. There was also a strong association between silicosis and age of the miner. All the cases were found in those who were 40 years of age and above.

Chi-square test of association was 5.7 with a p value of 0.01, which was statistically significant at 5% level of significance.

Kathleen Kreiss, and Boguang Zhen reported similar findings in their study of the risk of silicosis in Colorado mining community.[19] [American Journal of Industrial medicine 1996]. They found more case among those who were 40 years of age and above.[19, 23]

Similar findings were also found in a longitudinal follow-up of South African miners, the majority of the silicosis cases developed in ex-miners who had left the industry. [Hnizdo and Sluis-Cremer, 1993]

The potential bias could be founding recording of dust particle levels, since those who are working on the surface did not have dust levels recorded ending up putting the average in all missing values.[18] (clinical biostatics).

This could also contribute to the non-significant results shown in the binary logistic regression with dust particles.   The other potential bias is the retrenchment of miners in the 1980's before privatization of mines, this can have an effect on the prevalence since those who are not well are among the first to be put on retrenchment list. So if the study was done in the early 1980 the prevalence could have been higher.

There was one case that was diagnosed after 9 years of exposure to silica dust, which can prompt one to think that the 10 years cut off point could have missed some cases diagnosed below 10years of service. But I don't think this can be the case since all those who are diagnosed with silicosis are kept in employment until they reach third stage that is when they get medical discharge.

A strong association was shown between silicosis and years of service. A chi-square test was 16.21 with p-value of 0.001 and when tested for the strength of association using a binary logistic regression, odds ratio was 4.55 at 5% level of significance the p-value was 0.001 and confident interval of 1.861, 11.27. The CI excludes 1 and odds ratio is more than 1 and p- value less than 0.05, which is statistically significant. See tables 4.4 and 4.5. Prevalence of silicosis (>1/0 ILO) was correlated to years of exposure to underground mining. This is in line with the findings of Steen and collogues in their study of the prevalence of occupational lung disease among Botswana men formally employed in the South Africa mining industry and the study of Trapidol et al. 1998.Prevalence of Lung Diseases in a Random Sample of former mine workers Libonde District, Eastern Cape, South Africa and among Colorado foundry workers by Kathleen in 1996.

No statistically significant association was noticed between the amount of dust one is exposed to when put in the logistic model figure4.5 contrary to most of the findings, [7, 8,12,21,22] but when tested for association with a chi-square test of association the x^2=5.74 and the p-value was 0.02 which was statistically significant, figure 4.6. The weak association can be attributed to the fact that the levels were in form of dust particles and the different mines have different free silica level contents, so the 150ppcc of dust for Mufulira for example cannot have the same amount of free silica like 150ppcc of Nkana. Though the annual average dust level were below the country's permissible levels some miners still developed silicosis due to cumulative effect of silica of the years.

Non of the smokers was found with silicosis and as the number of smokers was very small 3 out of 1122(0.3%) that rules out smoking acting as a confounder.[12, 26]

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS.

The study has made nearly all the objectives but one. I could not determine the average period it takes for one to move from one stage to the other because all the cases where stage one making it impossible to determine the period it takes for one to move to another stage. The prevalence of silicosis was determined so is the prevalence of silico- tuberculosis. Chibuluma had the highest prevalence with Nkana had the least prevalence. Miners in dust producing areas had the highest prevalence. Silica levels couldn't be related to silicosis successfully because the readings were in dust particles instead of respirable free silica levels (quartz) making correlation difficult because as I said earlier different mines had different silica levels in their virgin rocks.

Compared to other studies done in other countries like South African gold mines the prevalence is on the lower side, but it should not make the mine owners complacent because the target for ILO is the total elimination of silicosis in the mining industries.

RECOMMENDATIONS.

1.The Mine Safety Department of the Ministry of Mines should re-start measuring the silica levels in respirable dust as it used to happen before. This will make it easier to determine the association between dust particles and silicosis and to do risk assessment or dose response researches unlike these days when they just measure the dust particle levels. The mining rocks in different mines contain different levels of silica (quartz). The same amount of dust particles in Mufulira mine cannot contain the same amount of quartz in

Nchanga mine for instance. Unless the study was coffined to one mine then coloration could have been shown between dust and silicosis.

2. Other mines to look at Nkana mine and see what measures they are taking if any, to control and prevent silicosis.

3. Medical history should be taken annually so as one can get a better picture of miners' history since the miners are scared to give their full history when they are recruited for fear of failing the medical examination. That is why my research ended up with only three smokers.

4.They should be a follow up of ex-miners especially those who don't come back for their annul medical examination to determine the level of silicosis among the ex-miners. This can be done by compelling them to leave their contact addresses when they are undergoing discharge examination and questionnaires can be sent to them after some years of retirement to inquire about there the state of their health. Most of them once they retire they never come back for medical examination despite the travel expenses being covered by their ex- employers as per act.

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